Vision ScienceS Society

Second Annual Meeting
May 10-15, 2002
Sarasota, Florida

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Program Summary

Friday

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Saturday AM Talks: South Hall
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Tuesday AM Talks: South Hall
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ABSTRACTS

Friday

Friday PM Poster Session: Attention; Awareness; Flash Lag; Letters and Reading; MT; Object Recognition and Viewpoint; Perception Versus Action; Perceptual Learning; Surfaces; Visual Cortex

Attention

Abstract 1 B1.01

Reversal of visual hemineglect: Differential influences of deactivating either contralateral posterior parietal cortex or the superior colliculus.

Erin M. Woller, Will H. Barnes, Bertram R. Payne, and Stephen G. Lomber University of Texas at Dallas, USA, University of Texas at Dallas, USA, Boston University School of Medicine, USA, University of Texas at Dallas, USA

In human subjects, damage of posterior parietal cortex in the right hemisphere often produces a neglect of visual stimuli in the left (contralateral) visual field. Unilateral removal or reversible cooling deactivation of the equivalent region in cats also results in an equally severe contralateral neglect, with the cats unable to report the position of visual stimuli in the contralateral hemifield as assessed by visual orienting. In order to compare the effects of cooling posterior parietal cortex or the superior colliculus in the left hemisphere while posterior parietal cortex of the left hemisphere was deactivated, we implanted cooling loops bilaterally in the posterior middle suprasylvian (pMS) sulcus and over the dorsal surface of the left superior colliculus. As expected, cooling of right pMS sulcal cortex resulted in a profound neglect in the left hemifield with no performance decrease in the right hemifield. Additional deactivation of left pMS sulcal cortex resulted in a restoration of visual orienting performance in the neglected hemifield. Qualitatively, the responses in the restored hemifield were strong, accurate, and indistinguishable from normal. Across the entire visual field, the only positions that maintained decreased performance levels were in the far periphery, bilaterally. Deactivation of the contralateral superior colliculus also resulted in a restoration of visual orienting responses into the neglect hemifield. However, these responses were much weaker and had longer latencies. Furthermore, across also positions in the left hemifield, mean performance levels were only about 50% correct. Therefore, deactivation of the contralateral superior colliculus results in a restoration of visual orienting responses that is both qualitatively and quantitatively inferior to that identified during cooling of the contralateral posterior parietal cortex.
Supported by NSF and NINDS.

Abstract 2 B1.02

Selective visual attention to novel stimuli determines emotional responses

Jane E. Raymond, Nader Tavasolli, & Mark Fenske U. of Wales - Bangor, UK, MIT, USA, U. of Wales - Bnagor, UK

Visual attention acts to facilitate processing of task relevant stimuli and inhibit processing of irrelevant distracting stimuli. We asked whether these processes, when directed at novel complex coloured patterns, affected emotional responses. Previous research has examined the impact of emotional stimuli on attention. Here, we examined the impact of attention on the generation of emotional responses. In a series of 2-task trials, 40 observers performed first an RT-task to locate a target in a simple, brief, left-right display of two novel pattern types (randomly generated colored squares or circles). They then rated the "cheerfulness" of a centrally presented pattern that was either the target or distractor in the preceding task. (In the baseline condition, stimuli were rated after selecting from unrelated stimuli). In some experiments, presentation of the stimuli in the first task was preceded by a brief presentation of happy, sad, or scrambled faces to determine if selective attention could modulate affective priming. The results were that (1) prior attention to stimuli lead to significantly better-than-baseline liking and prior ignoring lead to significantly worse-than-baseline liking, and (2) affective qualities of the face priming stimuli modulated liking (as shown previously), and (3) attention effects on liking were independent of affective priming effects. These results demonstrate that the state of visual attention at the time of initial exposure to a stimulus can determine subsequent affective responses. Although it is perhaps not surprising that targets are "liked", the finding that distractors are "disliked" has important implications for the affective consequences of stimuli used in marketing (e.g., banners on websites) that are frequently distracting.
Funding from ESRC (UK) R022250212

Abstract 3 B1.03

Feedback Circuits: Link to ability to redirect attention

B. R. Payne, S. G. Lomber, K. E. Schmidt, & R.A.W. Galuske Boston U Sch Med, USA; U. of Texas, USA; MPI Brain Research, Germany; MPI Brain Research, Germany

Visuo-parietal (V-P) cortex is critically important for redirecting attention. It is also the dominant source of cortical feedback signals to primary visual cortex (1ºVC) in the cat. The signals are transmitted either directly or via the massive V-P to LPl to 1ºVC pathway. Unilateral cooling deactivation of V-P cortex completely blocks the ability to redirect attention from a cynosure to a novel stimulus moved into the contralateral half of the visual field, yet additional cooling deactivation of contralateral V-P cortex has the positive, paradoxical effect of restoring proficient orienting into the previously defective field. We reasoned that if feedback projections and 1ºVC contribute in significant ways to the ability of cats to reorient attention we should detect decreased neural activity in 1ºVC during unilateral V-P deactivation and

an amelioration of the depression during bilateral V-P deactivation. The latter would suggest that normal signal amplification in 1ºVC is a pre-requisite for the ability to redirect attention to a new location.

We used optical imaging of intrinsic 1ºVC signals and single neuron physiology to assay the neural impact of deactivating V-P feedback pathways. In accord with the anatomy, cooling deactivation of V-P cortex reduced activity and broadened tuning in the grating-orientation preference map in ipsilateral 1ºVC. Yet, contrary to expectation, additional deactivation of contralateral V-P cortex had an additive effect, and reduced neural activity and broadened orientation tuning even further. The opposite direction of the impacts of the bilateral cooling on the neural and behavioral measures promotes the view that neither 1ºVC nor feedback activity are critical for the reorienting of attention to a novel stimulus moved into the visual field. These data suggest that the process of redirecting attention, at least in this instance, is primarily an executive feed-forward function of V-P cortex.

Supported by NINDS, NSF, DAAD, MPG.

Abstract 4 B1.04
Withdrawn

Abstact 5 B1.05

Attentional changes with age: Evidence from attentional blink deficits

James B. Maciokas, Leedia Svec, & Michael A. Crognale
University Of Nevada

Purpose: Increased deficits with age have been well documented in such tasks as cued location, visual search and divided attention. All of these tasks are spatial measures of attention. A well-studied phenomenon the “attentional blink” (AB), a marked deficit in detecting a second target for up to 600ms within a rapid serial visual presentation (RSVP), is a temporal measure of attention. As an extension of our previous work, we investigate the AB and its time course with age in a population of elderly subjects with intact executive function.
Methods: A RSVP paradigm was used. The RSVP consisted of two target letters amongst numeric distracters presented at a rate of 100ms per item. Participants were instructed to report the second target and to ignore the first target during single-task conditions. During dual-task conditions participants were to report both targets. Both conditions were counterbalanced for a total of 480 trials. Stimuli subtended 1cm and were viewed binocularly from 57cm.
Results/Conclusion: Significant differences in the magnitude and the time course of the AB were observed with age. Although the older subjects showed the AB effect at short latencies (as did the young subjects), the window of time for the AB effect was expanded for the older subjects, suggesting a prolonged deficit. Greater variability was observed among the older group consistent with previous reports of individual selectivity of aging effects. Results are discussed in the context of cognitive slowing and reduced attentional resources

This research was supported by an NIA Grant to M.A.C.

Abstract 6 B1.06

Information accrual for unattended shapes in negative priming

Fani Loula & Marisa Carrasco New York University

Introduction & Goal: Negative Priming (NP) refers to a decrement in performance (reaction time) in response to an item that has been previously ignored and which is now being presented as the target. Recently, Carrasco & McElree (2001) demonstrated that attention speeds up information accrual at the attended areas. Moreover, Frieder & Carrasco (2001) showed that NP for unfamiliar shapes occurs even for short display durations (< 200ms) under covert attention conditions. In this study, for the first time we explore how information accrues over time for attended and unattended shapes under covert attention.
Method: We used time-course functions derived from the response-signal speed-accuracy trade-off (SAT) procedure and a modified NP task that requires a symmetry judgment of a target. Observers viewed a series of displays with a pair of overlapping novel shapes (a green target overlapping a red distracter) presented in the center of the screen, and were asked to determine whether the target was symmetrical or not. In a negative priming paradigm, unbeknownst to the observers, in a third of the trials the red overlapping distractor re-appeared as the green target in the following trial (distracter-–>target). In another third of the trials the green target appeared as the target again (target–>target). In the rest of the trials (control condition) all the shapes were novel.
Observers were prompted with a visual cue to respond to the display at different time lags, ranging from 100ms to 1000 ms, following the display presentation.
Results & Conclusion. Reaction times and accuracy data were analyzed using the SAT procedure, which provides information regarding both discriminability and temporal dynamics. The rate of information processing was slower for unattended shapes than for attended ones. These results shed light in the mechanisms underlying the NP effect and provide a unique new theoretical and methodological framework for the study of the NP effect.

Abstract 7 B1.07

Reduced crowding with illusory contours supports an attentional locus for crowding

Edward M. Hubbard, Naveen Krishnan & Vilayanur S. Ramachandran Center for Brain and Cognition, Torrey Pines High School, Center for Brain and Cognition

What is the neural basis of conscious awareness? Studies of blindsight patients (due to circumscribed V1 lesions) have suggested that V1 is the locus of visual awareness. However, the existence of extensive visual processing without awareness suggests that V1, while necessary for consciousness may not be sufficient. We explored the amount of processing that can occur in the absence of conscious awareness by means of the "crowding" effect, in which flanking distractors make it harder to identify a peripherally presented target. He et al. (1996) and Ramachandran et al. (1998) have demonstrated extensive processing of crowded items in the absence of conscious awareness. He et al. therefore attribute crowding to the limited

resolution of visual attention. Von der Heydt (1995) showed that illusory contours can arise as early as V1 and V2, and studies of patients with neglect suggest that illusory contours may arise pre-attentively. To determine whether crowding is due to attentional limitations, we tested twenty subjects with four open or four closed pac-men stimuli that would form either an illusory contour (IC) or an amodally completed (AC) rectangle, with crowders either present or absent. If IC perception precedes crowding, subjects should be better in the IC condition than in the AC condition. To assess the magnitude of crowding, our observers judged whether rectangles of different aspect ratios were "tall" or "wide" (aspect ratio discrimination). Without crowders, performance was similar on IC trials and AC trials. With crowders present, performance on AC trials was significantly impaired relative to the no crowder condition. However, in the IC crowded condition, performance was significantly better than in the AC crowded condition. These results are consistent with the claim that crowding occurs late in processing and may result from the limited resolution of attention.

Supported by NIMH 1 RO1 MH60474 to V.S.R> and NIMH 1 F31 MH63585-01 to E.M.H.

Abstract 8 B1.08

The time course of attentional selection among competing locations

Fred Hamker, & Rufin VanRullen California Institute of Technology, USA

It is still a matter of debate whether observers can attend simultaneously to more than one location. Using essentially the same paradigm as was used by Bichot, Cave & Pashler (Perception & Psychophysics, 1999) to show that attention can be "split" among 2 separate locations, we demonstrate that their previous findings only reflect intermediate stages of (incomplete) attentional selection.

Our subjects were asked to discriminate the shapes (circle or square) of 2 oddly colored targets within an array of 8 stimuli. After a certain SOA, 8 letters were flashed at the previous stimulus locations, followed by a mask. For a given SOA, the performance of subjects at reporting letters in each location was taken to reflect the distribution of spatial attention. In particular, by considering the proportion of trials in which none or both of the target letters were reported, we were able to infer the respective amount of attention allocated to each target without knowing, on a trial by trial basis which location (if any) was receiving the most attentional resources.

Our results show that for SOAs around 100-150 ms, attention can be equally split between the two targets, a conclusion compatible with previous reports. However, with longer SOAs, attention ultimately settles at the location of one single stimulus.

This is a natural prediction of a computational model of attention (Hamker, Soc. Neurosci. Abstr, 2001) in which the planning of saccadic eye movements guides attentional selection. The results can be accounted for by a model of decision making in which the current output of a "refined" saliency map continuously feeds areas in the fronto-parietal network, which select the unique location of an eye movement by a competition over time. Activity from these areas is fed back continuously to extrastriate visual areas. Thus, the SOA determines the state of this competition at the time the letters were flashed and ultimately the distribution of attention at different locations.

This work was supported by DFG HA2630/2-1 and in part by the ERC Program of the NSF (EEC-9402726).

Abstract 9 B1.09

Interactions between spatial attention and the processing of discontinuities

Anne Giersch INSERM U405, France

A modified short-term priming task was combined with a cueing procedure to explore attentional effects on the modulation of the processing of discontinuities. Stimuli were displayed successively with a SOA of 250 msec: they were composed of two horizontal line-segments, either collinear or parallel, subtending 1 of visual angle. Parallel elements were connected on one side, forming a U-shape, whereas collinear elements differed on their length. The subjects's task was to decide whether the gap separating the elements of the second stimulus was located to the right or to the left. Previous results showed that RTs increase when a stimulus composed of collinear elements is followed by a stimulus composed of parallel elements with a gap on the same side, or the reverse. A series of experiments showed that these effects were orientation and location dependent and suggested that they rely on the modulation of the processing of line-ends and virtual lines (Giersch & Fahle, in press, Perception & Psychophysics). In the present experiments, the first sequence included two identical stimuli instead of one, in two square frames 4 wide. The second stimulus was unique as previously. Either one or the two frames were cued at the end of the first stimulus presentation. Results showed (1) a global disadvantage for stimuli composed of collinear elements, especially in non-valid conditions. (2) The cueing effects varied with the characteristics of the first stimulus, and (3) were reversed by lorazepam (benzodiazepine affecting GABA transmission and believed to affect the processing of discontinuities, Giersch, Vis. Cogn., 8, 549-564, 2001). (4) Location-specific modulations of the processing of discontinuities were absent in valid and non-valid conditions. The results suggest that attentional effects are dependent of the characteristics of the stimuli displayed in the cued location. Interactions between attention and the processing of discontinuities may arise, in a diffuse way.

Abstract 10 B1.10

An analysis of the time course of visual marking

Glyn Humphreys, Bettina Jung-Stallmann, & Chris Olivers U Birmingham, UK, U. Birmingham, UK; U. Birmingham, UK.

In the real world, visual search operates across time as well as space. Visual search over time has been studied in the laboratory using the 'preview' search procedure, where there is staggered presentation of distractors over time. Using this procedure it has been found that there is prioritised selection of new stimuli, a result attributed in part to top-down inhibition of irrelevant old information ('visual marking'). We used a probe dot detection paradigm to measure attentional allocation in

preview search, varying the time at which the probe appeared. A distinct time course to probe detection was observed. Relative to when probes fell at 'neutral' areas of the display, there was initially good detection of probes falling on 'old' stimuli followed by impaired detection at old locations, after previews had been shown for longer periods. This time course is consistent with participants initially attending to old stimuli before inhibiting them in order to prioritise selection of the new displays. We discuss (i) the implications of the results for understanding visual selection over time and (ii) the relations between the data and studies showing dual task interference with preview search.

Abstract 11 B1.11

Processing benefits from diffuse attention when the stimuli are harder to discriminate

Elisabeth M. Fine & Adam Reeves Schepens Eye Research Institute; Harvard Medical School, USA, Northeastern University, USA

We (Fine, 2000, Fine & Reeves, 2001; ARVO) presented data showing that under some conditions observers are better able to identify stimuli when they are required to monitor four locations in visual space than when they are required to monitor only two. This phenomenon occurred with a letter identification task (26-alternative), but not an E-orientation discrimination task (2-alternative). Here we present data comparing multiple vs. simple discrimination tasks for the same stimuli and stimulus presentation on vs. off the primary (horizontal/vertical) meridia. Stimuli were presented at 5 deg eccentricity. In Experiment 1, 10 observers both identified 10 letters and made 2AFC discriminations on the same letters (consonant or vowel). There was no difference in performance (corrected for guessing) for either response type between the monitor-2 and monitor-4 conditions (77±2% vs. 74±4% for letter identification; 67±3% vs. 70±3% for consonant/vowel discrimination). In Experiment 2, we used the 26 letter identification task. One group of observers (n = 9) identified the letters when they were presented on the horizontal and vertical meridia, a second group when they were presented 45 deg from the primary meridia. For both presentations, performance was better in monitor-4, although the effect was reduced off the primary meridia (62±4% vs. 73±2% on meridia and 84±1 vs. 89±1% off meridia). On the meridia there was little difference in performance for the horizontal and a large difference in performance for the vertical meridian; off the meridia the benefit of monitor-4 over 2 was fairly constant across location. Inferior performance in the monitor-2 condition is surprising, as it suggests less efficient processing when attention is focused. We hypothesize that focusing attention consumes resources. Thus, while an easy task (which needs few resources) can benefit from focused attention, this benefit is overwhelmed in an effortful task, which competes for the same resources.

Abstract 12 B1.12

Driving and covert orienting: Differential effects of dual-task conditions on selective attention and arousal

Elena Festa-Martino, Anna Gindes, & William Heindel Brown University, USA

Neuropsychological investigations have demonstrated that attention is composed of multiple interacting subsystems mediated by distinct neurological substrates. The covert-orienting paradigm has been used successfully to differentiate between selective attention and alerting within the posterior spatial orienting system. The purpose of this study was to examine the impact of a secondary task on selective attention and alerting. A simulated driving task and an orienting task were administered under both single and dual-task conditions. In the driving task, a staircase procedure was used to adjust the amplitude of the "wind shear" applied to the car, such that observers were able to maintain the car in the center lane 90% of the time. In the orienting task, reaction time to identify the spatial location in which a target appeared was measured. Observers fixated on a point flanked by two boxes at the horizon of the center lane while the car was stationary. One, both, or neither of the boxes brightened prior to the presentation of a target. RT differences between the valid and invalid cue conditions served as an index of selective attention, and RT differences between the double and no cue conditions served as an index of the alerting effect. In the dual-task, observers performed the orienting task with the driving task, keeping the amplitude fixed to the individual observer's 90% criterion level. Observers showed significant selective attention and alerting effects in the spatial orienting task under both single and dual-task conditions. The alerting effect, but not the selective attention effect, increased significantly during dual-task. These results indicate that within a covert-orienting paradigm, dual-task conditions selectively disrupt the alerting component within the posterior attentional system.
Supported by NIH AG15375-01.

Abstract 13 B1.13

Object localization without object recognition in the split brain: A possible role for spatial attention

Diego Fernandez-Duque & Sandra E. Black U. of Toronto, CANADA, U. of Toronto, CANADA

Patient P.A., who has a posterior callosotomy and right mediofrontal stroke, was assessed in his ability to recognize objects and their spatial location. When a set of pac-men was briefly displayed in the right visual field, P.A. was able to recognize both shape and location. In contrast, when stimuli were displayed in the left visual field, P.A. was unable to report object features either verbally or with his right hand. He couldn't report whether two or four pac-men were being displayed, whether the pac-men were arranged to form an illusory square, and whether the pac-men were facing outward or inward. These data reveal an impaired callosal transfer of object information in P.A. In contrast, P.A. revealed unimpaired spatial abilities to left visual field stimuli. He was able to locate the cursor at the center of the display using his right hand, and to verbally report the pac-men's location. We are currently exploring whether P.A.'s ability to localize objects that he cannot recognize is mediated by a covert orienting of attention to the object's location.

This research was supported by a post-doctoral fellowship from the Rotman Research Institute and by a grant to the first author from the Heart and Stroke Foundation of Ontario.

Abstract 14 B1.14

Sex differences in shifting attention within and between objects

James M. Brown, Bruno G. Breitmeyer, Jonathan Hand, & Frances Browning U. of Georgia, USA, U. of Houston, USA, U. of Georgia, USA, U. of Georgia, USA

Purpose. The spatial frequency-specific and hemispheric nature of sex differences in spatial frequency-based and location-based inhibition of return (1) suggested differences between men and women in object- and space-based visual processing. We tested the hypothesis visual processing is more object oriented in women relative to men using an attention cuing paradigm (2).
Methods. Stimuli were sets of vertical and horizontal bars. On each trial a cue appeared briefly at the end of a bar. On 10% of the trials no target appeared. Cues were valid on 76% of the trials when a target appeared. On invalid trials the target appeared equally often at the other end of the cued bar (within-object condition) or at the end of a nearby bar (between-object condition). The cue-to-target distance was the same for within- and between-object conditions. Male and female participants responded as quickly as possible to the onset of the target.
Results. Invalid-cue costs were larger for between- than within-object shifts, replicating prior findings. While costs for within-object shifts were similar, costs for between-object shifts were greater for women than men.
Conclusions. A bias towards object oriented processing in women is indicated by their greater difficulty shifting attention away from a previously cued object (between-object condition). Women may take longer to shift attention from one object to another because objects hold their attention relatively more than men.
(1) Brown, J. M., Morris, K. A., & Srinivasan, N. (1999). Sex differences in spatial frequency based and location based inhibition of return. Investigative Ophthalmology and Visual Science, 40, (4), p.753.
(2) Egly, R., Driver, J., Rafal, R. D. (1994). Shifting visual attention between objects and locations: Evidence from normal and parietal lesion subjects. J. Exp. Psychol.: Gen. 123: 161-177.

Abstract 15 B1.15

Configuration and distance interact to determine object- or space-based attetnional deployment

Bruno G. Breitmeryer, James M. Brown, Katherine A. Leighty, & Caleb Williamson U. of Houston, USA, U. of Georgia, USA, U. of Georgia, USA, U. of Georgia, USA

Configuration and Distance Interact to Determine Object- or Space-Based Attentional Deployment

Purpose. An "object advantage" prevails when comparing object-based attentional shifts over the same distance within a bar vs. space-based shifts across bars1. Following up on findings that attention shifts are facilitated by line tracing2, we tested the hypothesis that the object advantage is due to a facilitation of such shifts along the stimuli.
Methods. Stimuli were pairs of bars {e.g. | |}, brackets {e.g. [ ]}, or arcs {e.g. ( )} with the distance between endpoints within a member equal to the distance across the endpoints of a pair of members. Attentional cues appeared briefly at one end of one of the members of a pair each trial. On 20% of the trials no target appeared. The cues were valid on 75% of the trials when a target appeared and invalid for the rest. On invalidly cued trials, the target appeared equally often in either the same stimulus or else the other stimulus of a pair. Participants responded as quickly as possible to the onset of the target.
Results. Valid cueing yielded faster RTs for all stimulus types. For straight lines, results replicated prior findings1: invalid-cue costs were larger for across- than within-object shifts. A similar, smaller, effect occurred for arcs, but no effect occurred for brackets.
Conclusions. The object-based advantage of attentional deployment is subject to Gestalt configurational factors such as good curve and good continuation. In the absence of such factors, as in the case of brackets, space-based deployment seems to prevail.
1. Egly, R., Driver, J., Rafal, R. D. (1994). Shifting visual attention between objects and locations: Evidence from normal and parietal lesion subjects. J. Exp. Psychol.: Gen. 123: 161-177.
2. Avrahami, J. (1999). Objects of attention, objects of perception. Percept. & Psychophys. 61, 1604-1612.

Abstract 16 B1.16

Top-down modulation of biased competition during covert spatial orienting

Edward Awh, Michi Matsukura, & John Serences U. of Oregon, U. of Oregon, Johns Hopkins University

According to biased competition models, spatial attention facilitates target discrimination by protecting the processing of attended objects from distractor interference. Supporting this view, the relative improvement in visual processing at attended locations relative to unattended locations is substantially larger when the display contains distractor interference. The present research shows that even when the level of distractor interference and the attended locations are held constant, spatial cueing effects can vary dramatically as a function of the context in which a trial is presented. When there was a high probability of distractor interference, spatial cueing effects were significantly enlarged relative to a condition in which distractor interference was less likely. This context-driven modulation of the spatial cueing effects was restricted to trials that contained distractor interference; with displays that contained no distractors, spatial cueing effects were unaffected by the probability of distractor interference. This interaction of display and context suggests that the context effect is not a result of changes in the level of signal enhancement at the attended locations. A change in signal enhancement should be evident even in the absence of distractor interference. Instead, we suggest that a high probability of distractor interference stimulates a top-down increase in the degree of distractor exclusion at the attended locations. While a number of studies have shown that observers have top-down control over where spatial attention is directed, these studies provide new evidence of top-down control over how visual processing is affected at the attended locations.

Abstract 17 B1.17

Change Blindness for motion in macaque monkey
James Cavanaugh and Robert Wurtz, NEI, NIH

We are often unable to detect large permanent changes in a visual scene when they occur at the same time as a transient visual disruption. This "change blindness" has been studied in human psychophysics using visual transients like "mudsplashes" or blanks. Unfortunately, the tools available for exploring the neural basis of such phenomena in humans are limited. For study at the neuronal level, we need to observe change blindness in other species. In macaque monkeys, we impaired the ability to detect a change in direction of motion by accompanying the change with a brief visual transient. We were able to diminish the change-blindness by cueing the location of the change, indicating that the change was still visible. This could provide clues to the neural representation of visual scenes.

We assessed the monkey's ability to detect a change in direction of motion in a field of moving dots under several conditions. While the monkey fixated on a central point, several fields of drifting dots appeared. After a delay, the dots in one field changed direction. The monkey was rewarded for making an eye movement to the field that changed, or for maintaining fixation if no fields changed. In some trials, the change in direction was accompanied by a brief blank. The blank impaired the monkey's ability to detect even large changes in direction of motion. When the monkey was cued to the location of a potential change, he was once again able to detect changes in direction, presumably by focusing attention where the cue indicated.

Since the monkey was able to detect changes when cued, this suggests that change-blindness for motion was not due to interference with the visual system's ability to detect the change, but rather to a disruption of perceptual awareness of the change. This task provides a tool for the electrophysiological study of attentional mechanisms and the transformation of visual information from early processing to later perceptual levels.

Abstract 18 B1.18

Quantitative comparison of ocular dominance column width in optical images
Matthew A. I. Ua Cruadhlaoich & Anna W. Roe, Yale U., USA, Yale U., USA

There has been some controversy regarding the susceptibility of ocular dominance column width to environmental influences. Löwel (1994) and Roe et al. (1995) had claimed that ocular dominance column width is affected by abnormal visual experiences such as strabismus or amblyopia. Horton and Hocking (1996) subsequently placed these claims into question by demonstrating that there is significant normal variability in the width of ocular dominance columns, both across individuals and with respect to eccentricity. Assessing this variability has proven difficult because a standard means of quantifying ocular dominance column width is not available (cf. Kaschube et al., 2001). Here, a mathematically-justified, standardized method of calculating mean ocular dominance column width for optical images of primary visual cortex was formulated. The utility of this method was tested by comparing results obtained through its use with those acquired by alternate methods and by applying it to previously published maps. Mean ocular dominance column width was quantified for a large body of optical images from normal adults of three species of macaque monkey, *Macaca fascicularis*, *Macaca mulatta*, and *Macaca nemestrina*, and two visual eccentricity groups, 1º to 3º and 5º to 10º. Cross-species and eccentricity comparisons made from these results were used to determine the variability of ocular dominance column width measurements. Results from this study provide a benchmark by which to compare other sets of ocular dominance column width data, including those from other species, from normal developmental studies, and from studies on abnormal visual development. The successful implementation of this novel technique suggests that it may be suited for future use in additional studies.
Supported by: Packard Foundation and NEI.

Awareness

Abstract 19 B1.19

Signal detection theory and implicit representation
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Purpose: This theoretical study gives a signal detection theory framework for evaluating claims that there are implicit representations of information not available for standard psychophysical tasks. Claims of subliminal perception as evidence for unconscious processing have been criticised on SDT grounds as merely indicating criterion effects or as simply reflecting "below threshold but above chance" performance. Physiological evidence from fMRI and ERP studies may be critiqued on the same grounds.
Methods: However using orthodox signal detection theory, one can make claims for evidence in favor of a more surprising type of implicit perception. If a "neurometric observer" (using physiological measures, such as single unit recordings or evoked potentials) had a higher sensitivity than that demonstrated psychophysically by the subject, information, unavailable for subject's psychophysical performance is represented in the brain. Interestingly, in such a case, even a forced choice psychophysics experiment (e.g. demonstrating blindsight), would give very low performance. Analysis is straightforward in the case of direct brain recording, but indirect analysis must be used in the case of scalp ERP measurements. We will present the framework for such analyses and how it may be applied to experiments on change perception where performance improves dramatically when a cue is given.
Results: For change blindness, the derived physiological and psychophysical "sensitivities" for uncued and cued trials can be used to give evidence for implicit representation (consistent with information in a visual pathway not available for the psychophysical task). Although an analysis giving the contrary result cannot be used to rule out implicit change perception (brain areas may be involved that do not generate measurable signals), it can be used to show that purported evidence of implicit perception is unconvincing.
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Abstract 20 B1.20

Dissociation between visual awareness and sensori-motor performance fails in paracontrast but not metacontrast
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Purpose. A metacontrast mask suppresses the visibility of, without influencing reaction time (RT), to the target. We investigated if this dissociation holds in paracontrast. Methods. The target was a 13.3 ms, .86 deg diameter disk shown 2 deg to either the left or else the right of, and 1.6 deg above, fixation. Two 13.3 ms mask rings (inner and outer diameters of .89 deg and 1.66 deg) were centered at the two possible target locations. Mask/target (M/T) contrast ratios were 1 or 3. Observers' task was to indicate, by key press, the target position. SOAs ranged from -293 ms to 224 ms. To control for "bottleneck" effects on RT when stimuli are in rapid succession, we also used "pseudo-masks" (an array of 4 .6deg x .6deg squares separated from the target contour by 1.69 deg) designed to not mask the target. Differences between the RTs in the mask and pseudo-mask conditions (D RT) defined the sensori-motor effects of the mask. In other experiments, observers used a staircase method to match the perceived brightness of the target to that of an unmasked reference. Results. For target visibility, para- and metacontrast yielded the usual U-shaped functions. Peak paracontrast occurred at SOAs of -150 to -100 ms, compared to prior reports in the -60 to -20ms range. D RTs for metacontrast fluctuated around averages of -5.5 ms and 1.7 ms for M/T
ratios of 1 and 3. However, for paracontrast D RTs depend strongly on SOA, peaking at SOA = -150 ms. The peak D RT values are 28.7 ms and 51.1 ms for M/T ratios of 1 and 3. Conclusions. The dissociation between visual awareness and sensori-motor performance in masking does not result from a sensori-motor pathway immune to masking effects. The dependence of the dissociation on stimulus timing can be explained by a dual-channel model wherein fast and slow activities interact.

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Abstract 21 B1.21

Visual illusion without awareness
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Visual adaptation has been successfully used as a psychophysical tool for studying the functional organization of the visual awareness. It has been shown that simultaneous presentation of flanking distracters impairs orientation discrimination in the periphery of visual field. In such conditions the crowded target is inaccessible to the awareness of observer. In the present study orientation-selective adaptation to illusory lines induced by two line gratings abutting each other with a phase shift was examined in crowded and non-crowded conditions. First, we tested the effect of crowding on illusory stimuli. Then visual adaptation to illusory lines in crowded and non-crowded conditions was studied. To role out the effects of lower level adaptations we used an animation paradigm in which the orientation of two grating lines altered repeatedly during adaptation phase. The performance of subjects deteriorated in crowded compared to non-crowded conditions: there was a significant difference between the performances in the two conditions ($P< 0.001$). Orientation specific adaptation to illusory lines preserved in both crowded and non-crowded conditions. Percent correct of same adapt-target and different adapt-target was significantly different in the two conditions ($P< 0.001$). We conclude that crowding effect occurs after processing of illusory contours in the visual stream. Since cortical area V2 is known to be involved in the processing of illusory lines, preservation of the adaptation to crowded illusory stimuli suggests that V2 is not a neural correlate of consciousness.

Abstract 22 B1.22

Peripheral Disappearance Elicited by Abrupt Contrast Decrements.
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We present data to indicate that an abrupt decrement in contrast can elicit the disappearance of stimuli viewed in the periphery of the visual field (Exp. 1). Such elicited disappearance can be produced by luminance changes in stimuli that are darker or lighter than the background. It can also be elicited by contrast decrements due to manipulating the background instead of the target (Exp 2). We also studied the effects of target eccentricity (Exp.3). Under all of the conditions we employed, the proportion of trials upon which disappearance occured increased with the size of the contrast decrement (CD) and eccentricity, but the duration of disappearance remained roughly constant (~ 2 sec) over these ranges. Since this disappearance phenomenon occurs abruptly and completely, it is somewhat different than the gradual fading effects reported by Troxler (1804). The duration of this CD elicited disappearance is somewhat similar to the duration of Troxler fading, however, so we hypothesize that reappearance in these two phenomena may involve the same mechanisms. This technique provides investigators with a way to abruptly remove stimuli from conscious awareness, and address many issues concerned with implicit visual processing.

Abstract 23 B1.23

Signal Detection Theory as a modeling tool for resolving controversies surrounding unconscious perception
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The concept of unconscious perception has generated continual controversy throughout psychology's history. We propose that much of cognitive psychology rests on mistaken or tacit assumptions that significant, high-level (e.g., semantic) processing occurs outside the realm of consciousness. A key issue in this controversy is the measurement of consciousness. Experimental conclusions hinge on this basic issue. For

example, if consciousness is equated with verbal report of phenomenal experience, it is trivial to show that some stimulus aspects were processed "unconsciously". Such findings can be considered subjective threshold effects. However, such measures of awareness are inherently flawed. Still, some have claimed that unconscious processing exists even when objective detection measures show null sensitivity (i.e., d' = 0). This claim has been difficult to validate and is fraught with problems (e.g., the problem of proving the null hypothesis).

Our methodological and theoretical approach to this controversy involves applying a Signal Detection Theory model of joint detection and identification. In this paradigm, detection and identification performance are measured on every trial. We have shown that detection and identification are quantitatively related for simple as well as complex stimuli. This model offers an interpretation for a common example of unconscious perception: Correctly identifying a stimulus following a miss. Such a finding is perhaps unsurprising to sensory psychophysicists. Nonetheless, many cognitive psychologists use tasks that claim to index unconscious processing (e.g., exclusion tasks), but we have shown that these results, too, are likely susceptible to subjective threshold criterion artifacts (Haase & Fisk, 2001). Granted, SDT is neutral regarding consciousness, but our findings do converge with contemporary neural models (e.g., Tononi & Edelman, 1998) emphasizing discriminative and integrative abilities as conscious processes.

Abstract 24 B1.24

A temporal /nasal asymmetry for blindsight: Evidence for extrageniculate mediation

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Some patients with hemianopia due to striate cortex lesions show above chance ability in reporting visual stimuli presented in the blind visual field, a phenomenon commonly known as blindsight. Here we report a patient, MP, with a dense right hemianopia whose blindsight shows a temporal/nasal asymmetry. MP was tested in a 2-alternative forced-choice localisation task, with either the right eye or the left eye patched in separate blocks. On each trial a 2 degree black circle appeared on a light-grey background in the blind hemifield, either 10 degrees ('near') or 20 degrees ('far') from fixation (or no stimulus was presented on 12.5% of trials), and MP reported 'near' or 'far'. Eye position was monitored throughout testing to ensure central fixation. When targets appeared in the contralesional temporal hemifield, MP's localisation performance was extremely accurate. In contrast, MP performed at chance with targets in the contralesional nasal hemifield. The temporal/nasal asymmetry is consistent with blindsight in MP's hemianopic field being mediated by a subcortical, extrageniculate route.

Deprivation

Abstract 25 B1.25

NMDA-Dependent Recovery of Visual Acuity Following Monocular Deprivation

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Monocular deprivation leads to anatomical and physiological changes in the visual cortex, as well as reduced visual acuities. These changes can be ameliorated by reverse occlusion. The visual and physiological recovery, however, is labile and results in poor vision in both eyes -- bilateral amblyopia (Murphy & Mitchell, 1986). The underlying causes of these behavioral and physiological results have been a puzzle, however, the visuotopic loss of NMDA expression in the visual cortex promoted by monocular deprivation provides some clues. We initiated a series of studies to determine the rearing conditions that promote recovery of NMDA expression and whether those conditions would lead to permanent recovery of visual acuity. Kittens were reared with various regimens of monocular deprivation and reverse occlusion by eyelid suture. The tangential pattern of NMDAR1 immunostaining was analyzed in supragranular sections from unfolded and flattened visual cortex. Visual acuity was measured using the jumping stand. We found that reverse occlusion alone did not promote recovery of NMDAR1 expression, however, just 4 days of binocular vision after monocular deprivation did promote recovery of NMDAR1. We designed a new rearing regimen, based on the role of NMDA in long-term plasticity in the visual cortex, that promoted both recovery of NMDAR1 expression and permanent recovery of visual acuity after reverse occlusion. These results suggest that NMDA expression is required for permanent recovery of visual acuity and provide a key piece to solving the puzzle of bilateral amblyopia.

Supported by grants from CIHR, NSERC and PREA

Abstract 26 B1.26

The effects of early pattern deprivation on the development of the ability to detect local motion and to discriminate its velocity

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Purpose. To measure the effect of early pattern deprivation on the development of sensitivity to detect the presence of motion and to discriminate velocity.

Methods. Subjects were patients treated for bilateral congenital cataract (duration of deprivation = 3.3 – 6.2 months; M = 4.4 mo), patients treated for unilateral congenital cataract who had

patched their nondeprived eye 2 - 10 hrs/day throughout early childhood (duration of deprivation = 2.0 - 8.2 mo; M = 4.5 mo), and comparably aged normal controls (n = 9/grp). Subjects were at least 5 yrs old at the time of the test. We used a 10 deg Gabor and the method of limits to determine the minimum velocity required to detect movement. We used 10 x 10 deg patches of 1c/deg sine-wave gratings and a 2-alternative temporal forced-choice staircase procedure to measure the velocity that was just noticeably faster than 6 deg/sec.

Results. One-way ANOVAs revealed that both unilaterally ($p < 0.01$) and bilaterally ($p = 0.05$) deprived patients needed a significantly greater velocity than controls in order to detect movement of the Gabor's carrier grating, with no significant difference between patient groups ($p > 0.20$). Patients did not detect the movement until the velocity was about double that required for the control subjects. However, patients had normal velocity discrimination thresholds ($p > 0.40$), with all groups requiring about a 34% increase in velocity to detect that the sine wave was moving faster than 6 deg/sec.

Conclusions. Early pattern deprivation adversely affects the mechanisms underlying motion detection but, at least under some conditions, not those involved in velocity discrimination. The results suggest that early visual input plays different roles in the development of different aspects of the processing of local motion.

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Flash Lag

Abstract 27 B1.27

TMS reveals the correct location of flashes in motion-mislocalization illusions.

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Dual-pulse transcranial magnetic stimulation (TMS) to the occipital cortex causes a brief illusory flash (phosphene). Here we trigger phosphenes during a moving visual stimulus. This causes subjects to see an image from the past – the stimulus located where it was earlier in its trajectory ("retrieval"). When TMS is used to retrieve a flash that had been displaced by a motion illusion, the retrieved flash is seen not as a repetition of the erroneous percept, but at the position of the real flash.
A) TMS occurs while a "clock hand" rotates around fixation. Coincident with the phosphene, two hands are visible: one which is part of the ongoing motion, and one caused by TMS. The reported location of the first hand corresponds to the stimulus position 25-80ms after TMS; reports for the latter correspond to 25-50ms prior to TMS.
B) At some position in the trajectory, the hand is displayed with a different color ("flash"). The effect is similar to Cai's "asynchronous binding illusion" (VSS'01), as viewers do not detect discontinuity, but report the position of the flash to be further forward in the trajectory. Displacements cross both meridianal borders. When TMS follows the flash with a long delay (~300ms), two color flashes are perceived sequentially. The first flash is mislocalized as before, then TMS retrieves a flash at the correct position.
C) The direction of motion reverses at the flash. The flash and reversal still appear continuous, but the perceived location falls short of the true position by as much as 20 degrees. The perceptual blankness around the true flash position makes observation clearer at shorter TMS delays, revealing the clearest "retrieval" at ~200ms.
Here, TMS makes neural excitability states visible, revealing moments in a dynamic cortical process. The optimal position of the stimulating coil suggests that a correct representation of the color flash is linked to lower visual cortex, but does not reach consciousness intact.

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Abstract 28 B1.28

Effect of attention on flash lagging

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[Purpose]
The perceived location of a flashed target and that of a moving target differed even when they are physically same. We investigated whether attention on the moving target plays any role in the phenomenon.
[Experiment]
We used circular moving disks around the fixation point as moving stimuli. A flash stimulus was presented near to one of the disks (target) at a time about the middle of 4s disk rotation. The observer judged whether the flash was perceived ahead of or behind the target in terms of rotation angle. Repeating the judgement with controlling the flash location, the observer adjusted the flash angle to be aligned with the moving target (i.e., flash, target, and fixation point were to be collinear). The target disk was cued before the trial in one condition (cue condition) while no cue was presented in the other condition (no cue condition). To examine whether the knowledge of the target influences the flash lag effect, the amount of the flash lag was compared between the conditions. The number of the disks and the disk rotation speed were also varied.
[Results]
Flash location was ahead of the moving target to be aligned perceptually in both the cue and no cue conditions. However, the amount of the difference from physical alignment location (lag effect) was larger in the no cue condition than in the cue condition. When the observer knew the target and tracked it, flash lag effect was smaller.
[Discussion]
The results suggest that attending to the moving target reduces the amount of flash lag effect. Attentional states should be considered in interpreting flash lag effects.

Abstract 29 B1.29

Memory for initial position: A Fröhlich Effect or an Onset Repulsion Effect?

Timothy L. Hubbard & Michael A. Motes Texas Christian U.

Memory for the initial position of a moving target may be displaced forward in the direction of target motion (referred to as a Fröhlich Effect, e.g., Müsseler & Aschersleben, 1998) or displaced backward in the direction opposite to target motion (referred to as an Onset Repulsion Effect, e.g., Thornton, in press). There are important methodological differences between studies reporting a Fröhlich Effect and studies reporting an Onset Repulsion Effect (e.g., a Fröhlich Effect is typically found with faster velocities and when the target appears to emerge into a window, whereas an Onset Repulsion Effect is typically found with slower velocities and when the target is presented in isolation). In the current experiments, a computer-animated horizontally or vertically moving target was presented, and after the target vanished, observers indicated the remembered initial position or remembered final position of the target. Experiments 1 and 2 extended previous studies (Hubbard & Motes, 2002) in which an Onset Repulsion Effect was exhibited with slow velocities; Experiment 1 presented much faster velocities, and Experiment 2 added an surrounding window adjacent to the trailing edge of the target's initial position and leading edge of the target's final position. Whether a Fröhlich effect or Onset Repulsion Effect is exhibited may also reflect dynamic aspects of memory, and so Experiment 3 varied whether observers indicated remembered initial position before or after indicating remembered final position. Overall, results suggest a Fröhlich Effect is more likely when the target emerges into a window and an Onset Repulsion effect is more likely when the target is presented in isolation. Velocity per se did not influence whether a Fröhlich Effect or an Onset Repulsion Effect was exhibited. The relationship of displacements in memory for starting point to displacements in memory for final point (i.e., to representational momentum, e.g., Hubbard, 1995) is also discussed.

Abstract 30 B1.30

Flash lag in the frequency domain

Christopher R. L. Cantor & Clifton M. Schor U. of California at Berkeley

A flashed object presented in spatial alignment with a moving object is generally perceived as lagging behind the moving object. One explanation of this flash-lag effect is the "motion-interpolation" model; the perceived position of the moving object results from interpolation over the path it follows after the occurrence of the flash. An alternative explanation is the "differential-latency" model; the moving stimulus is processed faster than the flash, and thus has traveled some distance beyond the point of the flash when both are perceived together.

In a temporal-order judgment task the abrupt and simultaneous onset of a moving stimulus and a flash is perceived as synchronous (Nijhawan et al. 1999). This is not the case for stimuli with temporal frequency spectra of narrower bandwidth. (I) We used temporal Gabors with a bandwidth of 2 octaves to control the peak temporal frequency of stimuli in a temporal-order judgment task. We found that subjects perceived higher frequency stimuli as delayed relative to lower frequency stimuli. (II) In a moving Vernier task subjects compared the alignment of two identical gratings drifting at equal velocity. We windowed the gratings with Gaussian temporal envelopes differing in bandwidth, so that the gratings ramped on and off and drifted for the period of time in which they were visible. We found a flash-lag effect in Vernier judgments that depends on the difference in the widths of the Gaussian envelopes. The "motion-interpolation" hypothesis does not offer a predicted result for experiment II. Our results are consistent with the hypothesis that greater processing delays exist at higher temporal frequencies.

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Abstract 31 B1.31

Motion interpolation of a unique feature into stimulus gaps and blind spots

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Purpose: When a moving bar gradually shrinking in size also changes to a different color for one frame, the odd color is seen as belonging to a smaller bar further along the motion path (Cai & Schlag, VSS 2001). One explanation of this illusory shift in position and size is that the abrupt color change may just be delayed and assigned to a later occurring bar. Here we present experiments to test this possibility. Method: In the first experiment, a gap was inserted into the trajectory of the moving and shrinking bar. A sudden color change occurred immediately before the gap. In the second experiment, the odd bar was longer than the other bars which were all of the same length. The bar's path of motion started near fixation, passed through the blind spot and continued beyond it. The one frame with the longer bar was positioned to fall just outside the blind spot in monocular viewing. In both experiments, observers judged the apparent location of the odd bar. Result: In the first experiment, subjects perceived the odd-colored bar to be in the middle of the gap, with its size being the size of the bar that would have appeared at that location had there been no gap. In the second experiment, the long bar was perceived to lie within the blind spot. Conclusion: Since there is no incoming sense data in the gap in the first condition, the odd-colored feature could not have been assigned to any stimuli actually occurring there. The changing values of size and position must have been interpolated into the gap, with the assignment of color being delayed relative to the construction of the size and location of the bar. In the second condition, this path interpolation continued even into the blind spot, creating a unique visual percept wholly within the blind spot. We suggest that the brain represents continuous and abrupt changes in fundamentally different ways, with the assignment of abrupt changes being delayed.

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Letters and Reading

Abstract 32 B1.32

O letter channels, where art thou?
Bosco S Tjan, Susana T.L. Chung, & Gordon E. Legge U. of Southern California, U. of Indiana, U. of Minnesota, USA

At VSS 2001, we reported that the spatial-frequency tuning characteristics for letter identification could be accounted for by the product of a function describing letter-identity information vs. spatial frequency and an observer's contrast sensitivity function (CSF). This result obviates the need to invoke specific channels for letter identification (e.g. Solomon & Pelli, 1994). Here, we tested our theory by adding a pedestal white noise to the noise-masking paradigm used by Solomon & Pelli. A sufficient amount of pedestal noise can render an observer's intrinsic noise ineffective and hence bypasses the CSF. Our theory predicts that tuning functions should appear broader when the CSF is bypassed. In contrast, the letter-channel model predicts no difference. To test our hypothesis, we measured contrast-energy thresholds for identifying 1.6 letters embedded in luminance noise. The masking noise was produced by high- or low-pass filtering a white noise (rms contrast of 20%) at one of nine cutoff frequencies (including a no-noise and a unfiltered white noise condition). The spatial tuning function of a letter "channel" is the derivative of the threshold vs. cutoff-frequency functions so obtained. Then, we re-measured contrast-energy thresholds with an additional white noise (pedestal) added to the stimulus and the masking noise. This pedestal noise had an rms contrast of 9%, several times higher than the intrinsic noise of our observers for the testing condition. Consistent with our prediction, observers showed an increase in tuning bandwidth in the presence of the pedestal noise (from an average full-width-at-half-height of 1.4 to 2.7 octaves). Averaged peak tuning frequency also decreased from 3.5 to 2.7 c/letter. These findings are consistent with the idea that the observed letter "channels" are the results of an interaction between letter-identity information across spatial frequencies and the visual system's limit in spatial resolution.

Supported by NIH grants EY12810 and EY02934.

Abstract 33 B1.33

Figure/Ground and left-right movement discrimination developing when child is learning to read
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One of the predominant theories to explain reading problems is that children who are dyslexic (poor readers) have immature magnocellular pathways. If magnocellular pathways control reading, then tuning up the magnocellular pathways should improve reading fluency. Since left-right movement discrimination of sinewave gratings, relative to a sinewave background provides the optimal stimulus for magnocellular pathways at both low and high levels of processing, we used this paradigm to investigate perceptual learning in children who are learning to read. Contrast Sensitivity Functions (CSFs) for left-right movement discrimination using a 2 AFC task were determined for thirty-five children in a public elementary school, 5 normal readers in grades K-3, and 5 dyslexic readers (determined using The Dyslexia Screener) in grades 1-3. Test spatial frequencies of 0.25, 0.5, 1, and 2 cyc/deg surrounded by one of a 4-octave range of backgrounds were used to test the effects of adjacent background frequencies on left-right movement and figure/ground discrimination. Following one practice session, figure/ground and left-right discrimination were easiest for normal readers when test and background spatial frequencies were equal, and most difficult for dyslexic readers. The direction discrimination CSFs of dyslexic readers ressembled the CSFs of children in Kindergarten. Normal readers were 3-6 times more sensitive than dyslexic readers to the direction vertical sinewave gratings moved, this difference being highly significant ([$F(3,1) = 37.93$, $p<0.0000007$]), when analyzed using a 2 factors ANOVA (4 test frequencies x 2 readers types) in a repeated measures design (5 different backgrounds). Moreover, a developmental trend, $p<0.0027$, in the direction discrimination CSF was found only for normal readers. Children who are normal readers transitioned, so that left-right and figure/ground discrimination were easiest when the same spatial frequency channel was activated by test and background frequencies, whereas dyslexic readers had great difficulty with this task. This study shows that not only is figure/ground discrimination required for learning to read, but left-right movement discrimination is also a key component required for reading. This study provides more evidence that magnocellular pathways provide the physiological substrate that controls reading.

Abstract 34 B1.34

Optimal letterspacing for reading can be learned
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A previous study found that graphic designers read nonstandard letter spacing more quickly than other people, suggesting that people can learn to read nonstandard letter spacing at near-normal rates (Hunter-Kahn & Florer, ARVO, 2000). To examine this suggestion directly, in this study subjects practiced reading Bookman text with a letter spacing of 3.25 M spaces (letter spacing 2.7 times wider than standard Bookman letter spacing), for a period of 10 days, for 30 seconds a day. On the first day of practice, mean reading rate for the nonstandard spaced text was 101 words per minute (wpm). After training, mean reading rate rose to 158 wpm. These higher reading rates did not differ significantly, $t = 0.65$, $p(1) < .01$, from the mean reading rate (165 wpm) for standard spaced Bookman text. To examine whether what the subjects learned had generality, reading rates for the subjects were then assessed on a series of eight other nonstandard-spaced Bookman texts, and on standard spaced Bookman text. Reading performance on these other texts did not differ from non-practiced subjects, nor did reading rates improve on Bookman text with standard letter spacing. Another subject read a Bookman font with different letter spacing for 10 days (nine different letter spacings). Her reading rate for standard spaced text (152 wpm) did not differ from her rate for standard spaced text prior to practicing (150 wpm). These results suggest that subjects can learn to read nonstandard letter spacing within a period of two weeks, but that the ability to generalize reading performance from one letter spacing to another may be limited.

Abstract 35 B1.35

The role of transients in object recognition for good and poor readers

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The M-pathway whose function has been reported to be impaired in dyslexia, contributes significantly to ventral object recognition as well as dorsal stream attentional processing. This experiment aimed to investigate whether transience of stimulus onset and offset is critical in explaining the impaired contrast sensitivity associated with dyslexia. 212 school children aged 5-15 years participated in the study. On the basis of Neale reading accuracy and Raven's progressive matrices performance 20.3% of children were classified as learning disabled (LD), 17.9% as dyslexic (DD) and 61.8% as normal readers (NR). Contrast sensitivity was measured for flicker defined contrast reversing letters (58.5 Hz reversal) presented on a computer either with abrupt onset (duration 34 msec) or with ramped onset/offset stimulus profiles of duration from 34 to 85 msec. Thresholds were determined using a PEST procedure. Unpaired t-tests indicated that there was no significant difference in the contrast levels required for the discrimination of the E between reading groups for stimuli where the contrast was ramped on and off. However there was a significant difference ($t(169) = 3.35$, $p=0.001$) between the performance of the LD and NR groups when abrupt onset /offset was used, although the DD group did not perform significantly differently from the other two groups. Thus the processing of transients differentiates the performance of learning disabled and normal readers in flicker-defined letter recognition.

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Abstract 36 B1.36

Learning to identify unfamiliar letters in central and peripheral vision

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Reading in peripheral vision is slow and inefficient. One plausible explanation for slow peripheral reading is that the peripheral retina lacks the chance to practice, unlike the fovea that is used constantly to read and thus is highly practiced. If so, then adequate training on a task that is novel to both the fovea and the periphery should yield the same magnitude of improvement at both locations. To test this "lack of practice" hypothesis, I tracked the improvements in contrast thresholds for identifying letters of a new alphabet-set, created by rotating each individual Greek letters by 180 , in the fovea and at 10 in the lower visual field. Letters were embedded within static two-dimensional Gaussian luminance noise. Six levels of Gaussian noise contrast were used (rms contrast: 0 to 0.2). Eighteen normally sighted observers were randomly assigned to one of 3 groups: training at the fovea, training at 10 lower field and a no-training control group. A pre-test consisted of measuring contrast thresholds for identifying the rotated-Greek letters at the fovea and 10 lower field, for all noise levels. Letter size used was twice the acuity at each eccentricity. During training (over 5 consecutive days), contrast thresholds were measured at the trained eccentricity only. The post-test, identical to the pretest, was conducted on the day after training concluded. The control group received only the pre- and post-tests. After 5 days of training, observers of both training groups showed an average improvement of 25% in the optimal contrast thresholds for identifying rotated-Greek letters at the trained eccentricity and about 10% at the untrained eccentricity. The average improvement for the control group between pre- and post-tests was also about 10%, at both eccentricities. The similar magnitude of improvement at the fovea and 10 lower field following training suggests that the periphery is capable of learning as well as the fovea.

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Abstract 37 B1.37

Invariance of the psychometric function's slope across the visual field, for contrast-dependent character recognition

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The psychometric function for the recognition of singly-presented digits as a function of stimulus contrast was measured at 2-deg steps across the horizontal meridian, under monocular and binocular viewing conditions. The ML-PEST staircase procedure (Harvey 1997, Spatial Vision) was used in a 10-alternative, forced-choice recognition paradigm to gather the data. At each retinal position, a full range of stimulus sizes were examined; contrast data for a given size/position condition were normalized to contrast threshold and the observer's response data pooled across sizes to achieve independence of stimulus size. Slope estimation was by Harvey's PsychoFit, a maximum-likelihood 2-parameter estimation method of psychometric function fitting. The contrast normalization excludes threshold fluctuations from the slope estimate which results in estimates about 50% higher than conventional ones. To compare slope values across studies, the b' (beta prime) measure of maximum slope, specified as proportion-correct/log10-unit, is proposed and conversion rules to an assortment of other slope measures are provided (Strasburger 2001, Percept. Psychophys.). Both the Weibull and logistic functions provided excellent fits to the observed data. The slopes of these functions at their point of inflection ranged from b' = 4.0 to 5.0 proportion-correct/log10-unit contrast, for both monocular and binocular viewing and for all loci in the visual field. A single psychometric function shape, centered around a threshold value, therefore describes recognition performance at all retinal loci and binocularity. The function's slope is rather steep and at least twice that reported for a number of detection tasks. Methodological reasons for these pronouncedly high slopes are discussed, including work by Leek et al., Kaernbach, Klein, Wichmann & Hill, and Link.

MT

Abstract 38 B1.38

MT neurons do not signal relative disparity
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Psychophysical studies have shown that relative disparity, the difference of two absolute disparities, is important in perceptual judgements such as stereoacuity. A recent study showed that a small but significant population of V2 neurons signals relative disparity, whereas V1 neurons do not (Thomas et al. 1999, SFN Abstr.). A logical hypothesis is that higher visual areas may contain more neurons signaling relative disparity. In this study, we tested whether MT neurons signal relative disparity between their classical receptive field (CRF) and surrounding regions.

We recorded 40 neurons from 3 awake fixating rhesus monkeys. A bi-partite (center/surround) random-dot stereogram was presented, with the center patch covering the neurons' CRF. Dots in both the center and surround patches moved at the neuron's preferred velocity, and both the center and surround disparities varied from trial to trial. Disparity tuning of responses to the center patch was obtained for each of 3-5 surround disparities, and each tuning curve was fit with a gabor function. If neurons signal relative disparity, the tuning curves should shift by an amount equal to the surround disparity. For each possible pair of surround disparities, we calculated the shift in the peak or trough of the tuning curves relative to the difference in surround disparity (shift ratio). A shift ratio of 1 indicates that the shift was equal to the difference in surround disparity, consistent with relative disparity encoding. A shift ratio of 0 indicates that there was no shift with surround disparity, consistent with absolute disparity encoding. Although the median shift ratio of 0.041 was significantly different from 0 (sign-test, $p=0.0005$, $n=209$ shifts), the distribution was tightly clustered around 0, and only 1% (2/209) of shift ratios were larger than 0.5. The results suggest that MT neurons do not signal relative disparity in a center-surround configuration, but rather signal the absolute disparity in their CRF.
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Abstract 39 B1.39

Simulating the time course of MT neuron responses with a model based on V1 neuron properties
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It is well established that there is a close relationship between smooth pursuit eye movements and MT visual motion signals (Lisberger & Movshon, J.Neurosci.,1999). However, existing models of this visual-motor transformation contain components that are inconsistent with known physiology or lack the millisecond-by-millisecond response outputs needed to adequately capture the temporal dynamics of pursuit. We sought to overcome these deficits by using a model of MT neuron responses based directly on V1 neuron inputs (Perrone & Thiele, ARVO., 2000). The model incorporates two V1-like units based on spatio-temporal energy filters: the first has sustained low-pass temporal frequency tuning (S), whereas the second has transient band-pass temporal tuning (T). The response of the model MT sensor is given by: $\log(T+S+a)/(|\log T-\log S|+d)$. The additional terms control the spatial (a) and temporal (d) frequency tuning bandwidths of the MT sensor. This model provides an excellent description of the spatio-temporal frequency response properties of MT neurons (Perrone & Thiele, Nature Neurosci., 2001). Here, we examined the time course of the model sensor responses to a variety of moving dot pattern stimuli, including the step-ramp stimulus motions (Rashbass, J. Physiol., 1961) typically used to elicit smooth pursuit. The model inputs were 16-frame movie sequences composed of 256 x 256 pixel images. To compare the performance of the model to the properties of MT neurons, we measured the latencies and the transient/sustained ratios from the responses of the model MT sensor. The model replicated the transient overshoots in firing rate often found in the activity of MT neurons when the speed of the visual stimulus changes (Lisberger & Movshon). Our results show that a model of MT responses based on VI neuron properties can account for some of the distinguishing features of the visual motion inputs that drive pursuit.

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Abstract 40 B1.40

Direction tuning of macaque MT neurons: a reverse correlation study
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We compared direction tuning curves of motion sensitive neurons in area MT of the macaque monkey by using two different methods. First we presented a large patch of a random pixel array with motion impulses (8-13 ms) pseudo-randomly moving in 8 different directions. Spike trains of the neurons were recorded and reverse-correlated to the stimulus sequence. The temporal response profiles were biphasic with an excitatory response (in the range of 40-70 ms) and a delayed inhibitory response (40-60 ms relative to the excitatory response). For some neurons the response to different directions had different response latencies. We compared directional tuning of these reverse correlation experiments with conventional long duration motion trials, by repeatedly presenting one large patch of a random pixel array moving pseudo-randomly in 8 different directions for one second (10-15 repetitions). For both the reverse correlation and conventional method we fitted the direction tuning curves by gaussian functions, taking the response probability (reverse correlation) or the average response frequency (conventional method) for each direction. The results show that direction tuning curves are sharper in case of repeated long stimulation (conventional method). The sharpening of direction tuning in case of longer stimulus presentation compared to motion

impulses might be due to temporal summation of motion impulses.

Object Recognition and Viewpoint

Abstract 41 B1.41

Lights, camera, action! An interaction between illumination and viewpoint change in object recognition.
Wendy D. Zosh, Quoc C. Vuong, & Michael J. Tarr Brown University, USA

Research in spatial cognition and object recognition has indicated that an "active" observer (i.e. moving) shows an advantage in their ability to recognize an object from a different viewpoint relative to a "passive" observer (i.e. stationary) who is presented with the same image geometry. Some researchers have attributed this advantage to the contributions made by the body senses (e.g. vestibular and proprioceptive) to an observer's ability to spatially update their location in the environment. However, a potential source of information that may be exploited by the visual system is the differential effect an interaction between illumination and viewpoint has for observer and object movement. Phenomenologically, the retinal projections will differ for the two types of motion due to the interaction with illumination sources. If an object rotates relative to a fixed light source, approximately the same area of the visual field will be illuminated, whereas when an observer moves about an object (relative to a fixed light source), the area illuminated in the visual field will change with orientation. The overall pattern of shading and shadows will differ for the two conditions despite equivalent physical geometries across rotations. To address this, we investigated whether the interaction between illumination and viewpoint change provides sufficient visual information to confer the same advantage seen for an active observer to a stationary observer. Preliminary findings suggest that the local feature information contained in images is sufficient to show an active observer advantage in object recognition.

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Abstract 42 B1.42

Not all views are created equal: Object identity momentum via dynamic displays
Quoc C. Vuong, & Michael J. Tarr Brown University, USA

An object rotating in depth presents a coherent sequence of views but each view is seen only briefly. This scenario raises two questions addressed in the present study: (1) Do observers encode the dynamics of the motion sequence or only the discrete views that comprise the sequence? (2) If motion dynamics are encoded, how do they affect recognition? Observers viewed a movie of an object rotating in depth (study) followed by a static frame showing a single view (test) and judged whether study and test showed the same or different objects. We also manipulated the diagnosticity of the shape information present in the stimulus set and where the test view fell along the rotation trajectory implied by the movie (preceding, early, middle, late, following – all equally spaced). We found that: (1) test frames that followed the trajectory of the motion sequence were better recognized than test frames that preceded the motion sequence; (2) test frames that were actually seen in the sequence were better recognized than following test frames; (3) test frames from the end of the sequence were better recognized than frames from the middle or early part of the sequence. We conclude that observers are biased to encode or remember views that occur near the end of an implied motion trajectory. Moreover, observers use dynamic information to predict unseen views of an object that are consistent with the implied direction of motion. Interestingly, a similar pattern across test conditions was observed for both same and different object trials, suggesting that information encoded about object dynamics is not limited to the particular object being viewed, but instead generalizes to visually-similar objects.

Abstract 43 B1.43

PRIMING FOR DEPTH-ROTATED OBJECTS DEPENDS ON ATTENTION
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Studies using a short-term priming paradigm show that attended images prime themselves and their left-right reflections, whereas ignored images prime themselves but not their reflections (Stankiewicz et al., 1998). In two experiments with 3D rendered grey-scale images we tested priming for common objects rotated in depth. In Experiment 1 objects were rotated 90 degrees in depth across the line of sight. Attended objects primed themselves in the same view and when rotated, whereas ignored images only primed themselves in their corresponding view. The effects of view and attention were additive. Experiment 2 tested priming for orientations in which surfaces and parts change from study to test view. Objects were shown in two orientations that were rotated 60 degrees in depth within the line of sight. One view was a complete side-view of the object, thus occluding old and revealing new parts/surfaces compared to the second view. Priming results were similar to experiment 1, with substantial priming for all but the ignored rotated view condition. However, the effects of attention and view interacted, with a greater cost for attended than for ignored rotated objects. These data support models of human object recognition that rely on qualitative different representations (e.g. Hummel & Stankiewicz, 1996), namely part-based or structural representations for attended and holistic or view-like representations for ignored images.

Abstract 44 B1.44

Learning New Structural Descriptions in the Understanding of Elementary Motions

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Perception and understanding of the orientations of objects depend on structural descriptions of spatial relations. As a consequence, altering the orientation of a perceived object can profoundly affect reasoning with respect to the object's shape or rotation. To learn more about structural descriptions in spatial understanding, we are investigating the processes by which people learn to correctly predict the outcomes of rotations that initially are very difficult. The method incorporates a virtual reality (VR) computer system with stereoviewing, photorealistic graphics, smooth motion, and user interaction with the scene. The object is a transmitter dish attached to a shaft; the dish is at different orientations to the shaft and the shaft is at different orientations to the environment. Each trial in the experiment includes three self-paced phases designed to allow optimal learning. First, the participant reasons about the direction the dish will face after a rotation of the shaft and indicates this direction by adjusting the direction of an arrow. Second, the participant receives written feedback and a demonstration of the correct answer in VR. Third, the participant rotatates the assembly and observes the motion. One version of this task provided insightful computer visualization that made correct reasoning easy. Interestingly, although this task required attention to the motion and user interaction with the assembly, participants failed to learn the new structural relations. In a different task, the displays did not include the added visualization. This task was initially difficult, but participants were able to learn the structural relations necessary to reason accurately. There were large individual differences in the overall level of performance. Three psychometric variables accounted for 78% of this variance: spatial ability, fluid intelligence, and mastery motivation. Spatial learning in VR transferred to reasoning with real objects.

Abstract 45 B1.45

Interaction of viewer centered representation and object centered representation of three dimensional space

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Two experiments were executed in order to investigate the relationship between attention in real three-dimensional (3-D) space and depth perception. Three fixation points were located on the central line of sight. They were located 140 cm, 240 cm, and 340 cm from the observer. Two near targets and two far targets were arranged around each fixation point. Spatial cuing paradigm (Posner et al.,1978) was used in order to control observers' expectancy. Following detection of a target, depth estimation between a fixation point and a target (magnitude estimation) was required. In experiment 1, the distance of fixation points from observers were changed randomly every trial. On the other hand, they were blocked in experiment 2. Other conditions were the same in both experiments. The result of experiment 1 showed that the estimation of depth was more adequate when the expectancy was valid in nearer fixation point than when the expectancy was invalid. That is, it is suggested that depth perception depends on whether observers expected the position of targets or not and on the validity of expectancy. In experiment2, more remarkable result was shown in all fixation points.

The reaction time of target detection around far fixation point was longer than around near fixation in experiment2. This seems to indicate the viewer-centered representation. In addition, the results on reaction time and depth perception in experiment1 have the interference that observers should allocate attention over all fixation points every trial. However, in experiment2, because they could allocate attention around only one fixation point as object-centered representation, the performance were better than experiment1. It is suggested that the representation of attention in 3-D space may be constructed by interaction between viewer-centered and object-centered representations.

Abstract 46 B1.46

Differing viewpoint effects in the ventral and dorsal visual streams revealed using fMRI

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Neuroimaging studies using object stimuli have typically focused on activation produced in the ventral occipital and temporal cortices, which are part of the ventral stream of visual processing. Many of these studies, however, also report activation in a region of the posterior parietal cortex, a part of the dorsal stream, that is activated by object stimuli. We investigated the contribution of this parietal region to object viewing, by using a priming paradigm in combination with high-field fMRI. Subjects were repeatedly presented with images of common and novel objects. Some of the repeated images were identical to the initial presentation and some of the images were of the same objects, but rotated in depth. We found that area LO, part of the ventral stream, showed viewpoint invariance, responding the same way to identical and rotated images of objects presented earlier. This result corresponded to behavioural data that showed equivalent performance with identical and rotated images. Area cIPS, part of the dorsal stream, showed priming only with identical images, and appeared to treat rotated images as new objects. This difference in the pattern of priming-related activation in the two areas may reflect the respective roles of the ventral and dorsal streams in object recognition and object-directed action. This difference may also reflect the use of object-based versus observer-based frames of reference in the ventral and dorsal streams.

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Abstract 47 B1.47

Viewpoint preferences during the exploration of novel 3D objects

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A set of studies was conducted that investigated how participants explored the three-dimensional structure of novel objects. Participants rotated a virtual object on a computer screen about any axis to learn the objects' 3-D structure. Their exploration patterns were recorded and revealed that participants focused on a limited number of views of these objects, specifically 'plan' views that were defined as 'front' (axis of elongation is parallel to the line of sight), 'side' (axis of elongation is perpendicular to the line of sight) and 'back' views. In contrast, views that were 'intermediate' or half way between the front and side views were virtually ignored. These results were found in studies that presented the objects on a computer monitor and in a study that presented the objects in a fully immersive virtual reality environment. These findings suggest that storing these plan views of the objects may be important for subsequent recognition of novel objects. In fact, we found in a related study that studying plan views results in faster subsequent recognition than studying intermediate views. The reasons why plan views may be important for creating stored object representations will be discussed.

Abstract 48 B1.48

Detecting depth rotated bilateral symmetry

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Axes of bilateral symmetry in an image are a potential cue to the 3D orientation of objects. Published results are mixed with regards to our ability to detect symmetry rotated in depth. We investigated the role of depth cues on the detection of symmetry for patterns rotated in depth. METHODS: Dot patterns (24 light grey dots on a black background) 1 in diameter were presented at the center of a CRT screen. Vertical, Horizontal, 45 , and 135 orientations of symmetry were presented in separate blocks of trials. Symmetry detection was tested for 7 different rotations of the CRT screen spanning ±75 relative to the observer. Each depth rotation was tested in a separate block of trials. Subjects were tested monocularly using their dominant eye. In FULL VIEWING the room was illuminated, and the subject could see the CRT screen and all other surfaces that could provide monocular depth cues. In the NO DEPTH CUES condition, the room lights were off, and the central region of the CRT was viewed through a tube which prevented subjects from seeing anything but the dot patterns. The accuracy and reaction time for detecting symmetry and asymmetry were recorded. RESULTS: Asymmetric patterns viewed through the tube appeared to float in space at an indeterminate distance from the subject. Subjects were unable to correctly determine the screen rotation when looking through the tube. For FULL VIEWING, the speed and accuracy (>90%) of symmetry detection were similar for depth rotations between ±60 . At the ±75 rotations, symmetry detection was slower and less accurate for all symmetry orientations, with a larger effect for oblique symmetry. Testing in the NO DEPTH CUES condition extended the disruption of symmetry detection to the ±60 depth rotations. CONCLUSIONS: We found that symmetry could be detected despite large rotations in depth. Although restricting depth cues made symmetry detection more difficult, the effect was not to the degree reported in other studies.

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Abstract 49 B1.49

Image complexity determines degree of viewpoint dependence

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We investigated the extent to which the recognition of images is viewpoint dependent across rotations in the picture plane. The experiments employed a set of novel images that made it possible to examine the influence of the number of parts composing the image. The images consisted of from 2 to 8 cylindrical parts arranged radially within a circular space with 10 possible part locations. Reaction time to correctly identify a rotated version of a sample image revealed two main effects. First, the number of parts strongly determined RT, such that RT was fastest when there were either few (e.g. 2) or many (e.g. 8) parts, but was slowest when there were an intermediate number of parts (e.g. 5), forming an inverted U-shaped function. Second, the viewpoint dependence of the images, as measured by the slope of the RT function for an image across 30 to 120 degrees of rotation, varied strongly with number of parts. Images with few (2) or many (8) parts displayed flat slopes, revealing a lack of viewpoint dependence. Images with intermediate numbers of parts (5) displayed high positive slopes, showing strong viewpoint dependence. The inverted U-shaped functions for RT and viewpoint dependence mirror the function of total possible shape configurations for a given number of object parts. For the radial images used here, there were a smaller number of possible configurations for objects with low or high numbers of parts (e.g. 45 possible 2-part images: all combinations of 2 locations taken from a space with 10 possible part locations) while there were high numbers of possible configurations for the middle range (e.g. 252 5-part images: all combinations of 5 from 10). This suggests that image complexity, measured by the size of the "shape space" of possible forms implied by the number of image parts, influences how well the representation of an image generalizes to new viewpoints.

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Abstract 50 B1.50

The influence of attention on the recognition of depth-rotated objects and faces

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Purpose: Stankiewicz et al. (1998) suggested that attention is necessary for encoding view–invariant object representations. We examined this hypothesis using realistic depth–rotated

faces and non–face images. Methods: A sequential matching paradigm was employed whereby a face or a chair was presented at learning along with characters in its surround. The learning images were presented in frontal or 3/4 view. In the full–attention condition, observers followed the letters with their eyes while paying attention to the image. In the divided–attention condition, observers had to count the number of characters that were digits. At testing, the target was presented along with two distractors of the same category. The target test image and distractors were either in the same view or a different view than at learning. 40 Ss were tested on 2 blocks, one for each attention condition. Five trials for each testing view (same and different) and object category (face and chair) were presented randomly in each block. Results: Recognition accuracy performance produced a significant three-way interaction between Attention, Stimulus Category, and Testing View. In the full–attention condition, recognition in a different view was not significantly different than recognition in the same view for both faces and chairs. In the divided–attention condition, recognition of faces in a different view was significantly lower than recognition in the same view. However, recognition of chairs was equivalent in same and different views under divided-attention. Conclusions: We postulate that a face representation formed without attention may not contain the necessary information required to produce a match with its rotated equivalent. In contrast, the information used to recognize chairs after a small rotation may be encoded and stored in memory irrespective of attention.
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Abstract 51 B1.51

Evidence for a pre-match 'mental translation' on a form-matching task
David Bennett Brown University, USA

PURPOSE AND APPROACH. The aim was to explore whether there is a pre-match ‘mental translation’, analogous to ‘mental rotation’ and ‘mental scaling’, on a Same-Different simultaneous form-matching task. The basic approach was to vary the environmental separation of the forms, while holding constant everything else that might affect reaction time.

METHOD. On a Same-Different task, subjects were presented with two forms flanking a fixation triangle, all shown in the same depth-plane. Distance (simulated) to the forms was varied. Viewing was in stereo. Total visual angle spanned by the centers of the bases of the two forms, in each eye, was held (essentially, effectively) constant as distance to the forms (and so environmental separation) varied. The forms and fixation triangle were shown resting on a bar that spanned a textured enclosure; the top of the bar crossed at eye-level and the bar was anchored to the floor of the enclosure by struts. The top half of the back of the enclosure was open, with the forms silhouetted against a blank field. So: form edge-information and gaze angle were both held constant as distance to the forms (and so environmental separation) varied, and there was no backing surface. In Experiment I, the forms were shown for 400msc; in Experiment II, the forms were shown for 300msc, and the Same-Different discrimination was made slightly easier.

RESULTS AND CONCLUSION. In Experiment I, reaction time rose with increases in environmental separation ($n = 34$, $p < .01$, R-squared = .9295; Same trials). Results for the 16 subjects run so far in Experiment II also indicate a rise in reaction time with increases in environmental separation ($p = .029$; Same trials). In both cases, the slopes suggest a fast process. In sum, the results are evidence that comparisons of the forms were preceded by a fast ‘mental translation’, analogous to ‘mental rotation’ and ‘mental scaling’, with the locations of the forms coded in a non-retinal frame of reference.

Perception Versus Action

Abstract 52 B1.52

The role of binocular information in the control of perception and action
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Purpose: This study examined the dissociation of perception and action when participants judged the orientation of a frontal trapezoid window or pointed to its edges. Viewed monocularly the perspective cues in the display create the illusion of a window strongly slanted in depth. When viewed binocularly, the illusion is reduced.
Method: Participants (N=14, mean age 24 yrs.) wore LCD goggles allowing random presentation of monocular and binocular vision over trials. For the Perceptual Task participants aligned the orientation of a rod that was slowly rotated by an experimenter to match the orientation of the display (total viewing time: 7.5s). For the Motor Task participants pointed with their index fingers to the side of the display without touching it (total viewing time: 2.5s). Finger movements were recorded with an optoelectronic camera system. The perceived orientation angle (perceptual error), the transverse plane angle between the two finger tips (motor error) and reaction time (RT) were analyzed.
Results: The average perceptual error with respect to the true orientation of the display was 13.9 for binocular vision and 24.9 for monocular vision. The average motor error was 1.3 for binocular vision and 19.6 for monocular vision. Preliminary analysis revealed an average RT of 214ms for binocular vision and 227ms for monocular vision.
Conclusions: Perspective cues for slant induced errors in both perception and action. However, during pointing towards the trapezoid window only the monocular presentation caused significant motor error. These results demonstrate that binocular information has a differential influence on perception and action, which may reflect processing differences in the dorsal and ventral visual stream.

Abstract 53 B1.53

Grasping remembered objects: Pinpointing the transition between on-line and off-line visuomotor control modes.
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The scaling of grip aperture in visually guided prehension is largely insensitive to size-contrast illusions, but the same is not

true of grasping movements initiated after a delay. When does the transition between veridical and illusory size-scaling occur? In experiment one (No-delay), participants (N=10) viewed a target object and an adjacent flanker object for 500 msec, and reached to grasp the target object in response to a subsequent auditory cue. Unpredictably, vision was occluded either at cueing or at movement onset. In experiment two (Delay), the target array was viewed for 500 msec followed by a 2.5 sec period of visual occlusion and then an auditory initiation cue. Unpredictably, vision was restored either at cueing (and withdrawn at movement onset), or not at all. In both experiments, peak grip aperture was insensitive to flanker size when vision was available between cueing and movement onset. When vision was unavailable at this time, peak grip aperture was modulated by flanker size in a direction consistent with a perceptual size-contrast effect. The magnitude of this effect was similar for both experiments. We propose two discrete modes of visuomotor control. On-line visuomotor control accesses a veridical representation of object size, and requires vision at the time of movement programming (i.e., between cueing and movement onset). Off-line control accesses a perceptual representation of object size, and is engaged when vision is unavailable at the time of movement programming. The transition from on-line to off-line control occurs within one reaction time (approx. 310 msec) or less of visual occlusion.
Supported by NSERC, CIHR and the Canada Research Chairs program.

Abstract 54 B1.54

More errors in an action-based response: blindfolded walking and the horizontal-vertical illusion
John W. Philbeck George Washington University

Purpose. When observers indicate the magnitude of previously-viewed exocentric spatial intervals by walking without vision, their responses often do not show evidence of the depth foreshortening typical of other behavioral indications (e.g., visual matching: Loomis et al., 1992). Is the visuomotor system accurately registering spatial layout, or is walking influenced by biases that do not depend on stimulus depth? This study tests the second hypothesis by presenting all stimuli in a frontoparallel plane, thereby removing the depth component. Method. Eleven observers binocularly viewed a single white line (23 - 183 cm long) on each trial. The stimuli were projected onto a wall in a well-lit room and were oriented either horizontally or vertically. The task was to close the eyes and reproduce the line length, by walking either straight ahead or after first turning 90 deg to the right. In a separate block, observers gave verbal estimates of line length. Results. (1) Both verbal and walking responses showed a horizontal - vertical illusion of about 13%. (2) Regardless of the line's orientation, observers walked farther when walking straight ahead than if they turned before walking. (3) Walking responses were subject to large overshooting errors (37% of the physical line length). Conclusions. Despite its reputation as an accurate indicator of spatial layout, blindfolded walking is subject to a variety of errors when used to indicate the magnitude of exocentric intervals, some of which are clearly perceptual in origin. At least some of walking's apparent insensitivity to perceptual depth foreshortening can be explained by response biases that do not depend on depth cues.

Abstract 55 B1.55

The effect of the Titchener circles illusion on grasping and manual estimation of two and three dimensional targets
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Goodale and Milner (1992) proposed a dual visual system, with a ventral cortical stream involved in visual perception and identification, and a dorsal stream mediating visually guided action. This has been supported by findings that perceptual judgement is affected by pictorial illusions, while action is relatively unaffected (Aglioti et al 1995; Haffenden and Goodale 1998), although some contrary results have been reported (reviewed by Bruno, 2001). Previous studies have found that pantomimed grasping is fundamentally different from natural grasping (Goodale et al 1994) and action towards an illusion shows increased illusory bias as the delay between viewing and action is increased (Gentilucci et al 1996), indicationg that ventral stream representations are involved in driving these actions. It is therefore suggested that an action must be both goal directed and immediate in order for dorsal stream information to be utilised.

Two- and three-dimensional stimuli were compared to discover whether a stimulus must be 'graspable' in order for the dorsal stream to dominate in guiding a goal-directed action towards it. Subjects made grasping actions and manual estimations of a flat circle (2D) or to a disk of 3mm thickness (3D) in the Titchener Circles illusion. Movements were recorded using the ELITE motion tracking system (BTS, Milan) and analysis identified maximum in-flight aperture during grasping, and mean aperture in estimation. Results confirmed previous findings: manual estimation of the 3D target showed the illusory bias, whereas grasping did not, and was scaled to the true size of the disks. Maximum aperture in grasping to 2D targets was smaller overall, but showed the same pattern of effects; an illusion effect was found in estimation but not in grasping. These results suggest that although action towards a 2D stimulus is different to action towards a 3D stimulus in some respects, it still appears to be driven by dorsal stream visual information.

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Abstract 56 B1.56

Different illusory effects of the Judd illusion for perception and action after a temporal delay
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Milner & Goodale (1995) have provided a useful, if controversial model for investigating the contribution of visual information in motor action. We have explored the effects of the Judd Illusion upon perception (position matching) and motor action (pointing), in relation to this model. In the motor task participants made ballistic pointing responses towards the end point (left/right) or mid point (marked/unmarked) of a Judd illusion where as in the perceptual task participants made

judgements about the location of a line relative to these positions. When these tasks were carried out immediately after brief presentation of the stimulus, illusory effects were observed for both pointing and matching at the endpoints and unmarked midpoints. This at first appears to contradict the Milner & Goodale (1995) two streams hypothesis, however when a temporal delay was introduced between stimulus presentation and response a different pattern of effects emerged. For pointing, error increased at the end points but went in a direction opposite to the illusion for the marked mid point. For perceptual matching the error increase in size at both the marked and unmarked midpoint but not at the end point. We interpret these results as evidence for comparison process using separate visual motor and separate visual perceptual representations, in line with the Milner & Goodale's (1995) model.

Milner, A. D. & Goodale, M. A. (1995). The visual brain in action. Oxford University Press: Oxford.

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Abstract 57 B1.57

Roelofs' illusion provides evidence against a perception/action dissociation

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The location of a target presented within a static frame that is offset from the subject's midline has been reported to be perceptually mislocalized in the direction opposite that of the frame (Roelofs 1935). However, when asked to point to the target, the effects of frame offset are smaller, or even nonexistent in some subjects (Bridgeman et al. 1997). This dissociation of perceptual and sensorimotor localization appears to support the hypothesis that the brain contains separate maps of visual space for perception and action. However, an alternative explanation is equally viable. Previous measurements of the target's perceived location required subjects to compare the location of the target with a remembered array of targets seen earlier. Perhaps the subjects correctly perceive the current target but the remembered location of the comparison array is distorted by Roelofs' illusion. To test this alternative hypothesis, subjects were required to sit in complete darkness and indicate the remembered locations of 5 targets (0.5 degrees diameter) positioned in a horizontal array –4, –2, 0, 2 and 4 degrees from the midline. A large frame (21 x 8.5 degrees, 1-s duration) presented either centered or shifted 5 degrees to the left or right was accompanied by a verbal command to indicate the location of one of the remembered targets with a saccadic eye movement. Accuracy was found to be systematically biased, with the reported position of the targets skewed in the same direction as the frame offset. A second experiment demonstrated that subjects' report of perceived straight-ahead was similarly shifted in the direction of the frame. Thus, the presence of the offset frame distorts remembered visual space and the perceived straight ahead in a way that precisely explains the previous findings with Roelofs' illusion, and argues against the idea of separate maps of space for perception and action.

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Abstract 58 B1.58

Perceiving virtual geographical slant: action influences perception

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Previous studies have consistently demonstrated that people's conscious perception of the slant of hills is greatly overestimated although their visually guided actions show little evidence of this bias (Bhalla & Proffitt, 1999; Creem & Proffitt, 1998; Proffitt et al., 1995). The present studies examined the influence of movement on judgments of the slant of simulated hills using a locomotion interface. This device consists of a linear treadmill capable of simulating the added forces associated with walking up hills (Hollerbach et al., 2000), surrounded by three large projection screens. In all experiments, observers were transported to a location at the bottom of each hill in a virtual environment (a simulation of a portion of the Wasatch Mountains). In Experiment 1, observers viewed a target presented on the hill while remaining stationary. In Experiment 2, they were visually moved up the hill to the target, and then transported back to the bottom. In Experiment 3, they walked up the hill to the target, and then were transported back to the bottom. Participants responded with two conscious perception judgments of slant (verbal and adjusting a pie-shape segment of disk) and a visually guided action (adjusting a palm board to correspond to the slant of the hill) while standing at the bottom of the hill. We found that walking on the hills with simulated slope forces (Exp 3) greatly increased estimations of slant for both the conscious perception and motoric measures compared to no movement or visual movement. These results differ from the previous finding that manipulations of physiological potential on a stationary observer affected conscious judgments of slant, but not motor responses (Bhalla & Proffitt). This difference may have resulted from the interaction of physical walking and the ambiguity of the graphical information in the visual display. These results have implications for a bi-directional interaction between action and perception.

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Abstract 59 B1.59

Psychophysical dissociation of "how" and "what" tasks in normal participants

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Purpose: Milner & Goodale, 1995, propose that visual processing splits into a ventral, "what" stream devoted to conscious recognition processes and a dorsal, "how" stream

mediating motor control. Whereas the ventral stream receives input from both the magnocellular and parvocellular pathways, the dorsal stream receives only magnocellular input, suggesting that the "how" system may lack chromatic sensitivity. Here we assess the relative sensitivities to luminance versus chromatic variations in distinct tasks designed to selectively engage these two processing streams. Method: Taskwhat required the subject to register with a buttonpress the orientation (right, left, up or down) of a foveal isoceles triangle, briefly flashed, then masked. Taskhow required the subject to touch with a stylus the tip of the most acute angle of an isoceles triangle presented randomly in one of 4 orientations at one of 4 parafoveal locations. Each task used (i) equiluminant green targets varying in saturation, and (ii) isochromatic gray targets varying in luminance. Psychometric functions of green-target saturation and of gray-target luminance were obtained in Taskwhat. In Taskhow we measured movement duration and endpoint accuracy. Results: For saturation Green(p) and luminance Gray(p) yielding identical success rate p in Taskwhat, Green(p) targets yielded movement trajectories in Taskhow that were significantly slower and/or less accurate than Gray(p) targets. Conclusions: The process mediating performance in Taskwhat is relatively more sensitive to chromatic (vs. luminance) variations than the process mediating performance of Taskhow, supporting the dual claims that (i) Taskwhat and Taskhow selectively activate the "what" and "how" systems, and (ii) the "what" system is relatively more sensitive to chromatic variations than the "how" system.

Abstract 60 B1.60

'Representational momentum' in reaching action

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Purpose: Perceptual judgment of the final position of a moving target is shifted in the direction of motion ('representational momentum', RM). This illusion has been considered as a memory shift at a cognition level (Hubbard, 1995, Psychonomic Bulletin & Review), but it can be more related to visuomotor coordination as automatic compensation of processing delays. RM was measured with perceptual and action tasks to test this idea.
Method: Stimuli were presented on a CRT equipped with a touch panel. A target disk moved horizontally and the observers pointed the position where it disappeared either by adjusting a screen cursor (perceptual task) or by touching the screen with a pen (action task). For the action task, an open loop condition was also tested in which an LCD goggle prevented the observers from seeing the screen and their hand while responding. Target motion was observed either with free viewing or with fixation.
Results: With free viewing, similar amount of shift in the motion direction were found both for perception and action. With fixation, however, the shift was greatly reduced except under the open loop condition that yielded similar shifts regardless of fixation.
Discussion: RM found for an open loop reaching action suggests that the origin of this illusion lies in rather peripheral level. Pursuit eye movement seems necessary for perceptual RM (cf. Kerzel, 2000, Vision Res.), but it cannot be the primal cause because it does not affect RM for open loop reaching. Frame of reference is rather crucial. With fixation, positional coding against the background would suppress RM, while such information is not readily available under eye tracking or open loop pointing. More robust RM for action is consistent with our previous result of larger positional bias by action than by perception for a drifting Gabor patch (Yamagishi, Anderson, & Ashida, 2001, Proc. R. Soc. Lond. B), supporting separate pathways for vision and action (Milner & Goodale, 1985).

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Abstract 61 B1.61

Perceivers walk the walk but talk short: Evidence for two visual pathways in distance perception

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It has been proposed that there are separate pathways for visually guided action and for visual awareness of the world (Goodale & Milner, 1992). The former may depend on body-scaled informative structures. Distance, for example, is specified by the horizon-distance relation (Sedgwick, 1973) which relates the observer's eye-height to the angle subtended from the base of the target to the horizon. We compared verbal distance estimates to the action measure of walking to the same targets by blindfolded observers. Observers wore either 10 diopter base-up or base-down prism glasses (or none) which shifted observers' angle of gaze elevation from normal while leaving visual angles themselves unchanged. If visual angles are related to the body of the observer (through eye height and oculomotor information for gaze inclination, Grutzmacher, Andre & Owens, 1997) then distances should appear longer in the base-down and shorter in the base-up condition. We obtained radically different results for the action measure compared to verbal estimates. Observers' verbal estimates of distances 30, 60 and 120 feet were short, and accuracy was not affected by distance: estimates were 45, 45.1 and 47.4% of the true distances, respectively. In contrast, observers came very close to the target distances when walking, and accuracy was significantly affected by distance: observers walked 109.4, 96.8 and 84.9% of the true distances. The obtained pattern of results for the prisms was consistent with body-scaling of horizon-related visual information although the effect was very small on both measures, and not significant. (Target objects were far and relevant visual angles were small.) In conclusion, action measures of perceived distance are more accurate than verbal reports, and accuracy is affected by distance to the target. We suggest that this discrepancy is further evidence of separate visual pathways for visually-guided action and for the verbal report of perception.

Abstract 62 B1.62

Abrupt stimulus motion eliminates task-specific immunity to pictorial illusions

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Several studies have suggested that the grip-scaling component of manual prehension is largely immune to many salient pictorial illusions. More recent work has suggested that it is the focus of attention that accompanies reaching--not the choice of

reaching vs. judgment behavior per se--that is primarily responsible for this immunity. Thus, if one judges the size of a single element of a display that serves as a reaching target, then the effects of pictorial illusions on judgment and reaching appear quite similar (small effects for the horizontal-vertical and Ebbinghaus illusions, large effects for the Mueller-Lyer illusion). If this account is correct, then if stimuli are generated so that it is difficult to focus attention on a single element, the effects of these pictorial illusions should return. This hypothesis was tested by presenting participants with the horizontal-vertical, Ebbinghaus, and Mueller-Lyer illusions. Some participants made comparative judgments about the key elements of these displays; others made metric judgments about the sizes of single elements in millimeter units. Half of the stimuli were stationary; the other half abruptly shifted position on the computer screen at a rate of 5 Hz. The stimulus movement did not affect comparative judgments or judgments of non-illusion inducing stimuli. However, the effects of the horizontal-vertical and Ebbinghaus illusions were significantly increased. These findings provide further evidence that perception and action control are mediated by similar information processing systems. This work was supported in part by Northwestern University start-up funds and NIH grant 1-R01-HD40827-01.

Perceptual Learning

Abstract 63 B1.63

Neural plasticity and accidental human laser macular injury

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Purpose: To evaluate mechanisms of long term recovery of visual function based on three human laser accident cases and the remarkable recovery these cases demonstrated in the presence of macular damage. Methods: Visual acuity, contrast sensitivity, eye movement fixation pattern, the FM 100 hue color discrimination test and anomaloscope matches were used in analysis of visual function. CSLO Ophthalmoscopy and Optical Coherence Tomography (OCT) characterized the presence of retinal traction, scar, thickness and hole formation. Ophthalmoscopy was used to evaluate preferred retinal location (PRL) in focal contrast sensitivity tests. Results: Visual acuity, contrast sensitivity and color vision recovered within 3 months (cases 1 and 2). In case 1, a thinner than normal foveal thickness was measured with OCT. Foveal OCT measurements (case 2) showed a break in foveal thickness. Foveal PRL measurements indicated functionality for case 1 and non foveal functionality for case 2 which developed a new PRL superior temporal to the fovea. Color vision metrics (case 3) recovered completely within 12 months post. Visual acuity and contrast sensitivity were near full recovery at two years post. OCT imaging revealed a macular hole at 3 months post and ophthalmoscopy revealed the presence of traction about the hole. At 12-24 months considerable "filling" of the hole appeared with the absence of traction. Ocular motility involved foveal and parafoveal retina. Conclusion: These cases suggest that morphological changes in retinal recovery may induce higher order visual brain centers to accept weaker retinal afferent signals from damaged retinal sites. More severe scar and traction limit retinal and cortical neural plasticity.

Abstract 64 B1.64

Shape-specific perceptual learning in a figure-ground segregation task

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As shown in the classic Dalmatian dog demonstration, top-down knowledge aids figure-ground segregation. Such top-down knowledge is acquired through perceptual learning, and this study introduces a new paradigm to measure how learning affects figure-ground segregation. Subjects were required to detect symmetric dot patterns (targets) embedded in a random dot background field. The targets appeared on either the left or right side of fixation at a fixed eccentricity, and subjects reported the location of the target. Each subject was trained on two different dot patterns. To facilitate training at the beginning, bottom-up segregation cues were provided; targets were colored yellow amongst a background field of white dots. As learning proceeded across blocks, the color of the targets gradually changed to white, so that by the end of training, the dot field appeared homogeneous. During the testing phase, subjects were tested on both trained patterns and novel patterns using the homogenous displays. Subjects were significantly better at detecting trained patterns. This result allows us to study how the visual system acquires top-down visual knowledge to facilitate figure-ground segregation.

Abstract 65 B1.65

Topographical patterns of visual field recovery: Changes of objective and subjective visual field size in brain-lesioned patients

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We observed topographical patterns of functional recovery over sixmonths of visual restitution training, comparing changes of objective and subjective visual field size. Perimetric and campimetric tests served as objective measures of intact visual field size. The subjective position of the visual field border was indicated in a standardized chart of the right and left eye. After baseline testing, nineteen patients with post-genicular lesions of the visual system performed visual restitution training. Diagnostic procedures were repeated after six months of treatment. Correlations between objective and subjective visual field size and changes in both variables over the treatment period were determined. Topographical patterns of visual field recovery in both tests were analyzed. Even before training, subjective visual field size was substantially correlated with perimetric measurements. In parallel with an increase of stimulus detection in “objective” visual field tests, a decrease of subjective defect size was observed (significant for the left eye) during the treatment period, and correlations of subjective and objective visual field size increased. Form and size of the scotoma were adequately represented in most patients, with

foveal defects being perceived as larger than more peripheral parts of the scotoma. Training-induced improvement could also be recognized in patients'drawings. Visual restitution training increases intact visual field size in "objective" visual field tests but also affects the subjective representation of the defect. Objective as well as subjective measures of scotoma size reflect the architecture of the visual system because topographical patterns of recovery follow the laws of the cortical magnification factor and the subjective importance of improvement depends on the eccentricity of the border shift.

Abstract 66 B1.66

Does categorical perception result from perceptual learning?

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Categorical perception (CP) is apparent when equally different stimuli appear unequally different as a function of their category membership. Typically cross-category discrimination is better than within category discrimination of stimuli that are equally different on some physical metric. Although evidence suggests that CP effects can be acquired as a result of learning (Goldstone, 1994, JEP, 123, 178-200), the mechanism of this learning remains unknown. In fact, there has been little evidence that it is indeed a perceptual phenomenon. In contrast to explanations that CP results from linguistic labelling strategies (cf. Roberson & Davidoff, 2000, Memory & Cognition, 28, 977-986), we explored whether CP effects result from a perceptual learning (PL) process.

Specifically, we measured whether a CP effect, acquired as a result of training, was specific to stimulus spatial frequency and retinal location.

First, using a same-different judgement task we measured sensitivity to orientation differences between Gabor patches that varied in orientation from 0 deg to 3.5 deg. In separate experiments discrimination was measured for Gabors at each of two spatial frequencies (1 & 8 cpd) and at each of two retinal locations. Next observers were trained to categorise singly presented stimuli into one of two categories. These were defined by dividing the orientation continuum in half. During categorisation training stimuli were always presented with just one of the two possible spatial frequencies (exp. 1) or at one of the two possible retinal locations (exp. 2). Following category learning, observers' orientation discrimination was re-measured.

Specificity of acquired CP effects to stimulus parameters such as spatial frequency and retinal location suggests that CP results from perceptual learning in early visual processing mechanisms rather than central cognitive processing and argues for an influence of cognition on perception.

Abstract 67 B1.67

Perceptual deterioration predicts performance today

Sara Mednick, Neha Pathak, Ken Nakayama, & Robert Stickgold Harvard University, Harvard Medical School

Last year we showed that repeated, within-day testing on a texture discrimination task (TDT) induced performance deterioration. This deterioration was retinotopically specific. That is, baseline performance was recovered when targets were switched to the contralateral field. Further, performance also recovered following an hour nap rich in slow wave sleep. We now show that performance on the TDT not only decreases with repeated testing, but it also predicts subsequent performance after a night of sleep, for nappers and non-nappers alike. Thus nappers showed better performance than controls both at 7pm and the following morning. 24 subjects were tested on the TDT at 9am (baseline) and 7pm (T1) on Day 1 and then at 9am the following morning (T2). Half the subjects took a polysomnographically monitored mid-day nap on Day 1. In both nappers and controls, subjects' initial change in performance (T1-baseline) was highly correlated with their final change in performance, (T2-baseline) (controls, $r = 0.87$; nappers, $r = 0.58$; combined groups, $r = .80$). Performance varied significantly in the control subjects across the day. In contrast, all nappers showed either improvement or maintenance of baseline performance across the day. At T2, only nappers showed normal improvement (T2 vs. baseline) following a night of sleep. We suggest that performance at T2 is highly dependent on an information processing capacity limit that can be reached as a consequence of over-practice at T1. This capacity limit appears to vary between individuals, but is consistently refreshed by both daytime napping and nocturnal sleep.

Abstract 68 B1.68

Using external noise methods to isolate mechanisms of attention/perceptual learning

Zhong-Lin Lu & Barbara A. Dosher U. of Southern California, USA, UC Irvine, USA

We proposed a theoretical framework to distinguish three mechanisms underlying performance improvements in visual attention (1-5) and perceptual learning (6,7): stimulus enhancement, external noise exclusion via template retuning, and reduction of contrast gain-control or multiplicative noise. Measuring TVCs (threshold vs external noise contrast) at multiple performance levels under joint manipulations of external noise and attention/training can characterize the nonlinearities in the perceptual system and distinguish mechanisms and their mixtures (7,8). In visual attention, several pure cases of template retuning (2-4) and stimulus enhancement (1,4,5 have been reported. In perceptual learning in visual periphery, we found a mixture of stimulus enhancement and template retuning (6). Gold et al.(9) replicated our results with other stimuli; but instead concluded that perceptual learning only changed the signal not the noise. Our conclusions were based on a multiple-TVC constraint on nonlinearity, while Gold et al's were based on double-pass response consistency (10). However, the double pass method only assesses the internal to external noise ratio. We show that response consistency is a function only of the ratio. Mathematically, neither the multiple-TVC nor the double-pass method can distinguish stimulus enhancement from internal additive noise reduction, nor a mixture of stimulus enhancement + external noise exclusion from the changes only in signal claimed by Gold et al. We discuss empirical results,

the mathematical properties of multiple-TVCs and measures of response consistency, their relation to different classes of observer models, and to performance signatures of attention and perceptual learning.

1. Lu & Dosher, VR'98. 2. Dosher & Lu, PsychSci'99. 3. Dosher & Lu, VR'00. 4. Lu & Dosher, JEPHPP'00. 5. Lu, et al, VR'00. 6. Dosher & Lu, PNAS'98. 7. Dosher & Lu, VR'99. 8. Lu & Dosher, JOSA'99. 9. Gold, et al, Nature'99. 10.Burgess & Colborne, JOSA'88.

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Abstract 69 B1.69

Perceptual learning in peripheral vision with attention reflects (mostly) template retuning

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Under divided attention, perceptual learning of Gabor orientation identification in peripheral vision reflects a mixture of stimulus enhancement and template retuning with nearly equal amount of threshold reduction in a full range of external noise (1). In this study, we ask: what is the mechanism of perceptual learning in peripheral vision under focal attention? On each trial, two Gabors with equal contrast but independent orientations were displayed simultaneously at two spatial locations: upper-left (3.1 deg, 2.3 deg), and lower-right (-3.1 deg, -2.3 deg). The eccentricity and the parameters of the Gabors were identical to those in Dosher & Lu (1998). A central pre-cue occurred 217 ms before the onset of the Gabor. The observer was instructed to report the orientation of the Gabor only at the cued location, which varied randomly across trials. Six levels of external noise were added to the Gabors. The contrast of the noise in the two spatial regions was always the same in each trial. Two staircases, 3/1 and 2/1, were used to measure thresholds at two performance levels (79.3% & 70.7% correct) for each external noise level and each spatial location. A total of 1,296 trials were run in each of 20 sessions of training by each observer. All three observers showed a larger magnitude of learning in high noise (46% reduction in contrast threshold) than in low noise (25% reduction in contrast threshold). PTM modeling identifies a primary template retuning, and a secondary stimulus enhancement mechanism of perceptual learning. This contrasts with essentially equal learning in high and low noise with divided attention in (1). We conclude that perceptual learning in periphery with spatial attention, as in fovea (2), reflects mostly template retuning.

Dosher & Lu, PNAS, 1998.
Lu & Dosher, ARVO, 2001

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Abstract 70 B1.70

Learning to see the trees before the forest: Reversible deactivation of the superior colliculus during learning of local and global visual features

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Previous studies have established that the superior colliculus (SC) is critical for the rapid learning of pattern discriminations. This raises the question of whether pattern discrimination learning deficits during SC deactivation are related to an impairment in learning local or global pattern features. To answer this question, the ability of cats to learn three compound image discriminations was studied during bilateral reversible deactivation of the superficial layers of the SC. The animals concurrently learned to discriminate three pairs of visual patterns: 1) The congruent pair - a large T formed by small Ts versus a large 7 formed by small 7s. 2) The incongruent pair - a large T formed by small 7s versus a large 7 formed by small Ts. 3) The random pair - scattered small Ts versus scattered small 7s. The cats were trained to respond to the large T's in the congruent and incongruent pairs and the small T's in the random pair. In intact cats, learning of the random pair was slower than the rapid learning of the congruent and incongruent pairs. This finding demonstrated the theory of global precedence because the cats learned the global features of the congruent and incongruent pairs much more quickly than the local features of the random pair. In contrast, during bilateral deactivation of the superficial layers of the SC, the learning of the incongruent pair was significantly retarded and took longer than learning the random pair. Congruent and random pair learning rates were unchanged. The specific deficit in learning the incongruent pair indicates that the learning of global, but not local, elements of the visual pattern is impaired during deactivation of the SC. The unimpaired use of local features permitted the animals to learn the congruent and random pairs at normal rates. Therefore, deactivation of the superficial layers of the SC during pattern discrimination learning reverses the precedence for global visual features that is typical of normal learning.

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Abstract 71 B1.71

How does object processing change with perceptual expertise?

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To gain a better understanding of how perceptual expertise affects object processing, we trained subjects to be experts at a novel class of homogeneous objects. In contrast to earlier studies, the stimuli, although based on Greebles, were asymmetrical in terms of part arrangement. To assess how object processing changed with expertise, we ran an extensive battery of behavioral tests concurrently with expertise training, including: (1) a same/different task between two sequentially presented images of Greebles where both were either upright or inverted; (2) a same/different task between two simultaneously presented images of Greebles where we varied the presentation time from 50-500 ms; (3) a visual search task where subjects search for a familiar or unfamiliar Greeble among distractors that were either more or less visually similar; (4) an interference task where a Greeble or an object from a non-expert domain (e.g., a car) appeared flanked on both sides by either Greebles or objects from the non-expert class (subjects

were told to ignore the flankers and judge whether the target was upright or inverted); and (5) a recognition memory task for familiar versus unfamiliar examples from classes trained at either the individual level (Greebles) or basic level (Fribbles). Based on the assumption that post training configural (holistic) processing is applied automatically to objects from domain of expertise, it was hypothesized that subjects perform differently from their pre-training performance compared to control objects (expertise effects may facilitate or hinder processing). Indeed, this was the case with some tasks showing improved performance and others showing decrements in performance for experts. Such results suggest that perceptual expertise is not a unitary process, but rather recruits a wide variety of mechanisms in the perceptual "tool-kit" that reflect different components of the default processing applied by experts in their domain of expertise.

This research is a result of Perceptual Expertise Network – a collaborative award from James S. McDonnell Foundation.

Abstract 72 B1.72

Learning only after sleep in a contour integration task

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Performance has been shown to improve in texture discrimination tasks 6-8 hours after training in waking state (1) or following at least an hour day-time nap (2). However, the increase is the largest after a good night's sleep of at least 6 hours (3, 4). Here we studied the effect of time between testing sessions on the performance of normal human observers in a contour integration (CI) task. The CI task involves spatial integration at a longer range than in texture discrimination tasks.

Stimuli were composed of a background of randomly oriented Gabor patches, and a closed contour defined by Gabors of the same parameters (5.0 c/deg carrier frequency, 90% contrast). In a 2AFC paradigm, observers decided whether the contour, forming a smooth egg-shape, was pointing to the right or to the left. Angular difference between the path of the contour and contour elements was varied between 0-28 in 7 levels of increasing difficulty. Five 30 minutes sessions were completed within a day in the one-day group of observers, and one session was completed daily on five consecutive days in the five-day group.

The overall performance of the one-day group did not increase by the end of the experiment, although there was a slight but statistically not significant progress in CI by the third session. There was no time-of-day effect in the five-day group. The five-day group showed significant improvement between the 1st-4th and the 1st-5th sessions.

Our results are consistent with earlier studies of perceptual learning, and confirm a slow, sleep-dependent consolidation period in a task involving long-range spatial interactions.

(1) Karni, A. & Sagi, D. Proc Natl Acad Sci USA 88, 4966-4970, 1991
(2) Mednick, S. et al. Vision Sciences Society, First Annual Meeting, 2001
(3) Stickgold, R. et al. J Cogn Neurosci. 12(2), 246-54, 2000
(4) Gais, S. et al Nat Neurosci. 3(12),1335-9, 2000.
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Abstract 73 B1.73

Task-dependency of tuning characteristics change in the course of perceptual learning

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[Purpose] Last year in VSS, we reported that detection and discrimination learning might involve different mechanisms (Koyama et al. 2001). This year, using more sophisticated methods, we examined how attention changes tuning characteristics in each type of learning. [Methods] The subjects were divided into two groups. They participated in either coherent motion detection training or coherent motion direction discrimination training. In the detection training (n=5), subjects viewed two Newsome-type dynamic random dot displays successively and judged which of the two displays contained coherent motion (18% coherence). In the discrimination training (n=5), the subjects judged whether the directions of the coherent motion in two successively presented displays matched (difference of the two directions=20deg). Importantly, the same set of stimuli were used for both types of training with equal frequency. Before and after the training, the coherent motion detection thresholds were measured for nine directions including the trained directions. [Results] Surprisingly, the two groups showed opposite patterns of learning. The detection group showed more increase in sensitivity at the trained directions than untrained directions. In contrast, the discrimination group showed less increase in sensitivity at the trained directions than untrained directions. However, the pattern of learning became similar between the two groups when the two trained directions were separated by 90deg: in both groups sensitivity increase was greater at the trained directions than untrained directions. [Conclusions] Although both groups viewed the same stimuli equally often, they showed opposite patterns of improvement. These patterns of tuning characteristics changes may be explained by strong lateral inhibition of neighboring directions in the discrimination task but not in the detection task. The recent controversy as to the tuning pattern changes by attention may be explained by task demands.

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Abstract 74 B1.74

Perceptual learning of motion-pattern discrimination: Psychophysics and computational modeling

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Purpose. A) To study perceptual learning during a motion-pattern discrimination task and to probe for transfer of improvement from trained to untrained stimuli. B) To quantify a neural architecture and computational rules that mediate learning in a physiologically inspired model of motion-pattern

processing. Methods. A) In a graded motion-pattern (GMP) discrimination task, random dot stimuli were presented in which the global motion pattern was perturbed relative to a reference motion pattern. Subjects were separated into 2 groups and trained (8000 trials) to discriminate radial or circular perturbations. B) Learning was explored using an interconnected population of MST-like neural units to model psychophysical performance on the GMP task (Beardsley & Vaina, 2001). We tested several physiologically plausible learning rules to modify these lateral connections and shape the resulting population code. Results. A) For each observer, learning was evaluated using an ANOVA across sessions and a t-test of threshold differences between first and last sessions. Learning occurred across subjects and was retained, but did not transfer to the untrained orthogonal motion patterns. B) When we used Hebbian/anti-Hebbian learning rules, the model developed inhibiting interconnections between non-preferred units, resulting in human-like improvements in performance across training sessions. Conclusions. A) The lack of transfer in the GMP task is consistent with previously reported physiological evidence suggesting the existence of specialized motion-pattern detectors in humans. B) The model links these detectors within a functional context to MST, demonstrating how a highly interconnected neural architecture can encode the perceptual information necessary to perform the GMP task. Using simple learning rules, the strength of these connections changed with training, inducing lateral inhibition between non-preferred MST units. This leads to an efficient encoding specific for the trained motions.
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Abstract 75 B1.75

Unsupervised learning of visual structure
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How object and scene structure is represented is an important problem in vision. Considerations of coding efficiency and of systematicity suggest that representations of structurally related objects should share components (which, as our earlier results show, need not be generic, categorical, or mutually exclusive). Can a useful set of object fragments be acquired in an unsupervised fashion? Statistical interdependence criteria such as pairwise conditional probabilities of the fragments, or Barlow's "suspicious coincidence" ratio (the joint probability of two fragments divided by the product of their marginal probabilities), can provide a basis for unsupervised learning. If humans use such criteria in learning structured objects, they would tend to lump together a pair of highly interdependent fragments, perceiving them as a single shape. We tested this hypothesis in two experiments involving a part verification task, in which subjects are known to detect a unitary probe embedded in a larger target faster than a composite one. Altogether, over 90 subjects were tested. As predicted, mere exposure to a set of statistically controlled, structured stimuli (80 and 100 objects in the first and second experiments, respectively) led to a larger speedup for fragment pairs with higher interdependence (conditional probability). This effect was modulated in a complicated manner by the fragment coincidence as measured by Barlow's ratio. Single-fragment probes generally exhibited a smaller speedup than composites. Our study complements and extends recent results by Aslin and others that demonstrate some of the learning strategies used by the brain in dealing with structured stimuli. To elucidate the mechanisms behind this kind of unsupervised learning, we developed a computational model of visual structure acquisition, which accepts the same stimuli seen by the human subjects, and exhibits similar patterns of behavior.

Abstract 76 B1.76

Perceptual learning in human primary visual cortex
Christopher S. Furmanski & Stephen A. Engel UCLA, USA

Repeated practice of perceptual tasks often produces marked improvements in behavioral performance. While such perceptual learning is found across a variety of visual tasks, physiological evidence of corresponding neural changes in humans has remained elusive. We hypothesized that practice of a task thought to be mediated by early visual mechanisms (i.e., simple contrast-detection) would produce measurable changes in human primary visual cortex (V1). Here were used fMRI to measure the effects of perceptual learning on activity in V1. Subjects spent more than twenty days (>10,000 trials) practicing detection of sinusoidal gratings. In order to quantify the specificity of learning, fMRI measurements and behavioral thresholds for contrast-detection and orientation-discrimination were collected before and after training for several eccentricities and grating orientations. We found that V1 responses for practiced gratings were reliably greater than those responses collected prior to training. Critically, the specificity of changes in V1 responses mirrored the specificity of changes in perceptual thresholds; both the changes in detection thresholds and V1 responses were orientation, and spatial-location specific. While these results are consistent with several models of the neural mechanisms of perceptual learning, the simplest explanation of our data may be a bottom-up gain change produced by a re-weighting of synaptic connections.

Abstract 77 B1.77

Learning categorization mapping with a race model
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Neural network are generally based on the assumptions that connections represents strength of association. Although it lead to major breakthrough in the study of cognition, this solution has problem accounting for some of the most basic data collected on humans. First, this kind of network has conceptual difficulties generating predictions on reaction times. The most obvious one being that empirical reaction times are always asymmetrical. Second, learning is generally slow, even with second-order gradient descent.

We propose a network somehow similar to the architecture of standard supervised network. The main difference is that we do not assume that connections are strength of association and thus, we do not use the weighted sum approach. Instead, we assume that all the connections are equally strong. It is rather the time they take to become

activated that is crucial. Outputs are made by assessing whether a critical amount of connections are activated at any given moment. The first output to reach criterion is triggered. In essence, this type of network is the purest form of a winner-take-all network. It is at the same time an accumulator model often studied in cognitive psychology.

We explore such a network, called a parallel race network, and propose one simple learning rule that can learn arbitrary mapping of input to outputs. Among other things, this network can learn a XOR problem without the need for hidden units.

The speed of learning is very good. For example, XOR problems can be learned in around forty exposures to the stimulus set. In addition, it is simple to demonstrate what is the predicted shape of the response time distributions. It turns out to be very similar, if not identical, to human response time distributions. Finally, trade-offs are naturally implemented in this network using an increase in the decision criterion. Thus ROC curves can be generated for this network as well pretty easily.

Abstract 78 B1.78

Perceptual learning of motion direction discrimination in fovea reflects mixed but separable mechanisms of stimulus enhancement and template retuning

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The external noise plus perceptual learning paradigm and the perceptual template model (PTM) distinguish three mechanisms of perceptual learning: stimulus enhancement, template retuning, and multiplicative noise (or equivalently, contrast-gain control) reduction. Dosher & Lu (1) found a mixture of stimulus enhancement and template retuning in perceptual learning of orientation discrimination in periphery. A key test of the PTM framework is the separability of mechanisms. Pure template retuning was found in learning of orientation discrimination in fovea (2). Here, pre-training in high external noise is used to separate stimulus enhancement from template retuning in foveal motion direction discrimination. Two groups, either with or w/o pre-training in high external noise, performed first-order sine-wave (2.3 c/d, 8 Hz) motion direction discrimination. In the subsequent training, contrast thresholds were measured 70.7% and 79.3% correct using staircase procedures for each of eight levels of external noise added to the stimulus. Observers were trained in ten sessions of 1120 trials each. Without pre-training, perceptual learning reduced contrast thresholds by about 50 % across all noise levels, or equal contributions of stimulus enhancement and template retuning. Contrast thresholds were reduced by 37% during high external noise pre-training. Subsequent training reduced contrast threshold by 54% in low noise but only 24% in high noise. Improvements in low noise continued over days, while no significant improvement was observed in high noise after the first two training sessions. Pre-training in high noise nearly saturated high noise learning, leaving performance in low noise to improve as though no pre-training was administered. This suggests that learning in low noise is separable from learning in high noise. Stimulus enhancement and template retuning in learning first-order motion direction discrimination are mixed but separable.

Dosher & Lu, PNAS, 1998
Lu & Dosher, ARVO, 2001

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Surfaces

Abstract 79 B1.79

Anomalous contours prevent brightness spreading in phantom illumination displays

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In the phantom illumination illusion a homogeneous dark background (B) shows two different brightness levels due to the presence of surfaces (S) shaded with a linear luminance gradient ranging from black to white. The spatial distribution of the shaded surfaces is so that all their light ends can be virtually connected with a contour. The portion of the background (B2) facing the light ends of S appears brighter than the rest of the background (B1).

Two experiments are discussed that show that when the distribution of S is so that B2 appears like an anomalous surface, then the brightness spreading that characterizes the illusion disappears. The first experiment was conducted on a CRT and the subject's task was to rate B2 with respect to B1 on a –20/+20 scale. The second experiment was conducted with paper displays using a paired comparison method with a forced choice task between which B2s appeared darker.

While the results strongly suggest that the brightness spreading is subsequent to figure-ground articulation, phenomenal observation of the experimental displays suggests also the presence of a low level component of the illusion which determines local effects for each S element. The formation of anomalous contours cannot overwhelm these local effects but it can prevent their spreading beyond S and its immediate surround (global effect).

The illusion is also discussed in relation to other brightness/lightness effects, such as color neon- spreading, assimilation and the glare effect.

Abstract 80 B1.80

LAMINAR CORTICAL MECHANISMS FOR THE PERCEPTION OF SLANTED AND CURVED 3-D SURFACES AND THEIR 2-D PICTORICAL PROJECTIONS

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A detailed model of how the visual cortex represents slanted and curved surfaces in three-dimensional space is presented. These 3-D representations depend crucially on non-classical receptive field interactions with both intracortical and intercortical feedback playing major roles. Neurophysiological experiments have disclosed the existence of cells that are sensitive to angles (Pasupathy and Connor, 00), and to

disparity-gradients (Hinkle and Connor, 01). The model shows how such cells are organized within the laminar circuits of cortical areas V1 and V2, notably layers 6, 4, 3B and 2/3A, for representing slanted and curved surfaces. The model can explain slant aftereffects, contrast displays that involve disparity gradients, and variants of neon color spreading in 3-D. The model also explains how 2-D pictures that implicitly represent slanted and curved 3-D surfaces can generate 3-D figure-ground percepts. Apart from binocular disparities, various monocular cues, such as occlusion, contrast, relative size, and angles, give rise to compelling 3-D percepts. Many of these monocular cues by themselves are ambiguous. For example a specific angle in an image can be associated with different surface slants. The model explains how non-classical receptive field interactions within the laminar circuits of visual cortex can contextually disambiguate the classical receptive field responses to individually ambiguous cues. The model shows how these interactions explain data such as volume completion images (Tse, 99) and Necker cube multi-stable percepts (Kawabata, 86).

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Abstract 81 B1.81

Surface based mechanisms of attentional facilitation and inhibition in motion perception

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Purpose. The goal of this study is to investigate the mechanisms of surface-based attentional modulation of visual motion processing. We used the motion aftereffect (MAE) as a tool for quantifying the attentional facilitation and inhibition.
Methods. Adapting stimuli consisted of two dot populations, moving transparently with the same speed in different directions: Dots in the "effector" population E, the MAE of which was measured, moved coherently in one direction (0). Dots in the "distractor" population D moved in a direction orthogonal to that of E, and this direction reversed roughly every 3 s (+90 or -90 with respect to E's direction). Luminance-change "episodes," i.e., a proportion of dots becoming slightly brighter or dimmer, occurred randomly within each population. MAE was measured in three conditions: 1) Passive: observers had no attentional task. 2) Attend to effectors: Observers reported the direction of luminance change (brighter or dimmer) within population E. 3) Attend to distractors: Observers reported the direction of luminance change within D. MAE strength was measured by the percentage of directionally biased dots, among randomly moving dots, required to null the MAE.
Results. We found that the strength of MAE was increased when observers attended to the luminance change of the dots in population E, and decreased when they attended to that in the orthogonal component D, as compared to the passive viewing condition.
Conclusions. Attention to one of the features, in our case the luminance of transparently moving surfaces, results in both enhancement of the motion signal associated with the attended surface, as well as inhibition of that associated with the unattended surface. These results strongly suggest that, in the case of bivectorial transparent motion, attention is directed to the moving surface as a whole rather than to its individual features.

Abstract 82 B1.82

The role of convexity and part structure in modal and amodal completion

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What geometric constraints determine when the visual system will interpolate between two disjoined image fragments to create the percept of a single unified surface? In particular, to what extent does local contour geometry predict surface completion? We compared visual completion (both modal and amodal) across situations in which the local contour geometry was the same, but the surface geometry (i.e., its shape description) was very different. Observers viewed stereoscopic displays consisting of two inducers separated by an orthogonally oriented oval. The oval was given either near or far disparity relative to the inducers, thus requiring the inducers to complete either amodally behind the oval, or modally in front of it. The contours of the inducers leading up to the oval were bent either inwards or outwards, by the same angle, requiring either concave completion (inducing a two-part structure) or a convex completion (with no part boundaries). On each trial, two probes (a single or double “wiggle”) were briefly flashed--one along each inducer--and then masked. Observers judged whether the two probes were the same or different. From single-object-superiority / two-object-cost paradigms, we expect performance to be better for stronger visual completions. Accuracy and RT data revealed that, for both modal and amodal completion, performance was better in the convex case than in the concave case. The results support and extend Liu et al.’s (1999) findings, using a very different method. They indicate that modal and amodal completion depend not only on local contour geometry, but also on the shape description (such as perceived part structure) that the enclosed surface receives.

Abstract 83 B1.83

A computational model of the perception of partially occluded figures

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Purpose: Prior theories of the perception of partially occluded figures have stressed bottom-up, local processing, in which depth cues are necessary for discriminating contours "extrinsic" to an occluded figure from those "intrinsic" to it. Results of our experiments reported previously indicate that any contour feature can be used in such discrimination (e.g., orientation, curvature, spatial scale). Further, the percept is not based on mere integration of visible contours of the figure, suggesting

the operation of top-down, global processing. To verify these claims, we formulated and tested a new computational model.

Methods: The model is based on an exponential-pyramid architecture and processing involves two stages. The first stage (bottom-up) computes local variance of each contour feature (orientation, length) and verifies whether this variance is approximately constant across the image and spatial scale (receptive field size). Non-constancy of the variance indicates the presence (and position) of a figure in the image. The second stage (top-down) uses this statistical information to discriminate between intrinsic and extrinsic contours. The model has only one free parameter: the standard deviation of decisional noise. Model and human performance were compared across 11 experimental conditions.

Results: Subjects' performance was close to perfect when there was no overlap between the histograms of a givenfeature for the figure and for the occluder. Performance systematically deteriorated when overlap between the two histograms increased. The new computational model accounts well for all 11 experimental conditions.

Conclusions: Perception of occluded figures is not a purely bottom-up process integrating spatially local pieces of information. Instead, it begins with determining spatially global properties of the image, which are then used to make local perceptual decisions. Such a two-stage mechanism is computationally more robust.

Abstract 84 B1.84

Testing optimal Gaussian cue combination models with possibly correlated depth cues

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Estimates of depth from different depth cues are often modeled as Gaussian random variables that are typically assumed to be uncorrelated. Whether the cue estimates are correlated or not, the optimal cue combination rule is a weighted average of cue estimates whose weights can be computed directly from the variances of the cue estimates and their correlations. We test whether human cue combination performance is consistent with the optimal Gaussian rule with possibly non-zero correlation. Stimuli were slanted planes defined by linear perspective (a grid of lines) and texture gradient (diamond-shaped texture elements). The observer's task was to adjust the slant of the plane to 75 degrees. Feedback was provided after each setting and the single observer trained extensively until her setting variances in all conditions stabilized.
We chose a HIGH and LOW variance version of each cue type and measured setting variability in the four single-cue conditions (LOW, HIGH for each cue) and in the four possible combined-cue conditions (LOW-LOW, LOW-HIGH, etc) in randomized order.
We first fit the uncorrelated Gaussian model to the data by maximum likelihood estimation of its parameters. The results reproduced the observer's setting variances in all conditions to within 9% on average. However, there was an evident pattern in the deviations between fit and data: the observer's variances in the combined cue conditions were higher than would be expected given the variances in the single cue conditions (nested hypothesis test, $p < 0.01$). When we refit the model with correlation as a free parameter, the deviations between model and data were 4% on average (the largest deviation was 10%), but the same pattern of deviations was present (nested hypothesis test, $p < 0.02$). Our results indicate that, while the observer's performance was close to that predicted by the Gaussian models, the observer did not combine information from cues as efficiently as either model would predict.

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Abstract 85 B1.85

The visual perception of length along intrinsically curved surfaces

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Past investigations of the perception of length along 3-D surfaces (e.g., Gilinsky, 1951; Norman, Lappin, & Norman, 2000) have demonstrated that observers' perceptions of lengths along flat and cylindrically curved surfaces are systematically distorted. In the current experiments, we extended the past research and evaluated observers' perceptions of length and spatial extent along physically curved surfaces that possessed intrinsic curvature. The surfaces with positive and negative Gaussian curvatures were a hemisphere and a hyperbolic paraboloid with radii of curvature of 14 cm. The surfaces were covered with a random texture (to create a "carrier" for binocular disparity, etc.). Observers viewed these surfaces at two distances (50 and 180 cm) and on each trial were required to estimate the length between one of 40 possible pairs of surface regions by adjusting a 2-D line on a PC monitor until its length matched that of the curved length. The observers judged each of the 160 surface lengths (40 pairs x 2 surfaces x 2 viewing distances) ten times, and thus completed a total of 1600 judgments. The results showed that the observers were reliable and precise in their judgments (average Pearson r's of 0.97), but in general they were not accurate. The slopes of the regression functions relating adjusted length to actual length varied widely between 0.8 to 1.5. The magnitude of these large perceptual distortions varied across observers. There were smaller effects of distance, such that the perceptual distortions were typically larger at the nearer viewing distance. Thus, in conclusion, it is apparent from the results of this experiment and from past investigations that the perception of length and spatial extent is not veridical in any context, whether evaluating distances in empty space, or between locations on flat or curved surfaces, even in full-cue situations where binocular disparity and other optical information is available.

Abstract 86 B1.86

Surface interpolation and illusory boundary formation in stereoscopic images: the role of local element properties.
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Since White (1962) there have been many reports of the formation of illusory, depth-defined contours in sparse random-element stereograms. The most common example is that of the standard depth-defined square which floats above a random-element background. The boundaries of the square typically appear continuous and regular, in spite of the fact that there are large areas along the boundary containing no elements. Clearly in these instances the visual system employs an interpolation process to assign depth values to the ambiguous regions on either side of the boundary. The aim of these experiments was to identify constraints on this type of 3D interpolation/boundary formation, specifically, the role of local element attributes such as size and spacing on the perceived locations of depth-defined boundaries. Our stimulus was a sparse random dot stereogram depicting an 11.31 x 6.8 rectangular region in the plane of the screen with a 4.5 central square defined by 0.1 of horizontal disparity (2.5 cm) in depth. The monitor's display area was divided in half horizontally with the 3D test stimulus presented on the top portion. The same image was presented on the bottom half of the screen binocularly with zero disparity. The subject's task was to demarcate the boundary along the right edge of the disparate square in the 3D image using its 2D counterpart. To assess the effect of element properties on 3D surface interpolation we created versions of the test stimulus with gaps ranging from 0.6 to 3 deg., and separately varied element size and spacing. Results indicate that element spacing strongly influences interpolation and boundary formation but element size alone does not. We found that as average spacing increases subjects show increased interpolation across image gaps. These data show that 3D surface interpolation and the resultant boundary formation are not simply the result of local operations performed on isolated elements.

Abstract 87 B1.87

The perception of convex and concave surfaces under natural lighting conditions
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Much of the recent research on the visual perception of shape from shading has employed computer generated images, which often do not include several basic components of shading that are common in natural scenes, such as cast shadows, indirect reflections and specular highlights. The present research was designed to investigate the effects of these components on observers' perceptions of convex and concave bumps. In the simulated scenes, these bumps were positioned on an inside wall of a room that was illuminated by a square area light in the center of its ceiling. Images were created from a point of observation in the center of the opposite wall. The rendering model used a radiosity algorithm to calculate the indirect reflections within the room, and a ray-tracing algorithm to calculate the cast shadows and specular highlights. Each of these effects could be turned on or off independently, and they were presented to observers in all possible combinations. The simulated bumps had three possible depths for both the concave and convex surfaces, and their images were presented in both upright and inverted orientations. Observers judged the shape of each bump by adjusting a curve on the monitor display screen to match its apparent profile in depth. The results revealed large individual differences in the overall pattern of responses. For some observers there was an inversion of perceived relief when images were presented up-side down, though this effect was generally eliminated when cast shadows were present. A majority of observers had a strong bias to interpret the displays as convex, and the magnitude of perceived depth was significantly larger for the convex surfaces. In general, the highlights and indirect reflections had little effect on performance.

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Abstract 88 B1.88

Perceiving illumination direction in 3D texture
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Image texture due to 3D surface corrugations ("3D texture") differs fundamentally from image texture due to pigmentation variations of a smooth surface ("flat texture"). Flat texture yields no information concerning the way the surface is illuminated, whereas 3D texture is highly dependent upon the illumination.
Question: Is the human observer able to perceive the illumination direction from 3D texture?
Method: In order to address this question we extracted over sixty 3D textures due to natural materials from the Curet database. Fiducial illumination directions were 22.5º, 45º and 67.5º from the normal direction, all viewing directions were normal. The samples were clipped to circular discs and were randomly rotated in the picture plane. Observers indicated perceived illumination direction by way of an indicator panel showing a hemispherical boss on a plane, viewed normally to the plane. The simulated illumination direction was under the observer's control. Five observers viewed all samples in six different orientations.
Result: We find that the azimuth of the illumination direction can be perceived quite veridically except for the fact that 180º confusions are frequent. The elevation cannot be perceived with great certainty (deviations up to 45º occurring frequently) though the increase of perceived elevation with true elevation is significant. We find a number of interesting variations on this pattern that depend critically upon the type of texture.

Abstract 89 B1.89

The notion of 'purely time-based figure-ground segregation' is still justified

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Can our visual system bind elements together if their only shared feature is synchronicity of change?
Lee and Blake found evidence in favor of this idea using (a)synchronous motion reversals of shifting Gabor patches. Motion reversals in both, figure and ground, followed independent random processes, thus achieving synchronicity within each area and asynchronicity between them. Farid and Adelson replaced the Gabor patches by randomly distributed dots which moved back and forth within small apertures. They demonstrated that figure-ground segregation does not rely on the (a)synchronicity itself but on a contrast artifact resulting from low-pass filtering: long runs of dots produce low contrasts whereas repetitive reversals result in temporally high contrast. Here, we report about two new experiments using the same spatial stimuli but different temporal protocols. In the first one, we found that (a)synchronous motion reversals of dots on a CRT-screen were insufficient to segregate figure from ground, thus ruling out the involvement of motion detectors as an underlying mechanism for segregation. In contrast, introducing short breaks of about 30 ms before each reversal rendered the figure visible. Since small breaks also lead to temporally higher contrasts, this experiment is supportive of Farid and Adelson's hypothesis.
In a second experiment, we used the same random process for both, figure and ground, but with a constant temporal offset between them. Hence, contrast modulations in the figure appeared in the ground a few frames later. Segregation was possible with offsets longer than 30 ms.
We conclude that, whatever the integration time of the low-pass filter proposed by Farid and Adelson (typically around 100 ms), its output has to be read by a spatio-temporal mechanism able to detect offsets with a high temporal resolution in order to achieve segregation in these displays. Hence, the notion of a 'purely time-based figure-ground segregation' still seems justified.

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Abstract 90 B1.90

A dynamic but motionless cue for occlusion- and its consequences

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A stimulus' disappearance can be perceived to be caused by occlusion or by the stimulus simply being gone. Demonstrations of dynamic occlusion, such as Michotte's tunnel effect, traditionally have included motion, with the implication that motion may be a necessary ingredient. Here I demonstrate dynamic occlusion percepts that do not include motion. In these new phenomena, when part of an object is replaced with another, the second object appears to be in front, even when there are no static cues to the occlusion. The missing part of the first object is amodally completed through time. This completion has perceptual consequences. One is that the part that disappears will not match with a displaced copy to create apparent motion, as the disappeared part is perceived to still be in the same location, but occluded. Line motion is also affected: the perception of line motion is eliminated when the line's disappearance is attributed to occlusion. The existence of the dynamic but motionless cue to occlusion suggests that researchers should place less emphasis on the role of motion mechanisms in recovering occlusion relationships. In a new line of research, this cue is used to manipulate whether items presented in rapid serial fashion are perceived to be continually present. Ongoing RSVP experiments explore the effect on temporal thresholds for the perception of individual items and their order.

Abstract 91 B1.91

Resolving figure-ground ambiguity

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Recent theoretical work (Anderson, VSS 2001) has shown that occlusion geometry introduces an asymmetry in the depth relationships that can be inferred from near versus far contrast signals. Here, we show how this analysis predicts that the figure-ground relationships of a contour can be resolved by manipulating the depth of a few 3D dots.
Methods: We used two paradigms to assess the encoding of contours in ambiguous figure-ground displays. In Experiment 1, subjects were presented with a rectangle divided into light and dark halves by an irregular contour. Their task was to recall the shape of the dividing contour. A second screen contained either the left or the right half of the rectangle. Subjects indicated whether the irregular contour of the second shape was the same as in the first screen. Perceived border ownership in the 1st screen was manipulated with a few (2 or 6) dots; disparity either placed the dots behind, or in front of, the other half of the display. In Experiment 2 subjects observed similar displays and reported which side appeared as figure, and which as ground.
Results: When the dots were in front of the dividing contour, there was little effect on subjective judgments of figure-ground in Experiment 2, or the reaction times of Experiment 1. This implies that relatively near features (dots) do not uniquely specify the border ownership of further edges. However, when subjects were tested with the half that had contained dots more distant than the contour, reaction times were slowed. In this configuration, the far dots "capture" the regions surrounding the dots to a depth behind the contour, which resolves the border ownership of the contour.
Conclusions: There is an inherent asymmetry in the ability of relatively near and far depth signals to resolve border ownership. We will discuss how the failure to appreciate this difference between near and far depth signals on border ownership has led to erroneous claims about figure-ground perception.

Abstract 92 B1.92

Visual slant-contrast across space and attributes
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Purpose: The perceived slant of a test figure depends on the cue specifying the slant of an inducer (van Ee, Banks, & Backus, 1999). Slant repulsion occurs when relative disparity signals the inducer slant. Attraction occurs when monocular cues are used. We investigated the slant effects with regard to depth separation and lateral separation between inducer and test figure. Methods: Stereoimages were created showing a circular inducer (7.5 deg diam). The slant of the inducer was defined either by perspective, shading, motion or disparity. A central vertical test figure could be rotated in stereoscopic depth by the observer. The task was to adjust the test figure to the apparent vertical. Inducer slant varied between -60 to 60 deg. The lateral separation between the inducer and the test figure was varied in the first experiment. The stereoscopic depth separation between the inducer and test figure was varied in the second experiment. Finally, the possible effect of a frontoparallel reference frame was investigated. Results: 1) The repulsion and attraction effects (van Ee et al, 1999) were reproduced. 2) There were no pronounced effects of spatial separation up to 7 deg for either attraction or repulsion. 3) With depth separation the attraction was still present whereas the repulsion was reduced. 4) Both attraction and repulsion decreased when a frame surrounded the inducer. Conclusion: Both attraction and repulsion are spatially long-range processes, but contrary to the attraction the slant repulsion effect does not generalize in stereoscopic depth. The effects of a reference frame surrounding the inducer further demonstrate the spatial long-range modulation of perceived slant. It's hypothesized that slant from disparity is estimated by depth specific processes, contrary to slant from monocular cues. Finally, no slant attraction has been found after adaptation to monocular cues suggesting different processes for slant adaptation and simultaneous slant effects (Poom & Börjesson, 1999).

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Abstract 93 B1.93

Relative motion, not polarity, breaks 'surface tension'
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Purpose. To investigate the rules that underlie visual surface integration and segmentation. Methods. Observers viewed motion transparency: two fields of superimposed, drifting dots. One field (of black dots) drifted rightward, the other (white dots) leftward. This stimulus was used as the adaptor in a motion aftereffect (MAE) paradigm. Results 1. When tested with a static field of black and white dots, no MAE was reported; i.e. the expected polarity-contingent MAE was not expressed. Any polarity-contingent MAE would have to have shown up as a transparent MAE (that is, with the black dots in the test field undergoing illusory motion to the left simultaneously with the superimposed white dots undergoing illusory rightward motion); such effects are notoriously difficult to produce (because, we hypothesize, such a stimulus is treated as a single surface, which is assigned a single direction of motion). However, we reasoned that if we facilitated the segmentation of the black and white surfaces during testing, the MAE could be expressed. Results 2. Using the same adaptor described above, we then introduced a relative motion cue into the test (white dots moving upward, black downward). Now any horizontal polarity-contingent MAE would be added to these vertical motion vectors, producing a, in this case, clockwise deflection of the perceived shear axis. Four observers perceived tilts of 4-8 deg. Conclusions. Polarity alone was not sufficient for segmentation of the two surfaces (a likely necessary condition if each are to move in different directions), and hence the polarity-contingent MAE was either actively suppressed, or too weak to break this 'surface tension'. Only when a powerful relative motion segmentation cue was added was the surface tension broken, and the polarity-contingent MAE expressed. Ongoing studies are quantifying the contribution and interaction of such surface segmentation cues.

Abstract 94 B1.94

Highlights and surface gloss perception
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The perception of a glossy surface in a static monochromatic image occurs when a bright highlight is embedded in a compatible context of shading and a bounding contour. Although some studies address perception of gloss for whole objects, an observer may adopt an attitude of scrutiny in viewing a glossy surface, whereby the impression of gloss is partial and non-uniform at image regions at some distance from a highlight.
We investigated differential perception of gloss within a single object by using a rating scale and small probe points to indicate image locations. Experimental factors included luminance near highlights, highlight size, surface curvature and surface discontinuity.
Observers' gloss ratings were never uniform across a surface, but decreased as a function of a distance from a highlight. Rated gloss was not a function of the luminance near the probe point, however. When, by design, the distance from a highlight was uncoupled from the luminance value at corresponding probe points, the decrease in gloss ratings depended on distance and not on luminance level. Experiments with surfaces of a different curvature indicate that gloss ratings changed as a function of estimated surface distance or distance in depth, rather than as a function of the image distance of probe points from a highlight.
Also, surface continuity between a highlight and the probe point is important for the full propagation of perceived gloss.
Supported in part by: ONR N00014-01-1-0624 and AFOSR F49620-01-1-0397.

Abstract 95 B1.95

The interactive effects of symmetry and binocular disparity on visual surface representation
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Purpose. In order to recognize an object in our environment, we must first create a representation of its visual surface. Visual surface representation implicates the encoding and grouping of image attributes belonging to a same surface. The purpose of the study was to investigate the effects of bilateral symmetry and binocular disparity on the perception of a visual surface and how these two image features interact with each other. Methods. Exp. 1: Symmetrical dot patterns were presented to 3 observers with both halves of the pattern on either the same or different depth planes (disparity: 60.4 and 122.9 sec arc) for 250 msec. A 2ATFC constant stimuli procedure was used to measure symmetry detection thresholds (% matching dots) at each level of disparity. Exp. 2: Using the same procedure as Experiment 1, depth detection thresholds were measured at 4 levels of disparity (0, 30.1, 60.4, and 122.9 sec arc) for different levels of symmetry (6.25, 12.5, 25, 50, 75 & 100 % matching dots). Results. Exp. 1: Symmetry detection thresholds increased as a function of binocular disparity for all three observers. Exp. 2: The amount of symmetry in the pattern did not have an effect on the observers' ability to identify depth for any of the 4 levels of disparity. Conclusions. Under the specific stimulus parameters used, results suggest that depth created by disparity is a more predominant image attribute than is symmetry for visual surface representation. We are presently assessing whether manipulating certain temporal parameters (i.e., stimulus exposure duration) affects this predominance.

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Abstract 96 B1.96

Visual occlusion and infants' predictive tracking
Bennett I. Bertenthal U. of Chicago

The purpose of this study was to test whether young infants anticipate the reappearance of a moving object that disappears in a manner consistent with dynamic [‘occlusion. We tested 5-, 7-, and 9-month-old infants in a predictive tracking task in which a brightly colored ball rolled horizontally across a large computer-generated display. An occluding screen was placed along the path of the ball so that the ball was hidden for approximately one second as it translated across the display. As the front edge of the ball intersected with the occluding screen, its texture was deleted and it was accreted as the ball began to reappear from the screen (Occlusion condition). Predictive tracking was measured by whether or not infants anticipated the reappearance of the ball =]after it disappeared behind the screen.

In order to assess whether infants were specifically sensitive to the occlusion information or whether tracking was simply robust enough to withstand a brief interruption in spatiotemporal continuity, three additional conditions were tested: (1) Instantaneous Disappearance/Reappearance; (2) Implosion/Explosion; and (3) Virtual Occlusion (the occluding screen - while functionally present - was not visible). The results revealed evidence of predictive tracking by 7 months of age, but this was true only in the occlusion condition. These results will be discussed in terms of the specific information necessary for infants to perceive the continuing existence of objects that disappear for brief periods of time.

Abstract 97 B1.97

Eye movements facilitate simultaneous and sequential slant discrimination
Ellen M. Berends, Zhi-Lei Zhang, Yasuto Tanaka, & Clifton M. Schor U. of California at Berkeley, USA

Surface slant estimates are considered to be facilitated by saccadic gaze shifts between surface edges. Saccadic gaze shifts are assumed to lower slant thresholds by reducing positional noise associated with the retinal eccentricity, and by adding vergence signals to foveal estimates of absolute disparity at target edges where the disparity is largest. Do saccadic gaze shifts lower slant discrimination thresholds? We measured yaw-slant discrimination thresholds for two adjacent random dot surface patches presented either simultaneously (duration 2000 ms) or sequentially (duration 2000 ms each, inter stimulus interval 100 ms) for various target diameters (4 – 20 deg). When target diameters were large (> 8 deg) horizontal eye movements lowered thresholds for yaw slant discrimination in the simultaneous condition, but elevated thresholds for the sequential condition. We repeated this experiment with a spatial gap in each target that produced a pair of small coplanar test patches that were separated horizontally by 10 degrees. We varied the size of the two coplanar patches from 1 dot to 2 deg. For a given slant, as area increased edge disparities were constant while the visibility of disparity gradients increased. When patch diameters were small (< 1 deg), horizontal saccadic gaze shifts between the two patches improved sequential slant discrimination compared to when foveal fixation was maintained on one patch.
The improvement of simultaneous slant discrimination thresholds with eye movements is attributed to greater sensitivity to large relative edge disparities at the fovea than in the periphery. Sequential slant estimates with large fields appear to rely more on disparity gradients than absolute edge disparities. However, when disparity gradients are noisy (small patches), edge disparities become more useful. When the eyes fixate sequentially between widely separated edges, and thresholds are lowered by combinations of vergence and absolute edge disparities.

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Abstract 98 B1.98

Slant capture in the perception of multiple textured transparent surfaces
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OBJECTIVE: Surface transparency can result in the mixing of image textures projecting from multiple surfaces in the scene. At large viewing distances, the inference of multiple surfaces

depends primarily on the identification of independent texture distortions due to surface attitude and shape. In prior work (VSS 2001), we showed that two overlaid transparent textured surfaces differing by more than 90 deg in tilt could be reliably identified. Further, when both surfaces were seen, estimation of tilt was unaffected by the other textured surface. For smaller tilt differences, when only a single surface was seen, the estimated tilt could be predicted based upon an optimal probabilistic fusion model. In the present study, we determine whether these results extend to the perception of surface slant.
METHODS: Participants monocularly viewed two transparent textured planar surfaces rendered in perspective projection within a 24 deg diameter window. The mean slant of the two surfaces was random and uniformly distributed over [30,40] deg. The slant difference between the two surfaces was systematically varied over [-40,40] deg. Participants were asked to a) indicate whether one or two surfaces were seen and b) estimate, using a mouse-controlled gauge figure, the 3D attitude(s) of the perceived surface(s).
RESULTS: Our results for slant estimation differ dramatically from those for tilt estimation. When participants were able to see two surfaces, the presence of the second surface was found to decrease the reliability of slant estimation. When only one surface was seen, perceived attitude was dominated by the surface of greater slant. This bias cannot be predicted from measured uncertainties in estimating the slants of the individual surfaces.
CONCLUSION: The perception of overlapping transparent surfaces viewed at a distance is strongly affected by a "slant capture" effect that cannot be predicted by optimal estimation models.

Abstract 99 B1.99

Incomplete transfer between tilt and slant after-effects
Wendy J. Adams & Pascal Mamassian U. of Glasgow, Scotland

Introduction
We are interested in determining the level at which perceptual after-effects occur. Depth after-effects appear to be driven by adaptation at a surface representation level, rather than retinally-defined characteristics. For example, Domini, Adams & Banks (2001) showed that prolonged viewing of a stereoscopically defined curved surface produces after-effects related to the perceived curvature rather than the pattern of retinal disparities per se. Similarly, Köhler & Emery (1947) presented oppositely oriented lines alternately to two eyes but failed to find the depth after-effects predicted by low-level, monocular adaptation mechanisms.
We investigated whether:
(a) Monocular adaptation to tilted Gabor patches leads to binocular slant after-effects (SAE), or
(b) Binocular adaptation to a slanted surface produces monocular tilt after-effects (TAE).

Methods
After monocular or binocular adaptation, the amount of TAE and SAE were measured by the method of constant stimuli. The adaptation stimuli were Gabor patches rotated by ±3? from vertical presented to the left and right eyes. In the binocular condition they were presented to both eyes simultaneously, creating a percept of a slanted surface with zero tilt. The same stimuli were used for monocular adaptation, but were presented to the eyes alternately, creating percepts of zero-slant, tilted surfaces. Top-ups of the adaptation stimuli were presented between trials.

Results & Conclusions
Binocular adaptation produced large SAEs and smaller TAEs. Monocular adaptation produced large TAEs and smaller but clear SAEs, in contrast to Köhler & Emery's findings. This pattern of results suggests that a common, low-level adaptation to monocular orientation is involved in slant and tilt after-effects. However, the incomplete transfer between slant and tilt makes it clear that higher level adaptation is also involved, perhaps at the level of surface representation.

WJA funded by HFSP grant RG0109/1999-B

Visual cortex

Abstract 100 B1.100

The functional organization of orientation maps in owl monkey V1 and V2 revealed by optical imaging of intrinsic signals
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This study examined the organization of orientation preference in visual areas V1 and V2 of the nocturnal simian owl monkey (Aotus trivirgatus) using optical imaging of intrinsic signals. Owl monkeys are of interest because they have well developed cytochrome oxidase (CO) blobs in V1 and CO stripes in V2, but lack color vision. Polar maps of orientation preference were constructed by vector summation of single-condition maps acquired during the presentation of 4 or 8 angles of square wave grating stimuli. These maps were then compared to the patterns of CO staining in V1 and V2. As reported in other species, the V1 map contained regions where orientation preference changed linearly (linear zones) and regions where orientation preference was organized radially (pinwheels). Linear zones were prominent along the V1/V2 border and iso-orientation contour lines in the linear zones tended to intersect the border at right angles. Pinwheels occurred at a density of ~ 8 pinwheels/mm2 in V1. In V2, alternating regions of high and low orientation selectivity were observed that may correspond to regions of light and dark CO staining, respectively. Within the regions of high selectivity, orientation preference was arranged in a manner similar to that found in V1, including both linear zones and pinwheel centers. However, within V2 individual iso-orientation domains were larger and the density of pinwheels (~3.3 pinwheels/mm2) was about half of that found in V1. The organization of V2 into bands of high and low selectivity for orientation in owl monkey suggests that, as in diurnal primates, these bands segregate higher-order properties but in the absence of color vision. Overall, the organization of orientation preference in V1 and V2 of owl monkeys shows many features in common with the organization described in other simian primates. (Supported by EY01778, EY08126, HD15052, RR13947)

Abstract 101 B1.101

How do Laminar Circuits Coordinate their Development in the Visual Cortex? The Role of the Cortical Subplate.
Aaron Seitz and Stephen Grossberg Boston University, USA

How is the development of cortical maps in V1 coordinated across the cortical layers? Many neural models propose how maps of visually important properties like orientation (OR), ocular dominance (OD), and spatial frequency develop. These models show how spontaneous activity, before eye opening, combined with correlation learning, can generate map structures similar to those found in vivo. Most of these models do not discuss the ubiquitous organization of cortical cells into layers or how cells coordinate their development across these layers. This is an especially important problem given anatomical evidence that clusters of horizontal connections develop in layer 2/3 between iso-oriented regions before being innervated by layer 4 afferents, and that that the initial orientation preference of these connections is maintained after layer 4 afferents reach them. How is orientation preference coordinated across layers despite the fact that thalamic afferents wait in the subplate for weeks before the cortical plate? These problems are addressed within a model of how the cortical subplate develops its own OR and OD maps which then entrain those of the other lamina. Other evidence shows that subplate ablation interferes with the development of OD columns and OR tuning. We demonstrate that the same types of mechanisms which have been proposed to develop OR and OD maps in earlier models of the cortical plate can drive their development in the subplate. The model demonstrates how these maps may then be transferred to layer 4 by a known transient subplate-layer 4 circuit. The model also demonstrates how the subplate guides the early clustering of horizontal connections in Layers 2/3 and 5. Finally the model discusses how vertical correlations from the subplate guide the formation of interlaminar circuitry.

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Abstract 102 B1.102

Signalling properties of bursts and spikes in model thalamic relay cells
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Lateral geniculate neurons differ from simple "integrate and fire" behaviour in that they exhibit a low-threshold transient Ca2+ conductance. This leads to two distinct response modes: "tonic", in which the spike timing is relatively unstructured, and "burst mode", involving temporal clustering of the spikes. What are the properties of these distinct modes of firing for the transmission of retinal information to the cortex? We investigated this question by simulating an "integrate and fire or burst" model (Smith et al J. Neurophys. 83:588-610) of an LGN cell with synaptic input, and analysing its output using information theoretic procedures.

The information in the spike train was broken down into components reflecting the PSTH and autocorrelations using the approach of Panzeri and Schultz (Neural Computation 13(6):1311-1349). This also allowed the redundancy between the information contribution of individual spikes to be examined. We found that bursts lead to a higher information contribution from the PSTH than tonic firing, and this tends to be coupled with a negative contribution due to correlations between spikes. The consequence of this is that burst mode may have a higher instantaneous information rate, but that this is moderated over time by greater redundancy between spikes. The size of this effect depends upon the relative amounts of spontaneous input and retinal drive. We interpret this as consistent with the possibility that bursts may play a role in transient "updating" of the cortex, but that tonic firing is required for sustained information transfer in the aroused state.

Supported by the HHMI.

Abstract 103 B1.103

The first whole-head recordings of multifocal visually evoked magnetic field (VEF)
Takashi Owaki, & Tsunehiro Takeda U. of Tokyo, Japan, U. of Tokyo, Japan

Purpose: Although a few multifocal VEF studies have been reported previously, the number of the sensor channels was limited to 8 or 16 which covered only a part of a subject's head because of the constraint of their multifocal analysis systems. In order to record the whole-head multifocal VEF, we developed our original multifocal stimulus generator and multifocal analysis software. Their performance was tested. Methods: A PC-based multifocal stimulus generation system developed by our laboratory was used for stimulus presentation. The stimulus pattern consisted of 12 checkerboards around a fixation point: Four checkerboards were placed centrally and the rest of them were placed peripherally. We used achromatic luminance pattern reversals (condition L) and isoluminant red/green pattern reversals (condition I). Each checkerboard subtended 5 degrees of visual angle and the whole checkerboards subtended 22 deg of visual angle. Individual check size was 75 min of visual angle. The multifocal VEFs were recorded from four normally sighted subjects using a 64-channel whole-head MEG system (CTF Inc., Model-100). The first slices of the second-order Volterra kernels were extracted from the recordings with our original multifocal analysis software. Results: Clear responses were obtained in all subjects in the both conditions of L and I. The central checkerboard pattern reversals elicited larger responses than the peripheral ones. The sources of the responses evoked by the central checkerboard pattern reversals were localized around the calcarine sulcus according to the well-known retinotopic cortical representation. The difference in the locations of the sources between in conditions L and I was not clear, but the first responses in condition I started about 20 ms later than those in condition L. Conclusions: The fact that the results were consistent with those of previous multifocal VEF studies indicates the whole-head multifocal VEFs were measured appropriately.

Abstract 104 B1.104

Parallel processing in the visual system of zebra finches
Antonio V. Laverghetta & Toru Shimizu U. of South Florida, USA

The primary visual pathway in zebra finches, termed the tectofugal pathway, travels from the retina to the optic tectum to the thalamus (n. rotundus), and then to the telencephalon (ectostriatum). Three studies were conducted to examine 1) the hodological organization of the tectofugal pathway, 2) the morphology of n. rotundus neurons, and 3) the ultrastructure of n. rotundus. In the first study, anterograde and retrograde tract-tracing substances were deposited unilaterally into n. rotundus and ectostriatum. The results showed that the dorsal-anterior, central, and posterior divisions of n. rotundus project, respectively, to the ventral-anterior, central, and dorsal-posterior regions of the ectostriatum. In the second study, cell bodies from different anatomical subdivisions of n. rotundus were analyzed to identify possible morphological differences. The results showed that cells in the dorsal-anterior and central division are larger than those in the posterior region. In the third study, tissues of n. rotundus were examined with a transmission electron microscope. The results showed that all subdivisions of n. rotundus are primarily composed of asymmetric membrane specializations with clear, rounded synaptic vesicles. However, synaptic glomeruli are more prominent in the central and posterior divisions of n. rotundus. Taken together, the present results are reminiscent of the findings in mammals, in which the primary visual system consists of parallel processing pathways that differ in anatomical, morphological, and ultrastructural characteristics. Thus, birds may process visual information in a manner similar to mammals, namely through parallel processing visual channels. Supported by: University of South Florida and NSF

Abstract 105 B1.105

Asymmetrical response modulation between cell pair in cat striate cortex
T. Kasamatsu , Z. Zhu, K. Lin, Smith-Kettlewell Eye Research Institute, San Francisco, CA

Receptive-field responses, dynamically regulated by the excitation-inhibition balance operative in a given network, are either facilitated or suppressed by collinear flankers in a contrast-dependent manner. The flanker effects are widely spread in visual space up to 12 deg., though direct interactions between cell pairs as measured by cross-correllograms are usually limited to ~1 mm in visual cortex. To understand the nature of neural events taking place at flanker site and the dynamic interactions between two cells, we want to simultaneously register single-cell activity from cell-pairs with non-overlapped receptive fields. A pair of microelectrodes extracellularly registered single-cell activity from two cells separated by 2 mm or more. While concurrently stimulating two receptive fields with two optimally fitted Gabors, one Gabor can be treated as the target for one cell, but as the flanker for the other cell, and vice versa. The strength and property of reciprocal modulation was assessed in terms of the following attributes: firing thresholds, orientation difference, and the relative location between the two receptive fields. Interactions between two identified cells having non-overlapped receptive fields depended on both their global orientation (collinear or not) and orientation difference. The mutual interaction strength between collinear cells seemed to be stronger than that between non-collinear cell pairs. Modes of the interactions were very complicated. The modulatory effect of one cell on another was often found to be different from the effect in the reverse direction, including both modulation strength and property (facilitation or suppression), regardless of whether the cell pair was collinear or not. Our results showed that long-range lateral interactions in the cortex are reciprocated but not necessarily symmetrical. This means that even if two cells are shown to be interacting, they can exert an asymmetric modulatory influence upon each other.
Support: NEI grant EY 11711

Abstract 106 B1.106

Analysis of responses to drifting and stationary gratings in V1 of alert monkey
Igor Kagan, Moshe Gur, & D. Max Snodderly Technion, Israel; Technion, Israel; Schepens Eye Research Institute, USA

The majority of cells in monkey V1 have overlapping increment and decrement activating regions (ARs) and nonlinear response properties ("duplex" cells). We have recently shown that responses of these cells to sinusoidal luminance gratings are diverse and can not be predicted from receptive fields' spatial maps. Many of these cells have a significant quasi-linear (fundamental, F1) harmonic in the responses to drifting gratings. At the same time, flashing bars, moving edges and counterphase gratings mostly evoke on-off, or frequency doubled (second harmonic, F2) responses. Here we studied the neuronal responses in V1 of an alert monkey to grating patches of varying temporal and spatial frequency and patch width. We found that some cells responded with F1 modulation to high temporal frequency gratings, but showed frequency doubled (F2) or mixed (F1, F2, F3) responses at low temporal frequencies. In other cells little or no effect of temporal frequency on their harmonic content was seen. Most cells, however, showed profound dependence of the harmonic content on grating spatial frequency and width. The three main patterns were: 1) F2 responses to gratings of very low spatial frequency and/or small window; 2) Decrease of F2 and increase of F1 component with increase of spatial frequency and/or patch width; 3) Decrease of F1 component and appearance of "subF1" (i.e. less than F1) modulation with further increase of spatial frequency. Finally, the responses of many cells to stationary gratings of middle to high spatial frequency unexpectedly exhibited robust modulation in the range similar to "subF1" modulation elicited by drifting gratings. These results demonstrate that the form of the response, as well as the amplitude, depends on stimulus parameters, and they suggest an elaborate spatiotemporal structure of duplex receptive fields, based on interactions of increment and decrement ARs and surround.
Supported by NIH EY12243 and Technion VPR Funds 130347; 130358.

Abstract 107 B1.107

A computational model of recurrent, colinear long-range interaction in V1 for contour enhancement and junction detection

Thorsten Hansen & Heiko Neumann Dept. of Neural Information Processing, Univ. of Ulm, Germany

Physiological and psychophysical studies have demonstrated the importance of colinearity in visual processing. Motivated by these empirical findings we present a novel computational model of recurrent long-range processing in V1. Unlike other models which employ cocircular connection patterns, we restrict the long-range interaction to cells with colinear aligned RFs in accordance with empirical findings (e.g., Bosking et al., 1997). Besides colinear excitatory long-range interaction, the model uses isotropic inhibitory short-range interaction and modulating feedback. Self-normalizing shunting equations guarantee the saturation of activities after a few recurrent cycles. The primary computational goal of the model is to evaluate local, often noisy orientation measurements within a more global context and to selectively enhance coherent activity by excitatory, modulating feedback.

In a first study, the model quantitatively reproduces response facilitation and suppression to a single bar element depending on the local surround outside the classical RF (Kapadia et al., 1995). With same parameters, we evaluate the competencies of the model for the processing of artificial and natural images. We show that the model robustly increases the contour saliency (Li, 1999). Further, circular variance within a model hypercolumn is decreased along contours, but preserved at points of intrinsically 2D signal variations such as corners and junctions. Junctions can thus be robustly extracted based on a distributed, hypercolumnar representation. We show for a number of generic junction configurations (T, L, X, Y, W, Psi) and various natural images that junctions can be accurately and robustly detected. Moreover, localization is better and positive correctness higher compared to a detection scheme based on a purely feedforward
representation.

To conclude, the model realizes basic tasks of early and midlevel vision within a single, biologically plausible architecture.

Abstract 108 B1.108

Multifocal topographical evoked potential mapping

R. Gockeln, S. Riegert, I. Tutschke, & R. Winter Medical School Hannover, Dept. of Ophthalmology, Vision Sciences Lab., Germany

Purpose: This study illustrates how multifocal visual evoked components are derived from multichannel bipolar recordings and are analysed topographically. In addition to the potential wave shapes, the latency (ms) and the wavelengths (mV) of the components will also be influenced by the cortical site of the recordings.
Methods: Multifocal VEPs were recorded from different parts of the visual field (up to 30 of eccentricity) of both eyes of fifty normosensoric subjects; stimulating each eye separately. The pseudorandom alternated stimulus array was produced with a multichannel Roland Consults system (Retiscan, Wiesbaden/Brandenburg, Germany). The stimulus consisted of 60 sectors, each with 16 checks, 8 white (> 140 cd/m2) and 8 black (< 1 cd/m2). For electrode placement we used a bipolar (occipito-occipital) arrangement. The visual evoked wave shapes were recorded simultaneously from a row of four scalp electrodes placed along the sagital midline and four scalp electrodes placed along the transversal axis of the occipital cortex. Each of the eight electrodes could be used as the negative or the positive electrode.
Results: The data of these study show, that different recording channels display different average peak latencies and amplitudes ranging over the occipital cortex between 79,5 ms / 0,086 mV (4 cm inferior to 4 cm superior the inions) and 106 ms / 0,143 mV (2 cm inferior to 2 cm superior the inions). During recording of the mVEPs along the transverse axis one could observe a reduction of the amplitude maximum compared to the sagital axis. On the other hand, we found differences in the electrode location of the evoked components when different retinal areas are stimulated.
Conclusion: The multifocal VEP demonstrates a good correlation with the topography of the visual field by bipolar occipital recordings along the sagital midline. The bipolar recording site 2 cm inferior (negative electrode) and 2 cm superior to the inions seems to lead to more compatible results. For more accurate statements concerning objective visual field defects, one should evaluate the superior, inferior and the lateral hemifields separately.

Abstract 109 B1.109

Long-range interactions in macaque primary visual cortex

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We examined long-range interactions (cross-correlations) between neuronal pairs in macaque V1. Recordings were performed in the anesthetized and paralyzed M. fascicularis. The physical distance between neural pairs in our population ranged from m to about 3mm, and their receptive fields were located within 6deg of the fovea. Simultaneous responses of cells to a fast sequence of sinsusoidal gratings of varying orientation, spatial frequency and spatial phase were obtained using a four-electrode micropositioner. This stimulus is advantageous because it simultaneously drives neurons with differing orientation and/or spatial frequency preferences. In addition, the increased firing rate of the population makes it easier to detect inhibitory interactions between neurons. Shuffle-corrected cross-correlations in response to repeated stimuli sequences were calculated. The strength of the cross-correlations were measured as the height of the peak or trough, normalized by the largest correlation magnitude one could theoretically expect given the firing rates of the neurons. We studied cross-correlation magnitude as a function of the difference in preferred orientation of the cells. Large positive cross-correlations are more likely to occur between cells of similar orientation preference, while large negative cross-correlations are less dependent on the orientation preferences of the cells. These results suggest that excitatory and inhibitory interactions in V1 do not share the same orientation tuning. Inhibition, as a function of orientation difference, appears to be much broadly tuned than excitation. These data may help to

discriminate among different models of orientation selectivity in V1.

Support: NIH EY-12816 and NSF-IBN-9720305

Abstract 110 B1.110

Retinotopic mapping in children with normal vision
Ian P. Conner, Saloni Sharma, & Janine D. Mendola West Virginia University, USA, West Virginia University, USA, West Virginia University, USA

The visual system of human children is functionally immature at birth. Visual experience plays a key role in the maturation of human vision, as evidenced by the onset of amblyopia ("lazy eye") in individuals with abnormal early visual experience. Since amblyopia can be successfully treated with occlusion therapy as late as ages 9-10, it might be expected that even normally-sighted children at these ages may exhibit cortical retinotopic organization which is different from that of adults. This study mapped the retinotopic organization of the first eight visual areas in alert, non-sedated children ages 7-12 using the fMRI BOLD technique at 1.5 T and standard phase-encoded methods. The high-contrast, temporally modulated stimuli separately map polar angle and eccentricity in visual cortex, and are identical to those used with adults (Sereno et al., 1995). We obtained distinct and reproducible retinotopic maps in children which are qualitatively similar to retinotopic maps obtained in adults under the same conditions. We conclude that retinotopic mapping using non-invasive fMRI is feasible for motivated children in this age range. We anticipate that retinotopic mapping can be used as a basis for region-of-interest analyses of differences in early visual areas in children with visual pathologies like amblyopia.

Supported by NIH/NCRR to JM

Abstract 111 B1.111

Neural spike irregularity in adjacent cells of the same visual cortical column are unrelated despite other shared properties
David K.Chelvanayagam, Daping Hu, & Trichur R. Vidyasagar Australian National University, Canberra, Australia

Reliable visual information processing is required for coordinated visuomotor behavior. Yet, in visual cortical neurons, repeated presentation of optimal visual stimuli frequently fail to elicit output spike trains that show temporal precision from trial to trial except in the average spike rate, spawning the belief that a population of neurons is required to provide, on average, the required reliability. If so, neighboring cells in a cortical column that share common anatomical inputs and show similar physiological response characteristics to visual stimuli, such as orientation preference, may be expected to show similar degrees of irregularity in the inter spike interval (ISI). We measured ISI irregularity by computing the *coefficient of variation in two adjacent cells simultaneously in the cat primary visual cortex (*CV = standard deviation in the ISI/ mean ISI in a response window). Cats were initially anaesthetized (ketamine 15mg/kg and xylazine 3mg/kg mixture, i.m.) and then maintained on 70/30% N2O/O2 gaseous mixture and sodium pentobarbitone (1-1.5 mg/kg/hr, i.v.) with gallamine triethiodide (10mg/kg/hr, i.v.) for paralysis. We compared CVs from pairs of cells recorded from the same electrode (isolated with Spike2 software CED) that responded to the same stimuli over the same temporal window. Over a large number of trials, no significant correlation occurred between CVs for each cell. That is, in the common inputs to adjacent cells, there are enough random synaptic failures and variations in the sites of synaptic contact to explain the lack of correlation in their irregular firing.

Supported by Australian Research Council.

Saturday

Saturday AM Talks (North Hall)
3-D Shape

Moderators: Daniel Kersten and James Todd

Abstract #	Time	Authors
112	9:00	Kingdom & Kasrai
113	9:15	Li & Zaidi
114	9:30	Todd, Oomes, Koenderink, & Kappers
115	9:45	Madison & Kersten
116	10:00	Fahle, Morgan, Diehl,& Spang
117	10:15	Vanduffel, Fize, Peuskens, Denys, Sunaert, Todd, & Orban
118	10:30	Lages, Mamassian, & Graf

Abstract 112 9:00 AM

Colour contrast can facilitate perceived 3D shape-from-shading
Frederick A. A. Kingdom & Reza Kasrai McGill University, Canada, McGill University, Canada

It has been suggested that one of the purposes of colour vision is to help disambiguate material and illumination changes in naturals scenes, since whereas an intensity change might be due to either a change in material or a change in illumination , a colour change is invariably due to a change in material. Here we demonstrate a compelling phenomenon that can be explained by just such a role for colour vision. A plaid made from two otherwise identical orthogonal sine-wave luminance gratings appears corrugated in depth when colour contrast is added to one of the gratings. The perceived depth corrugation follows the pure luminance grating. A plausible explanation is that the mixed colour-plus-luminance grating is interpreted as a material surface and the pure luminance grating as shading. We measured the perceived depth of the corrugation for various amounts of added colour contrast by adjusting the amplitude of a textured disparity grating to match the corrugation, and found a monotonic relationship between colour contrast and perceived depth. We also report estimates

of the degree to which the illusory depth in the plaid is paralleled by a perceptual 'flattening' of the luminance contrast in the coloured grating, as measured using a matching technique . We conclude that colour vision can play an important role in helping to decompose the visual scene into its illumination and material layers, or 'intrinsic images'.

Supported by a CIHR grant #MOP11554 given to FK and a CIHR Doctoral award to RK.

Abstract 113 9:15 AM

Isotropic textures convey distance not 3-D shape
Andrea Li & Qasim Zaidi SUNY College of Optometry

Textures like polka-dots and isotropic filtered noise contain equal energy at all orientations in the spatial frequency spectrum. Isotropic patterns have been used to render convex 3-D shapes because it is thought that systematic deviations from isotropy in the projected image convey the shape of the surface. Li & Zaidi (Vis Res, 2000, 2001) and Zaidi & Li (Vis Res, 2002) showed that signature patterns of orientation modulations in the image are necessary for veridical shape perception of corrugated surfaces. Projected surfaces with isotropic textures do not exhibit these orientation modulations, but show increases in 2-D spatial frequency as distance increases, and increases in 1-D frequency along the direction of slant for increasing slant angles. Using a 5AFC task, we measured percepts of perspectively projected half-cycles of vertical sinusoidal corrugated surfaces overlaid with isotropic patterns. Images of upright concave and convex half-cycles exhibit lower frequencies in the central fronto-parallel section and higher frequencies in the slanted edge sections. Conversely, images of upright rightward and leftward slanted half-cycles contain lower frequencies along the edges and higher frequencies in the center. Observers correctly identified convexities, but consistently misperceived concavities and slants as convex and concave respectively. Spatial frequency modulations were therefore being interpreted exclusively as cues to distance: low frequencies were interpreted as closer and high frequencies as farther from the observer. For patterns like compound vertical gratings, frequency modulations cannot be detected, and corrugated surfaces appear flat. In images of pitched corrugations, isotropic patterns flow along lines of maximum curvature. These lines are nearly parallel across the image, and observers confuse sign of pitch and sign of curvature. Isotropic textures thus convey distance but do not, in general, convey qualitatively veridical 3-D shape.

Supported by NEI grant EY13312 to Qasim Zaidi

Abstract 114 9:30 AM

The perception of 3D shape from anisotropic texture patterns
James T. Todd, Augustinus H. J. Oomes, Jan J. Koenderink, & Astrid M. L. Kappers Ohio State U., USA, Ohio State U., USA, U. of Utrecht, The Netherlands, U. of Utrecht, The Netherlands

Most existing computational models of the visual perception of 3D shape from texture are based on assumed constraints about how texture is distributed on visible surfaces. To compute shape from blob textures, for example, it is typically assumed that the texture is isotropic and/or homogeneous. Other models have been developed for contour textures that assume contours are oriented along surface geodesics or directions of principal curvature. The present research was designed to investigate how violations of these assumptions influence human perception. The displays depicted roughly spherical objects with random patterns of ridges and valleys. These objects were rendered with two types of volumetric textures. Contour textures were created using a random pattern of parallel planar cuts through an object that could be oriented in three possible directions. Blob textures were created by carving each object from a volume of small spheres. These spheres could also be stretched in a horizontal or vertical direction so that the distribution of surface markings would be both anisotropic and inhomogeneous. Observers judged the pattern of ordinal depth on each object by marking local maxima and minima along designated scan lines. They also judged the apparent magnitudes of relative depth between designated probe points on the surface. There was a high degree of reliability on these tasks both within and between observers. When the different patterns of texture were compared, the variations in judged depth were remarkably small. Indeed, the observers' judgments were almost perfectly correlated across each possible pair of texture conditions. These findings suggest that human perception of 3D shape from texture is much more robust than would be reasonable to expect based on current computational models of this phenomenon.

This research was supported by grants from the National Eye Institute (R01-EY12432) and the National Science Foundation (BCS-0079277).

Abstract 115 9:45 AM

Perceiving depth from reflection
Cindee Madison & Daniel Kersten U. of Minnesota, USA, U. of Minnesota, USA

As an object moves away from a shiny flat surface, the images of the object's reflection and shadow move away from the object's image, providing potential depth information. There are important differences, however, in how reflections and shadows constrain depth estimation. Unlike reflection, depth from shadows depends on an assumed light source direction. Depth from reflection is constrained by the line connecting the object and its reflection (in 3D) which is normal to and bisected by the surface. Does the visual system distinguish shadow and reflection constraints in judging depth?
Observers viewed a simulated stereoscopic 3-D scene of a box containing a ball moving in a fronto-parallel trajectory from the lower left to the upper right. Observers judged the depth of the ball at the right-most peak of the trajectory by positioning a cursor on the right wall. Depth from stereo was perturbed by manipulations of the reflection and shadow in three conditions: 1) no-shadow and no-reflection; 2) the shadow followed the trajectory appropriate for a shadow (i.e. stereoscopically on the floor of the box) vs. reflection (beneath the floor) and; 3) the reflection followed the trajectory appropriate for reflection

(below the floor) vs. shadow (on the floor). For all seven naïve observers, the addition of shadow or reflection resulted in significantly different depth judgments. For six of these, the depth of the ball was judged closer to the observer for the shadow than reflection case (same image location), qualitatively consistent with the natural constraints on reflection and shadows.

Grant: NIH RO1-EY12691

Abstract 116 10:00 AM

An fMRI correlate of perceived 3-dimensional structure from purely temporal information

Manfred Fahle, Michael Morgan, Volker Diehl, & Karoline Spang U. of Bremen, Germany, City U. London, UK, Radiology, St. Jürgenstr. Bremen, Germany, U. of Bremen, Germany

The Pulfrich effect, i.e. the perception of depth from delaying the input to one eye by means of a grey filter, allows the production of 3 dimensional structure without changing the spatial layout of a stimulus. We used modifications of this effect in order to study which parts of human cortex are most strongly activated when 3 dimensional structure emerges. Three types of stimuli were presented in a 1.5 tesla Siemens Vision scanner: a) stationary dots; b) dots moving in random directions; c) a checkerboard consisting of different grey levels modulated sinusoidally over time (cf. Morgan & Fahle, Vision Research 40 (2000), 1667-1675). Observers tried to decide what predominant motion direction they perceived, when either looking straight at the (moving) stimuli or else with a neutral density filter in front of their dominant eye. Without the filter, any predominance of motion direction is purely subjective, but delaying the input to one eye creates “spatio-temporal disparities” similar to the Pulfrich effect. With the filter in front of the right eye, dots moving to the right appear in front of the horopter, while those moving to the left appear behind. Mean results of so far 4 observers (Brain Voyager, GeneralLinearModel) show no strong effect of the filter for stationary targets. However, for both dynamic stimuli, looking through the filter decreases activity in V1, while activity increases in a circumscribed area in inferior temporal cortex. Hence, this area seems to be involved in the computation of structure from (pseudo) stereoscopic information.

Supported by German Research Council (SFB 517).

Abstract 117 10:15 AM

Processing 3-dimensional structure from motion in humans and macaques.

W. Vanduffel, D. Fize, H. Peuskens, K. Denys, S. Sunaert, J.T. Todd, & G.A. Orban Neuro- and Psychophysiology Laboratory, KULeuven Medical School1, Ohio State Univ, Columbus, Ohio, USA2.

Single unit studies in monkeys suggested that area MT/V5 might be implicated in the extraction of the 3-dimensional structure of objects based upon motion cues only (Xiao et al., 1997, see also Bradley et al. 1998). The involvement of the presumptive human homologue of macaque MT/V5 (the human MT/V5+ complex) in the processing of 3D-structure-from-motion (3D-SFM) has been confirmed using fMRI (Orban et al., 1999). In addition, the latter study showed significant 3D-SFM sensitivity in a lateral occipital region and several regions in the intraparietal sulcus. In the present study, we bridged the gap between human functional imaging and monkey electrophysiology by performing contrast-agent enhanced fMRI experiments in awake monkeys (Vanduffel et al., 2001). Therefore, 8 human subjects and three monkeys were trained to fixate in the scanner while we presented two-dimensional and three-dimensional configurations of moving random lines. The human fMRI results were in agreement with those published. In monkey, the comparison of 3D versus the 2D dynamic displays revealed bilateral MR-activation in MT/V5, FST but not MST, as well as in areas V4, and VP. Smaller 3D-SFM sensitive MR-activation was observed in the intraparietal sulcus and several foci along the STS (anterior and ventral relative to FST). These results provide additional evidence that:
1) macaque MT/V5 is involved in the extraction of three-dimensional structure-from-motion, in agreement with single unit results,
2) human MT/V5+ might consist of several areas including homologous areas to macaque areas MT/V5 and FST,
3) there is an functional asymmetry between human and monkey intraparietal areas: human IPS is more involved in the processing of 3D-SFM compared to monkey IPS. sponsored by EU-project MAPAWAMO, and GSKE

Abstract 118 10:30 AM

Spatial and temporal tuning of motion-in-depth perception

Martin Lages, Pascal Mamassian, & Erich W. Graf University of Glasgow

Purpose. We used the Pulfrich stereo-phenomenon to investigate motion-in-depth. Independent control over temporal and spatial frequency content in our stimuli revealed the spatio-temporal tuning characteristics of motion-in-depth perception. Methods. Stimuli were presented to the left and right eye on a calibrated CRT display with a refresh rate of 120 Hz using a split-screen Wheatstone configuration. On each trial Ss verged on a fixation cross flanked by nonius lines as two sinusoidally oscillating sine-wave gratings were presented stereoscopically. The gratings were displayed in a Gaussian spatial envelope for 1 sec. After each presentation Ss had to indicate whether direction of motion-in-depth was clockwise or counterclockwise from a bird’s eye view. Interocular phase difference between left and right sine-wave gratings was randomised (-pi/4 to +pi/4) from trial to trial to determine a discrimination threshold. Spatial frequency of the gratings (1 cpd to 4 cpd) and temporal frequency of sinusoidal motions (0.25 Hz to 5 Hz) were systematically combined in different sessions.
Results. Phase thresholds for the discrimination of direction of motion-in-depth showed relative broadband temporal frequency

tuning with peak sensitivities between 1 and 4 Hz. Temporal frequency tuning appeared to be independent of spatial frequency content whereas velocity tuning curves shifted systematically with increasing spatial frequency. Conclusions. Physiological evidence indicates that binocular cells in V1 typically show temporal frequency tuning whereas cells in area MT are preferably tuned to velocity. The tuning characteristics from the present experiment support the idea that binocular disparity and motion are jointly encoded in V1 before image velocity is extracted at a later cortical stage, presumably area MT.

Acknowledgements. This research was funded by RS of London (ML), HFSP (PM), and NSF-IRFP(EG).

Saturday AM Talks (North Hall)
Shape and Texture

Moderators: William Merigan & Robert Hess

Abst#	Time	Authors
119	11:00	Suzuki
120	11:15	Merigan
121	11:30	Pasupathy & Connor
122	11:45	Hess & Ledgeway
123	12:00	Kourtzi, Bülthoff, Erb, & Grodd

Abstract 119 11:00 AM

Selective attention linearly weights inputs prior to population coding of shape.
Satoru Suzuki Northwestern University, USA

When an adapting shape and a test shape (backward masked) are presented briefly (e.g., 30 ms each) and in rapid succession (e.g., 200 ms ISI), global shape aftereffects occur in some basic geometric dimensions (e.g., skew, taper, curvature, convexity, and aspect ratio; Suzuki & Cavanagh, 1998, JEPHPP; Suzuki, 1999; 2000, ARVO). Recently, using overlapping outline shapes as adaptors, Suzuki (2001, Vision Research) reported that these shape aftereffects are strongly modulated by selective attention under appropriate conditions. In this study, the operational loci of this attentional selection were investigated by considering two distinct hypotheses. First, attention might linearly weight contour signals at an early stage of processing; signals from attended contours would receive a larger weight, whereas signals from ignored contours would receive a smaller weight—the early-contour-weighting hypothesis. Alternatively, attention might operate at the stage of (opponent) population coding of global shape attributes underlying shape aftereffects, such that attending to a particular shape attribute (e.g., a concave pattern) might primarily inhibit responses of neural units tuned to the opponent shape attribute (e.g., a convex pattern)—the opponent-shape-suppression hypothesis. These two hypotheses were contrasted by using pairs of overlapping adaptor shapes that were either opponent (producing opposite aftereffects) or non-opponent (producing orthogonal aftereffects). The results favored the early-contour-weighting hypothesis. Furthermore, the linear attention weights obtained (w[attended] – w[ignored] ~ 60%), using shape aftereffects as the dependent measure, was comparable to those previously reported by Reynolds et al. (1999, J Neurosci), using responses of V4 neurons as the dependent measure, suggesting that attentional selection of an overlapping shape is potentially mediated by attentional modulations of neural activity through V4.

Supported by NSF SBR-9817643.

Abstract 120 11:15 AM

Shape selectivity of V4 neurons for stimuli whose discrimination depends on V4
William H. Merigan U of Rochester, USA

Shape selectivity of V4 neurons for stimuli whose discrimination depends on V4 William H. Merigan, Department of Ophthalmology and Center for Visual Science, University of Rochester, Rochester, NY.

Purpose: To determine if V4 neurons show the requisite shape selectivity to mediate a discrimination that has been shown to depend on V4. Shape stimuli differed in geometric shape, but were matched in average luminance, contrast, orientation content, etc. ,Methods: The geometric shape stimuli consisted of a 4 x 4 arrays of oblique line segments, and thus, were closely matched in global properties. We tested discrimination of these stimuli by requiring monkeys to decide if successively presented stimuli were the same or different. The patterns were presented, under controlled fixation, at different locations in the visual field, such that the either first (sample) or second (test) stimuli of the comparison pair matched the location and size of the receptive field. An earlier study has shown that V4 lesions eliminated the ability of monkeys to discriminate these stimuli in this same testing paradigm. Results: Many V4 neurons showed moderate shape selectivity for the tested shape stimuli. The information in their response selectivity was sufficient to mediate correct discrimination based on the responses of only a few neurons. Conclusions: These results suggest that the discrimination of these shapes is dependent on neurons in area V4, and that these neurons have sufficiently selective responses to these stimuli to mediate the observed behavioral performance. Supported by EY 08898, and P30 EY01319 from NIH.

Abstract 121 11:30 AM

Population coding of complex shapes in macaque area V4
Anitha Pasupathy & Charles E. Connor Massachusetts Institute of Technology, USA, Johns Hopkins University, USA

We recently reported that many V4 neurons encode sections of complex shape boundaries in terms of their curvature and relative position (Pasupathy & Connor, 2001). For example, one neuron may be tuned for concave curvature to the right (of object center), another tuned for convex curvature at the top, etc. These tuning properties can be described with two-dimensional Gaussian functions on a curvature x angular position domain. In the current study, we estimated V4 population activity by summing the response-weighted

Gaussian tuning functions. We found that, while individual V4 cells encode boundary sections, the V4 population response represents complete shapes. To derive the population response to a given shape, we weighted each cell's tuning peak (in the curvature x position domain) by its response to that shape. We then summed the weighted tuning peaks and smoothed the resulting surface. This produced a multi-peaked function on the 2-dimensional curvature x position domain. The peaks in this function corresponded closely to the major boundary features in the original shape. The strongest peaks in the population response were those corresponding to sharper convex and concave boundary features. Shallow boundary curvature was represented more weakly. We quantified overall correspondence by calculating average distance (on the curvature x position domain) between population surface peaks and closest matching boundary features. Across 49 complex shape stimuli, the median average distance was 4.04 in the angular position dimension and 0.07 in the curvature dimension (which ranges from -1.0 (sharp concave) to 1.0 (sharp convex)). Thus, the V4 population signal represents complete shapes in terms of the curvatures and positions of their constituent boundary features.

Supported by NIH R01-EY11797and Pew P0212SC.

Abstract 122 11:45 AM

Direction- and speed-defined spatial contours; one mechansim or two?

Robert F. Hess & Tim Ledgeway McGill Umiversity, Canada, University of Nottingham, UK

Purpose. The visual system integrates local orientation information across space to define spatial contours (Field, etal V.R. 33, 1993). More recently, it has been shown that a similar integration occurs for the direction of local motion signals in different parts of the field if they are aligned along a spatial contour (Ledgeway & Hess ARVO, 2001). Here we ask whether similar spatial-linking rules hold for contours defined by a common speed different from that of the background. Methods. Using a standard 2AFC task, observers were asked to choose which interval contained the elongated contour (path). One interval chosen at random on each trial contained 158 micropatterns of random position and direction (background micropatterns) and in the other interval (path plus background)the motion directions of some (8) of the background micropatterns were arranged to lie along the invisible backbone of an elongated contour. The directions/speeds of motion of the micropatterns making up this contour could be varied independently from those of the background micropatterns. Performance was measured for direction-defined or speed-defined contours of varying straightness. Results. The results for speed-defined paths do not follow the specialized rules for detecting or disambiguating 2-D spatial contours because they do not depend on the curvature of the contour to be detected and operate under conditions where directional-linking has been rendered ineffective (e.g. when all motion directions are either random or all the same. Conclusions. The results show that while speed does enhance performance for motion-defined contours, it does so via a different route to that of directional-linking. For motion-defined contours, the Gestalt notion of "common fate" and "good continuity" occur via separate underlying mechanisms.

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Abstract 123 12:00 PM

Shape processing in the human motion area MT/MST

Zoe Kourtzi, Heinrich H. Bülthoff, Michael Erb, & Wolfgang Grodd Max Planck Institute,Tuebingen, Germany, Max Planck Institute,Tuebingen, Germany, University Clinics, Tuebingen, Germany, University Clinics, Tuebingen, Germany

Perception of object motion requires that the visual system integrates shape and motion information about objects. However, recent fMRI studies have implicated separate human brain regions in the analysis of motion (MT/MST) and shape (lateral occipital complex-LOC). We tested whether MT/MST is involved in the analysis of both object shape and motion using fMRI. We observed higher responses to intact than scrambled images of objects in the LOC and MT/MST, especially in a ventral subregion of MT/MST, suggesting that regions involved mainly in the processing of visual motion are also engaged in the analysis of object shape. These object selective responses in MT/MST were observed for moving objects and static 3D objects defined by disparity or shading but not for 2D silhouettes of objects. In contrast, these object selective responses were observed in the LOC for all of these object types. Further studies tested responses to shapes defined by different cues (i.e. disparity, motion or shading) by using event-related fMRI adaptation. Lower responses for the same shape defined by different cues than two different consecutively-presented stimuli implicate neural representations of shapes independent of the cues that define their contours. Our findings suggest differential processing of visual shape in the LOC and MT/MST.

Supported by Max Planck Society, McDonnell-Pew Foundation

Saturday AM Talks (South Hall)
V1

Moderators: Margaret Livingstone & Max Snodderly

Abstract #	Time	Authors
124	9:00	Adams & Horton
125	9:15	Mechler & Ringach
126	9:30	Snodderly, Kagan, & Gur
127	9:45	Dragoi, Sharma, Miller, & Sur
128	10:00	Livingstone & Conway
129	10:15	Zenger-Landolt &. Heeger
130	10:30	Duncan & Boynton

Abstract 124 9:00 AM

Shadows from retinal blood vessels cause local amblyopia by deprivation of photoreceptors

Daniel L. Adams & Jonathan C. Horton University of California San Francisco, USA

Cataracts deprive the whole retina, rendering the entire eye amblyopic. It is unknown if restricted portions of the retina can become amblyopic from local occlusion. We examined the effect of shadows cast by retinal blood vessels on the geniculocortical projection in 12 squirrel monkeys. Under general anesthesia and neuromuscular blockade, the animals' retinas were photographed and major vascular landmarks were calibrated in the visual fields. Next, one eye was enucleated and the remaining eye (in 2 cases) was injected with [3H]proline. After 10 days, the animals were perfused and striate cortex was processed for cytochrome oxidase (CO) and autoradiography. A CO pattern resembling the retinal vessels was present in the cortex of 9 monkeys. Each element in the cortical representation of the Purkyne Tree could be matched with its corresponding retinal vessel. Autoradiographs showed that cortical territory representing retina hidden by blood vessels was innervated exclusively by geniculocortical afferents serving the other eye. Remodeling of afferents has been described in classic studies of amblyopia from lid suture, but never locally in the cortex from a media opacity (in this case, a natural one) confined to a small area of the retina. Several retinas were plastic-embedded and thin-sectioned to measure blood vessel diameter and distance from blood vessel to photoreceptor layer. Mean pupil diameter was measured in living baby squirrel monkeys. The distance from pupil aperture to retinal vessels was also measured. Vessels as small as 30 µm in diameter were represented in the cortex, indicating that they cast shadows dense enough to cause local amblyopia. Optical analysis revealed that many vessels produced shadows that were entirely penumbra, demonstrating that partial eclipse of the pupil is amblyogenic. We conclude that focal occlusion from retinal blood vessels can produce local amblyopia in normal subjects.

Supported by NEI.

Abstract 125 9:15 AM

Re-evaluating the dichotomy between simple and complex cells in primary visual cortex (V1)

Ferenc Mechler & Dario L. Ringach Cornell University Medical College, USA, University of California at Los Angeles, USA

We revisit the quantitative evidence for the existence of discrete simple and complex cell classes in V1. The dichotomy, introduced by Hubel and Wiesel (1962, 1968), was initially based on qualitative measurements of receptive field properties. Later, Skottun et al (1991) provided quantitative support for this dichotomy by showing that, when neurons are stimulated with the optimal drifting sinusoidal grating, the ratio between the first harmonic of the spike rate and its mean (F1/DC) has a bimodal distribution in V1. Furthermore, the resulting classification corresponded well with Hubel and Wiesel's criteria.

Here, we show that the bimodal distribution of F1/DC, and the location of the dip at F1/DC=1, is predicted by a half-rectification model where the distributions of the intracellular first harmonic and mean responses are unimodal. This demonstrates the existence of a simple system that, with unimodally distributed physical parameters, generates F1/DC distributions that are statistically indistinguishable from the real data. Thus, surprisingly, bimodality of the F1/DC distribution does not necessarily imply the existence of two discrete classes of neurons. In addition, we tested published distributions of a large number of V1 characteristics (including sub-field segregation, orientation selectivity, phase sensitivity, and color tuning, among others) for the significance of bimodality and found none that supported the existence of distinct "simple" and "complex" cell classes in V1.

Future research may be able to demonstrate a dichotomy in a suitable feature space. Alternatively, our results, consistent with theoretical ideas put forward by Chance and Abbott (1999) and others, suggest that "simple" and "complex" cells may represent the extremes of a continuum of neuronal properties. Such a continuum could be generated by a rather uniform intracortical microcircuitry as opposed to the simple-to-complex hierarchy of the original model of V1 architecture.

Support: NIH EY-9314 (FM), NIH EY-12816 (DLR) and NSF-IBN-9720305 (DRL)

Abstract 126 9:30 AM

Receptive fields and quasi-linear response modulation in V1 of alert macaques

D. Max Snodderly, Igor Kagan, & Moshe Gur Schepens Eye Research Inst., USA, Technion, Israel

Although it has long been routine to classify neurons in V1 of anesthetized animals into simple and complex categories, it has not been easy to apply the original criteria to alert animals because of the omnipresent eye movements. In our experiments, effects of eye movements were minimized by compensating for them and by data processing. Activating regions (ARs) of 228 cells in parafoveal V1 of alert monkeys were mapped with increment and decrement moving and

flashing bars. Most cells had two ARs, one responsive to increments (INC) and one responsive to decrements (DEC). The majority of the cells (78%, "duplex") had completely or partially overlapping INC and DEC ARs. Simple cells with minimal spatial overlap of INC and DEC ARs comprised 14% of our sample. 114 neurons were also studied with drifting gratings of varied spatial frequencies and window widths. Responses to the stimulus condition generating the maximal harmonic (F0 or F1) and the one generating the maximal relative modulation, RM (F1/F0), were analyzed. Most duplex cells responded with considerable modulation at the stimulus temporal frequency in both the maximal harmonic condition (mean RM 0.60±0.41 to 0.92±0.45) and the maximal RM condition (RM = 0.79±0.43 to 1.12±0.46), with the range dependent on the method of correcting for eye movements. A subset of duplex cells had RM>1, the traditional criterion for identifying simple cells, even though variations in stimulus conditions evoked clearly nonlinear behavior. There was little or no correlation between the degree of overlap of INC and DEC ARs and the value of RM, indicating that neither linearity nor the spatial organization of receptive fields can be predicted reliably from RM values. Our results suggest that nonlinear duplex cells represent the largest neuronal class in primate V1, whereas the linear simple cells are less numerous, more homogeneous, and probably preferentially associated with the magnocellular pathway. Support: NIH R01 EY12243, Technion VPR Funds 130347; 130358.

Abstract 127 9:45 AM

Dynamics of neuronal sensitivity in primate V1 underlying local feature discrimination

Valentin Dragoi, Jitendra Sharma, Earl K. Miller, & Mriganka Sur MIT, Dept. of Brain and Cognitive Sciences, Cambridge, MA

Viewing a scene consists of saccades interspersed by brief fixations on image patches of correlated spatial attributes. To understand how image sampling affects the statistics of stimuli at the center of fixation, we recorded the eye positions of two behaving monkeys freely viewing natural scenes. We show that successively viewed patches have large net differences in local orientation structure. This influences the discrimination of local image features and their encoding by visual cortical neurons. We have examined perceptual changes in orientation discrimination induced by brief exposure to oriented image patterns in monkeys and humans, and then used the reverse correlation procedure to investigate dynamic changes in neuronal sensitivity in the primary visual cortex (V1) of behaving monkeys. We find that whereas brief adaptation to an oriented grating impairs perceptual discrimination of nearby orientations by broadening orientation selectivity and changing the preferred orientation of individual V1 neurons, it can actually enhance the discrimination of orthogonal orientations by sharpening neuronal selectivity. Our results indicate that successive fixations on image patches of dissimilar spatial structure enhance both the capacity of the visual system to discriminate local features and neuronal performance in V1.

Supported by McDonnell-Pew and Merck fellowships to V.D., by an MIT-Riken Neuroscience Center grant to E.K.M., and by an NIH grant to M.S.

Abstract 128 10:00 AM

Responses of V1 neurons to reverse phi stimuli

Margaret Livingstone & Bevil Conway Harvard Medical School, Boston, MA USA,Harvard Medical School, Boston, MA USA

Anstis (1970) showed that 2-stimulus apparent motion appears to go in the reverse direction if the two stimuli are of opposite contrast. He termed this reverse phi. Neural correlates of reverse phi have been reported in cat V1 (Emerson et al., 1987), primate MT (Livingstone et al., 2001), and wallaby pretectum (Ibbotson & Clifford, 2001). Here we present a quantitative evaluation of responses to phi and reverse phi apparent motion stimuli in alert macaque V1. Of a population of 118 V1 cells (60 complex, 38 simple, 20 S1) ALL showed direction-selective responses to 2-bar apparent-motion stimuli, and All of them showed reversed direction preference when the two bars were of opposite contrast. The reversal was not complete: the slope of the same-contrast direction index vs the inverting-contrast direction index was -.76, -.72 and -.67 for the 3 cell types, respectively, and the r2 was .96, .8 and .83.

This result implies that direction-selective cells are generated by combining spatially and temporally offset inputs that are linear with respect to contrast; that is they change their firing rate in opposite directions for stimuli of opposite contrasts, and it further implies that the direction-generating mechanism combines linear inputs of like contrast selectivity. This combination has been modeled as a sum (Energy model) or a product (Reichardt model). The Reichardt model predicts complete reverse phi. The Energy model predicts complete reverse phi after a squaring nonlinearity. The observed difference from complete reverse phi can be accounted for by rectification.

Abstract 129 10:15 AM

Surround suppression in human V1 explains psychophysical lateral masking

Barbara Zenger-Landolt & David J. Heeger Stanford U., USA, Stanford U., USA

Purpose: We used fMRI and psychophysics to test whether surround suppression in primary visual cortex (V1) can explain lateral masking. Methods: Observers performed a contrast discrimination task on a contrast-reversing sinusoidal grating target (1 c/d, 4 Hz), restricted to an annulus (4-7 deg eccentricity) both in the presence and absence of a full contrast lateral mask. We measured fMRI responses and psychophysical thresholds for each of several target contrasts, both with and without the lateral mask. V1 was identified using standard mapping procedures, and the analysis was restricted to the subregion of V1 responding to the target. Results: Contrast discrimination thresholds were increased in the presence of the lateral mask, in particular for low target contrasts. We used the psychophysical data to infer a nonlinear contrast response function, assuming that a fixed response difference is required for correct contrast discrimination. FMRI responses increased with increasing target contrast. In the presence of the lateral mask, responses were reduced by about a factor of two. The

amount of suppression we observed in the fMRI responses was very similar to that inferred from the psychophysical data. Measurements in a control experiment ensured that the reduction in the fMRI signal reflected a neural suppresion and not some confounding effect of blood flow. In the control experiment, the lateral mask was presented with a temporal delay (375 ms after the target offset). This eliminated the psychophysical masking effect and eliminated most of the reduction in fMRI signal caused by the lateral mask. Conclusion: V1 is a plausible candidate for mediating the lateral masking observed behaviorally.

Abstract 130 10:30 AM

Cortical magnification factor in human primary visual cortex correlates with Vernier acuity thresholds
Robert O. Duncan & Geoffrey M. Boynton Salk Institute for Biological Studies

We studied the relationship between visual acuity and areal cortical magnification factor (ACMF) in human primary visual cortex (V1) by comparing Vernier acuity thresholds with retinotopic maps measured with fMRI. Vernier acuity thresholds were measured at eccentricities of 3, 6, 9 and 12 degrees in ten subjects using a staircase procedure and a 2-AFC paradigm. As expected, Vernier acuity thresholds increase with eccentricity in a roughly linear fashion. Area V1 was localized in the same observers by projecting fMRI responses to standard retinotopic mapping stimuli (expanding rings and rotating wedges) onto a computationally flattened representation of the each subject's occipital cortical surface. Next, the eccentricity dimension of these retinotopic maps was carefully measured using flickering checkerboards restricted to annuli of 1.5, 3, 6, 9 or 12 degrees. These annuli alternated with uniform gray fields every 20 seconds. Similarly, the polar angle dimension was measured with flickering wedges presented along the vertical and horizontal meridians in alternation. We quantified the topology of activity maps produced by these stimuli within each subject using a modification of the complex logarithmic transformation. This provided an estimate of the area of cortex within V1 that represents a given patch of visual space. For each subject's cortical hemisphere, the area of V1 that represents the Vernier acuity stimulus was compared to Vernier acuity thresholds in that subject's contralateral visual hemifield. We discovered that across stimulus eccentricities and subjects, Vernier acuity thresholds are inversely proportional to the cortical area associated with the Vernier acuity task. At 3 degrees eccentricity, furthermore, we found a strong within-subject correlation ($p=0.025$; $R=-0.58$) between Vernier acuity threshold and ACMF; subjects with lower Vernier acuity thresholds have more area of V1 representing the stimulus.

Saturday AM Talks (South Hall)
Natural Images

Moderators: Bruno Olshausen & Wilson Geisler

Abstract #	Time	Authors
131	11:00	Olshausen
132	11:15	McDermott
133	11:30	Geisler, Diehl
134	11:45	Victor, Hardy, Conte
135	12:00	Olman, Schrater, Kersten

Abstract 131 11:00 AM

Sparse coding of time-varying natural images
Bruno A. Olshausen UC Davis, USA

I show that both the dynamical properties of V1 receptive fields and the spiking nature of neural activity are well suited to represent time-varying natural images in terms of a sparse code. Image sequences are modeled as a superposition of space-time kernels which are convolved with a set of coefficient signals. When the coefficient signals are constrained to be sparse - i.e., rarely active - the basis functions that emerge have similar properties to the measured receptive fields of V1 simple cells. That is, they are spatially localized, oriented, and bandpass, and they translate as a function of time. Thus, these receptive fields are well-suited to represent time-varying natural images using few active neurons, providing a simple and economical description of the environment. When a movie is encoded using the learned basis functions, the resulting output signals have a spike-like character in that they are mostly zero, interspersed with brief non-zero values that are punctate in time. This is in stark contrast to the continuous time varying pixel values that constitute the input stream. Together, these observations suggest that both the receptive field properties and the spiking nature of neural activity go hand in hand---i.e., they are not separate aspects of neural function, but rather part of a unified efficient coding strategy. I also show how the image model may be used in a generative mode to synthesize movies for use in both psychophysical and physiological experiments.

Supported by NIMH R29-MH057921.

Abstract 132 11:15 AM

Psychophysics with junctions in real images
Josh McDermott Massachusetts Institute of Technology

Junctions, formed at the intersection of image contours, are thought to play an important and early role in vision. The interest in junctions can be attributed in part to the notion that they are local image features that are easy to detect but that nonetheless provide valuable information about important events in the world, such as occlusion and transparency. These assumptions generally hold in the synthetic stimuli often used in the lab. Here we test the notion that there are locally defined junctions in real images that might be detected with simple, early visual mechanisms. Our approach was to use human

observers as a tool to measure the visual information available in local image regions.
We had one set of observers label all the points in a set of real images where one edge occluded another. A second set of observers was presented with variable-size circular subregions of these images, and was asked to judge whether the regions were centered on an occlusion point. Control experiments with synthetic stimuli confirmed that if locally defined junctions are present at the occlusion points, this task is easy given a small region surrounding the point. With real image patches the results were markedly different. Performance was poor for small regions and did not approach ceiling levels until observers were given fairly large (~50 pixels in diameter) regions over which to make the judgement. Performance also tended to be poor if these large regions were blurred and subsampled, ruling out the possibility that the effects are just due to junctions at coarser scales.
Our experiments suggest that although some junctions in real images are locally defined and can be detected with simple mechanisms, a substantial fraction necessitate the use of more complex and global processes. This raises the possibility that junctions may not play the bottom-up role in vision which they have often been ascribed.

Abstract 133 11:30 AM

Natural scene statistics and Bayesian natural selection
Wilson S. Geisler & Randy L. Diehl U. of Texas

Recently, there has been much interest in characterizing statistical properties of natural stimuli in order to better understand the design of perceptual systems. A fruitful approach has been to compare the processing of natural stimuli in real perceptual systems with that of ideal observers derived within the framework of Bayesian statistical decision theory. While this approach has provided a deeper understanding of the information contained in natural stimuli as well as of the computational principles employed in perceptual systems, it does not directly consider the process of natural selection, which is ultimately responsible for design. We propose a formal framework for analyzing how the statistics of natural stimuli and the process of natural selection interact to determine the design of perceptual systems. The framework consists of two components. One is a standard Bayesian ideal observer with a utility function appropriate for natural selection. The other is a Bayesian formulation of natural selection. In the Bayesian formulation of natural selection, each allele vector in each species under consideration is represented by a fundamental equation, which describes how the number of organisms carrying that allele vector at time t+1 is related to (1) the number of organisms carrying that allele vector at time t, (2) the prior probability of a state of the environment at time t, (3) the likelihood of a stimulus given the state of the environment, (4) the likelihood of a response given the stimulus, and (5) the birth and death rates given the response and the state of the environment. The process of natural selection is represented by iterating these fundamental equations in parallel over time, while updating the allele vectors using appropriate probability distributions for mutation and sexual recombination. We show that simulations of Bayesian natural selection can yield new insights, for example, into the co-evolution of camouflage and color vision.

Supported by NIH grants EY11747 and EY02688 to WSG and DC00427 to RLD.

Abstract 134 11:45 AM

Visual processing of image statistics: Qualitative differences between local and global statistics; quantitative differences between low- and high-order statistics
Jonathan D. Victor, Caitlin Hardy, & Mary M. Conte Weill Medical College of Cornell

Statistical features of images are crucial to discrimination of visual textures and image segmentation. We compared the strength of different statistical cues and tested simple models for how they are processed. Stimuli consisted of four arrays of black and white checks. In three of the arrays, checks were colored at random; in the fourth array ("the target"), a statistical bias was introduced in local first-order statistics (the number of white checks), local fourth-order statistics (the "even" texture), or in long-range correlations (bilateral symmetry). Each kind of bias was introduced in a graded fashion. Each array subtended 2.7 deg and was centered 4 deg from fixation. The number of checks in each array ranged from 6x6 to 16x16. Subjects (N=7) were asked (100 ms presentation, 4-AFC without feedback) to identify the target. For targets that were distinguished by their local statistics, 75% correct performance was achieved with
sub-maximal levels of statistical structure. For targets that were distinguished by bilateral symmetry, performance never exceeded approximately 50% correct even with maximal statistical structure. Some subjects showed a modest implicit priming effect when the target was in the same location on consecutive trials, suggesting a covert direction of attention by the statistically anomalous target. Conditions with greater statistical structure (and greater fraction correct) were associated with shorter
reaction times, but reaction times did not show a corresponding priming effect. We constructed a model (for fraction correct) consisting of detection, pooling, and decision stages. Discriminations based on local statistics were well fit by this model. There was a striking difference in the local detection stage between first-order and higher-order statistics, but similar pooling and decision stages. Performance for discriminations based on symmetry could not be fit in a satisfactory fashion by models of this simple structure.

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Abstract 135 12:00 PM

BOLD fMRI response to natural images
Cheryl Olman, Paul Schrater, & Daniel Kersten U. of Minnesota, USA

The development of statistical methodologies enabling quantitative study of natural images has brought about increased interest in measuring neural activity in response to natural stimuli. What is known about the response of primary visual cortex to image parameters such as contrast or spatial frequency has come from studies completed with stimuli such as checkerboards or gratings, but the correspondence between

these functions and the response of the visual system to natural inputs is not certain. We have developed a parameterization of natural images that characterizes the degree of "naturalness" of an image based on a small number of parameters derived primarily from the spatial frequency spectrum of the image (contrast energy, and log amplitude spectrum slope, and phase coherence). By presenting rapid sequences of images, drawn at random for each frame and varying between natural and unnatural in a controlled fashion, we have used high field BOLD fMRI to quantify the response of primary visual cortex to natural images. We believe that the technique of rapid presentation substantially reduces temporal blurring by the hemodynamic response function, a known limitation of BOLD fMRI measurements, and thus response can be measured rapidly. As an initial test of the viability of this method, a sequence of images was generated in which image r.m.s. contrast was modulated from frame to frame. The images were presented in rapid succession as the contrast energy was smoothly varied. The modulation of the positive BOLD response was correlated with modulation of contrast power. The measured modulation of the signal is in good agreement with previous fMRI studies using sine wave gratings to measure BOLD signal tuning to image contrast.

Supported by: NIH Grant RR08079, the Keck Foundation, and the MIND Institute

Saturday Posters Session: Amblyopia; Color; Eye Movements; Retina; Spatial Vision; Temporal; Texture; Tracking

Amblyopia

Abstract 136 B2.01

Non-Linear Transformation of Sinusoidal Gratings in Amblyopia

Erwin H. Wong, Dennis M. Levi, Brendan T. Barrett, & I. Pacey U. of Houston, USA, U. of California at Berkeley, USA, U. of Bradford, UK

PURPOSE: Both amblyopic and fellow non-amblyopic eyes show reduced sensitivity for static second-order stimuli (contrast modulation (envelope) of a sinusoidal grating (carrier)) (Wong, Levi & McGraw, 2001). In the present study we investigated whether that result was confounded by amblyopes having an abnormal early non-linearity to luminance. That is, an abnormal non-linearity to sinusoidal gratings could produce luminance artifacts at the envelope spatial frequency that might be detected in addition to the second-order (non-luminance defined) structure.
METHODS: We investigated this by having amblyopic and normal adult subjects view sinusoidal gratings (prior study carriers, contrast 5 - 90%) in which we varied the width of light and dark bars, with the provision that mean luminance was maintained. We psychophysically determined the point of subjective equality between light and dark bars for each eye of the amblyopes and the dominant eye of the control subjects.
RESULTS: All eyes perceived light bars to be wider than dark bars when bars were of equal width. This perception occurred for all sinusoidal gratings and corresponded to a non-linearity that weights luminance decrements more than luminance increments by a factor of 1.01 - 1.21. The weighting factors for both amblyopic and non-amblyopic eyes were not larger than that for the control eyes. Therefore, with respect to transformation of luminance, the second-order filter stage in amblyopia appears to receive normal first-order input.
CONCLUSION: We conclude that the loss of second-order sensitivity in our prior study was not confounded by amblyopes perception of a luminance (first-order) artifact at the envelope spatial frequency.
CR: None
SUPPORT: NIH grants 1K23EY14261-01 (EHW) & RO1EY01728 (DLM).

Abstract 137 B2.02

WHAT IS THE NATURE OF THE SPATIAL DEFICIT IN AMBLYOPIA ?

Anita J Simmers and Peter J Bex Institute of Ophthalmology, University College London

Purpose: It is well known that visual acuity and contrast sensitivity in amblyopia are attenuated at high spatial frequencies. Amblyopes, however do not report that images appear blurred or lower in contrast as would be expected from these sensory deficits. Instead amblyopes report severe perceptual distortions, which extend beyond the restricted spatial range of the amblyopic eye. The purpose of this study is to identify and quantify such perceptual distortions in amblyopia. Methods: Perceptual distortions were measured with monocular forced choice discrimination tasks and inter-ocular matching tasks. Intrinsic blur was measured with blur increment and matching as a function of the standard deviation of Gaussian edges. Orientation, position and numerosity global distortions were measured in the same way with psuedo-random arrays of highly visible and resolvable Gabor patches whose local orientation and position were systemically varied. Results: Discrimination thresholds in the amblyopic eye were elevated for blur, orientation and spatial position but were within the normal range for numerosity discrimination. Interocular matching thresholds were also elevated for orientation and positional uncertainty, but were within the normal range for blur and numerosity discrimination. Conclusions: Blur and numerosity are veridically represented within the amblyopic visual system, but the representation of local orientation and spatial position shows greater variability compared to normal. It is this increased local spatial uncertainty that underlies the spatial deficit in amblyopia.

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Color

Abstract 138 B2.03

Influences of chromatic texture on contrast induction

Kit Wolf & Anya Hurlbert U. of Newcastle upon Tyne, U. of Newcastle upon Tyne

A coloured background may induce a contrasting colour in a figure set against it. We have previously shown that contrast induction may be suppressed by chromatic texture either in the figure or in its surround (ARVO, 2002). We now investigate the effects of varying the chromatic contrast of the texture, and of adding texture both to the figure and to its surround. A method of sequential presentation is used to estimate the change in colour appearance of a 1 square figure induced by changing the chromaticity of its background (30 x 20). A neutrally coloured figure and background are presented initially for 0.5 s. The background chromaticity is then changed by a constant amount along the LM-axis, concomitant with a variable chromatic shift of the figure. After 0.5 seconds, a neutral mask is displayed and the observer signals whether the figure changed to become redder or greener. In different conditions, chromatic texture is added to the backgrounds and/or to the figures without changing their space-averaged chromaticity or luminance. Regular and irregular templates with spatial frequencies between 4 and 10 cpd. were used to generate textures with LM, luminance or S-cone contrasts. Induced contrast is measured as the amount of L-cone contrast that must be added to the figure to preserve its neutral appearance. We find that contrast induction in a textured figure is suppressed strongly even when the texture contrast is very low. This may explain why real-world objects, which are rarely uniformly coloured, do not normally change colour when set against different backgrounds. Contrast induction is less when texture is present in the figure only, than when it is present in both figure and background, despite the presence of more chromatic borders in the latter stimulus configuration. This result shows that contrast suppression cannot be due simply to the inability of contrast effects to propagate beyond these borders.
Supported by the Newcastle University Alumni fund.

Abstract 139 B2.04

Color thresholds in normal dichromats
Richard Van Arsdel & Michael Loop U. of Alabama at Birmingham, USA

The shape of spectral sensitivity functions indicates that normal and dichromatic humans detect spectral flashes with wavelength opponent mechanisms.As wavelength opponent mechanisms signal color, and normal humans detect the color of spectral flashes at threshold, we presumed that dichromatic humans would too. They do not. To see color, dichromatic humans require a flash around 0.4 log units above detection intensity. This suggests that dichromatic humans may have a defect in postreceptoral color processing, perhaps because dichromacy is an abnormal condition in humans. To test this, we determined color discrimination thresholds in normal dichromats: chipmunk, ground squirrel, and tree shrew. Animals were trained with food in a spatial two-choice discrimination. On 130 and 46 cd/m2 white backgrounds, detection thresholds were determined for increments that were white, 460nm, 540nm, 560nm, 580nm, 500nm long pass, and 500nm short pass. Animals were then trained to respond to the colored increments paired with the white when both were 0.5 log units above each animal's detection threshold intensity. Color discrimination thresholds were then determined by dimming stimulus pairs (colored vs. white). Across all stimulus pairs and animals these normally dichromatic species could discriminate the color vs the white at 0.11 (± 0.10) log units above detection threshold intensity. The ability of normally dichromatic species to discriminate color near detection threshold intensity is in keeping with spectral sensitivity results indicating detection by wavelength opponent mechanisms but suggests that the low color vision sensitivity of dichromatic humans is not due to dichromacy per se. USAF (RV); NSF (76972); NEI (07084).

Abstract 140 B2.05

Influence of higher order chromatic mechanisms on inhomogeneous chromatic discrimination
Taketoshi Uchida & Keiji Uchikawa Tokyo Institute of Technology, JAPAN

Purpose: Colors spreading on inhomogenous visual field have often been considered as noise in the previous experiments with the noise masking technique (Li & Lennie, 1997; Sankeralli & Mullen,1997). However, when the spatial frequency of the inhomogenous field is low these colors appear no more noise but may have a different effect on chromatic discrimination. Our aim is to investigate effects of the spatial frequency of chromatic modulation on chromatic discrimination mechanisms. Methods: The stimulus was a random-array of isoluminant chromatic patches displayed on a CRT monitor. The chromatic distribution of the patches was either along the r-axis or along the b-axis of the MacLeod-Boynton chromaticity diagram. The mean chromaticities of the patches were the equal energy white (r=0.692, b=0.016) and a purple (r=0.692, b=0.029). Chromatic discrimination experiments were carried out along 16 radial directions from the mean chromaticity. Four patch sizes were examined (uniform, 6, 14 and 46 minutes). Results: When the patch size was small discrimination thresholds increased along the same axis as the chromatic distribution of patches. Therefore, these two axes must be independent and the color opponent mechanisms may be responsible for this discrimination task. The chromatic distributions of patches worked as noise. On the other hand when the patch size was large the r-axis and the b-axis chromatic discrimination were affected by the chromatic distributions along the orthogonal axes. These effects cannot be accounted for by the same discrimination model for small patch size, which indicates that there must be a higher order chromatic discrimination mechanism for large patch size. Conclusions: The visual system can use the color opponent mechanisms to perform chromatic discrimination when inhomogeneity is of high spatial frequency and regarded as visual noise, but it may use a higher order chromatic mechanisms for low spatial frequency inhomogeneity.

Abstract 141 B2.06

Chromatic contrast and neural adjustments to blur
Leedia A. Svec, Thomas Reiner,& Michael A. Webster University of Nevada, Reno, University of Nevada, Reno, University of Nevada, Reno

The perceived focus of a luminance-varying image can be strongly affected by prior adaptation to blurred or sharpened

images or by simultaneous contrast from blurred or sharpened surrounds. We examined whether comparable adjustments occur for patterns defined by chromatic contrast, for which spatial resolution is inherently lower. Stimuli included natural images, filtered noise, and simple edges that were varied either in luminance contrast, or in LvsM or SvsLM chromatic contrast. The image spectra were filtered by multiplying the original amplitude at each frequency (f) by f to power n, with n varied from –1 to +1 in small increments to form an array of images ranging from moderately blurred to sharpened. A 2AFC ("too blurred" vs. "too sharp") staircase was used to vary the presented image in order to find the image that appeared best focused. Measurements were made before or after 3 minutes adaptation to blurred or sharpened images, or in the presence of blurred or sharpened surrounds formed by 8 adjacent images from the same array. Prior adaptation shifted the perceived focus of all patterns. For example, blurred adapting edges caused a test edge to appear sharper, or vice versa. These effects were selective for the color or luminance variations defining the pattern, but were weaker for color compared to luminance. Weak and color-selective spatial induction of blur also occurred for LvsM patterns, while little induction was observed from SvsLM surrounds. Moreover, blurred luminance surrounds could "capture" chromatic edges, causing physically focused color edges to appear blurred, even though the same surrounds caused a luminance test edge to appear sharper. Thus luminance surrounds had opposite effects on luminance and chromatic edges. These asymmetries suggest that the neural processes regulating blur perception may qualitatively differ for luminance and chromatic contrast.

Supported by EY-10834

Abstract 142 B2.07

Partitions of object colour space under illuminant and background changes

Hannah Smithson & Qasim Zaidi SUNY College of Optometry, NY, USA

Object colours appear to change under different illuminants and against different backgrounds yet retain sufficient constancy to enable object identification. We tested whether changes in object colour appearance are confined within colour categories. Boundaries between categories form geodesics in colour space. We examined changes in the geometry of colour geodesics as a function of illuminant and background. In order to simulate objects we used the reflectance spectra of 240 natural materials that were chosen to span colour space. To construct variegated background patterns, we divided the materials into 6 spectrally distinct sets (red-blue, blue-green, green-yellow, yellow-red, balanced, and neutral) and rendered them as random ellipses. For illuminants we used the spectra of direct sunlight and zenith skylight. For each background-illuminant pair, observers categorized each of the 240 objects as either reddish, greenish or neither in one set of trials, and as either yellowish, bluish or neither in a second set. The objects categorized as "neither" were subjected to repeated forced choices between R/G or Y/B to precisely delineate category boundaries. The results showed that the materials falling on colour boundaries show substantial overlap across the two illuminants. However, some material appearances did cross colour categories with a change in illuminant, despite prolonged adaptation to a single illuminant. Materials falling on colour boundaries also overlapped across backgrounds, but many material appearances crossed colour categories with a change in background. There were substantial changes in the shapes and locations of geodesics in chromaticity space. These changes provide tests of colour appearance models under adaptation to illuminant-background pairs.

Grant: NEI EY07556

Abstract 143 B2.08

Time course of L-M system adaptation to simple and complex fields

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Shapiro, Beere, and Zaidi (2001) examined the response of the L-M system as adaptation shifted from one chromaticity on an L-M line to another. The steady state results could be described by a post-opponent subtractive stage before a non-linear response function, but the shapes of the transitory threshold curves could not be explained by early multiplicative or subtractive adaptation, and were suggestive of the effects of higher mechanisms involved in adaptation to color modulations. In order to isolate the effects of the higher adaptation processes, we compare changes in response following adaptation to uniform chromatic fields to changes measured following adaptation to spatio-temporally complex fields. Lights were restricted to an L-M cardinal axis, with end-point chromaticities R and G and mid-point W. Difference thresholds were measured from probes on nine flashed backgrounds during adaptation to a uniform field with chromaticity R, G, or W, and after RG adaptation (i.e. adaptation to a field of 0.3 deg squares with chromaticities randomly assigned to R or G every 0.1 sec; the space and time averaged chromaticity of the field equaled W). We measured the same probe-threshold curves after 0.1, 0.25, 0.5, 1.0 and 2.0 sec of shifting adaptation from G to W, R to W, or from RG temporal alternation to W. Following steady R, G, and W adaptation, the probe-flash threshold curves form identical V shapes centered at or near the adapting chromaticity. During the shift from R to W and G to W the curve flattens before forming a V with a minimum at W. Following RG adaptation the threshold curves are flatter than following steady adaptation. The data provide an estimate of the effects and time course of higher-level adaptation.

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Abstract 144 B2.09

Color and motion: which is the tortoise and which is the hare?

Saumil S. Patel, Susana T.L. Chung, Harold E. Bedell, & Haluk Ogmen U. of Houston, USA, Indiana U., USA, U. of Houston, USA, U. of Houston, USA

Recent psychophysical studies have been interpreted to indicate the perception of motion temporally lags the perception of color. We sought to evaluate the generality of this

interpretation, using targets with a range of motion directions and velocities, and two psychophysical tasks.

Observers viewed a 18 sq.deg field of colored dots that moved at a constant speed (15-60 deg/s), and periodically changed their color (red/green) and direction of motion (up/down or up/left). In one experiment, the observers' task was to judge the predominant color of the dots during upward motion. In a second experiment, the observers judged whether the change in dot color occurred before or after the change in the direction of motion.

When the direction of dot motion reverses from up to down, our results confirm previous reports that one color is perceived to be predominant for each direction of motion if the phase of dot-motion change is advanced approximately 150 ms with respect to the change in dot color. However, when the direction of dot motion changes from up to left, the relative phase of dot-motion change shifts systematically from a phase advance (ca. 60 ms) to a phase delay (ca. 20 ms) as the speed of motion increases. In the second experiment, dot color and dot motion are perceived to change simultaneously when the phase of dot-motion change is delayed slightly with respect to the change in dot color, regardless of the angular direction change or dot speed.

Our results can be explained by considering how the stimulus and experimental task interface with various stages of color and motion processing. A task that requires the averaging of color information for motion in a specific direction involves neural processing that is unnecessary if just a change in motion direction or color has to be detected. If the moving stimulus reverses its direction, we suggest that a motion-opponency stage is engaged, which substantially slows the dynamics of motion processing.

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Abstract 145 B2.10

Individual differences in color categories

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Color-normal observers show large and reliable differences in the stimuli they choose as unique hues, yet the variations across hues are uncorrelated, suggesting that they are constrained by independent factors. We compared the patterns of variation for both unique hues (red, green, blue, and yellow) and intermediate hues (orange, purple, blue-green, and yellow-green), to test the relative status of different color categories. Stimuli were moderately-saturated, equiluminant pulses on a gray (30 cd/m2) background and fell along a circle within a threshold-scaled version of the LM vs S chromatic plane. The hue angles corresponding to each of the 8 colors were estimated by varying successive stimuli in two randomly-interleaved staircases. Measurements were made for 35 observers, all screened for normal color vision. If orange and purple represented color categories derived from more fundamental primaries, the focal choices for these hues might plausibly be correlated with an observer's unique hue settings (with red and yellow or red and blue, respectively). Instead, clear correlations did not emerge for any of the hue pairs. Settings of yellow-green and blue-green presumably reflected judgments of category boundaries rather than focal colors. These boundaries were again uncorrelated with the loci of the focal components. Moreover, the variance in settings did not distinguish unique and intermediate hues. Surprisingly, the lowest variance occurred for blue-green (roughly half the standard deviation of other hues and centered near the –L pole of the LM axis), even though focal green and blue show large individual differences. This pattern of results does not support a perceptual organization in which the dimensions of red-green and blue-yellow have superordinate status.

Supported by EY-10834

Abstract 146 B2.11

Which colours do not invoke the high-spatial-frequency tritanopia effect?

Alexander D. Logvinenko & Sara J. Hutchinson The Queen's University of Belfast, UK

A rectangular achromatic grating presented against a coloured background may appear tinged with either yellow-green (e.g., when against a yellow background), or blue (e.g., when against a pink background) provided its spatial frequency is high enough. This colour illusion, which is referred to as high-spatial-frequency tritanopia (HSFT), can be observed against backgrounds of only a limited set of colours. We investigated which colours do not produce HSFT. Such a no-illusion set (NIS) of colours is quite indicative of a possible colour mechanism of HSFT. If, as recently suggested (Hutchinson and Logvinenko, 2001 Perception 30 Supplement, p. 8), it is a result of poorer spatial characteristics of either (i) the opponent yellow-blue linear colour channel, or (ii) two unipolar (e.g., yellow and blue) linear channels each of which is followed by a rectifier, the NIS should be either (i) a plane, or (ii) a dihedral, through an achromatic locus, respectively. Generally, any explicit quantitative model of the S-cone pathway makes a specific prediction of the NIS. We have explored the equi-luminant and ML planes in the SML cone contrast space for a grating of 10.1 c/deg. In the ML-plane the NIS was found to be a narrow strip through the origin, with an angle of approximately 65 deg with the M-axis. In the equi-luminant plane the NIS was found to be a curvilinear line for $M - L < 0$. However, when $M - L > 0$ the NIS was not a line but a whole curvilinear sector. These results clearly indicate that at least two non-linear unipolar post-receptor chromatic mechanisms, making up an opponent pair, are involved in producing HSFT. Both mechanisms are driven by a difference between a S-cone input and a linear combination of M- and L-cone inputs transformed by static non-linearity. With both being half-wave rectified, one mechanism, produces a bluish illusory colour and the other produces a yellow-greenish illusory colour.

Abstract 147 B2.12

Chromatic signal-to-noise ratio affects chromatic gamut effect

Ichiro Kuriki NTT Communication Science Laboratories, Japan

[Introduction] If a chromatic contrast of a display were increased, a color patch of low chromatic saturation would

appear nearly achromatic, and vice versa*. The current study will report a strong asymmetry in this chromatic gamut effect according to temporal modulation, which may provide a clue to clarify the mechanism of this phenomenon. [Methods] An array of 44 x 33 multi-colored squares (36deg x 27deg) was presented as center- and surround-stimuli. The change in detection ratio for the center stimulus (probe; 2deg x 2deg) was measured during a slow change in chromatic contrast in the surround. The color of each square was randomly selected from 9 hues that equally distributed in hue around equal-energy white (W_eq). The chromaticity for the surround was varied in saturation, from zero to 0.050 in CIE u'v' distance from the W_eq, under isoluminance. A cycle of temporal modulation for the surround consisted of four 20s phases: 1) gray (W_eq), 2) increment, 3) maximum saturation and 4) decrement. In the phases 1 and 3, saturation was kept constant for 20s, at zero and 0.050, respectively. In the phases 2 and 4, saturation was modulated continuously between zero and 0.050 with an incremental- and a decremental-half of a raised-cosine envelope (0.025Hz), respectively. The chromatic modulation of the probe was independent from the surround, as a 1s raised-cosine envelope (1Hz) with the maximum saturation of 0.005 in u'v' distance. The probe was presented every 5s, except catch trials. 20 cycles were repeated in a session. [Result] Results were analyzed according to signal detection theory. Hit rates were significantly different between the phases 2 and 4, as well as between the phases 1 and 3. The false-alarm rate was higher in the decrement phase than in the increment phase. [Conclusion] The current result implies that the signal-to-noise ratio in the chromatic mechanism could be a cause of the gamut effect.

* Brown RO and MacLeod DIA, Curr.Biol., 7(11), 844-9, 1997.

Abstract 148 B2.13

Illuminant color perception of spectrally filtered spotlights

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Color perception in the "illumination" mode always accompanies the perception of object colors. The color perceived to belong to the illumination of the objects is based on clues from the scene within which the objects are perceived instead of being based on any view of the source itself. We have examined the clues on which the color percept of the illumination is based for variegated collections of matte surfaces without highlights. We simulated one of 5 distinct sets of 40 spectrally selective materials (red-blue, blue-green, green-yellow, yellow-red, and balanced) as random ellipses on one half of a CRT screen, and luminance matched achromatic materials on the other half. Equal-energy light filtered through one of 6 Kodak CC30 filters (R, G, B, C, M, Y), or a 0.7 transmittance Neutral Density filter, was simulated as a moving circular spotlight on the chromatic side. Observers matched this light by adjusting the spectrum of a similar moving spotlight on the achromatic side. The backgrounds surrounding the spotlight were presented in 3 conditions: dark, illuminated by the unfiltered equal energy light, and illuminated by dim (20%) equal energy light. Illuminant matches were almost veridical with bright surrounds but not with dim or dark surrounds. The presence of a second illuminant in the scene was thus important for accurate color scission into illuminant and surface colors. When the spotlights were the only illuminants, the chromaticity of the matching spotlight was set near the mean of the spotlighted chromatic region, and set equal to the mean when there was least overlap between illuminant and material spectra. Despite the chromatic information provided when the spotlight traverses materials of diverse spectral reflectance, the perceived chromaticity of the illuminant was close to the mean chromaticity of the scene, as if the visual system assumed that the mean reflectance of the chromatic region was almost a uniform function, i.e. a "near-gray world".

Grants: NEI EY07556

Abstract 149 B2.14

An effect of sinusoidal temporal modulation on high-spatial-frequency tritanopia

Sara J. Hutchinson & Alexander D. Logvinenko The Queen's University of Belfast, UK

There are a few colour phenomena which are caused by paucity of the S-cones. One is tritanopia of the central foveola i.e. S-cone scotoma, usually not seen but which can be made visible under intermitted light (Magnussen et al, 2001 Vision Research 41 2961-2967). It corroborates that the S-cone scotoma is filled in by some neural process.

Another is high-spatial-frequency tritanopia (HSFT). It is observed, e.g. when an achromatic grating is viewed against a coloured background. If spatial frequency of the grating is high enough it may appear tinged with either yellow-green (on yellow background), or blue (on pink background). It was recently shown that HSFT cannot be accounted for by filling-in within the S-cone pathway (Logvinenko, 2001 Perception 30 223-232). Here we present more evidence supporting this conclusion.

We have studied an effect on HSFT, of temporal modulation (range 0.5 – 10 Hz) of yellow (x = 0.452, y = 0.470, lum = 25.0 cd/m2) and pink (x = 0.309, y = 0.239, lum = 25.0 cd/m2) backgrounds against which an achromatic grating (x = 0.316, y = 0.335, lum = 27.5 cd/m2) is presented. Unlike tritanopia of the central foveola, HSFT is not significantly affected by sinusoidal temporal modulation of the background. Within the range 0.5 – 3 Hz, background modulation simply causes an apparent modulation of the apparent tinge of the hitherto neutral grating – it modulates between neutral and apparent yellow-greenish (on the yellow background) or blue (on the pink background). When temporal frequency of the background modulation exceeds 3 Hz, an apparent flickering of the grating disappears despite that flickering of the coloured background is still clearly visible. The apparent colour of the grating appears fused at the level approximately halfway between the two colour poles (neutral and apparent colour observed against non-flickering background). Thus we conclude that tritanopia of the central foveola and HSFT are based on differing neural mechanisms.

Abstract 150 B2.15

Colour effects on metacontrast masking and reading
Veronica T. Edwards & John H Hogben U. of British Columbia, CANADA, U. of Western Australia, AUSTRALIA

Temporal processing in individuals with dyslexia is often found to be abnormal. In vision, there are continual reports of deficits in dyslexic individuals on measures of magnocellular- (M-) system function. The nature of the relationship between deficits in M-system functioning and reading development is, however, unclear. That is, whether a deficit in M-system functioning is causally related to the reading failure of those with dyslexia is not known. This research explored the issue of causality using metacontrast masking. Initial studies on adults revealed that the wavelength of the background field on which metacontrast stimuli are presented influences the magnitude of the masking effect. Based on a two-component interpretation of metacontrast, this suggested that variations in background wavelength might be used to manipulate the degree of activation within the M-system. This provided a means to test whether degree of M-system activation influences reading performance. Accordingly, 36 children with dyslexia and 36 children with average reading ability were assessed on metacontrast masking and on three reading measures (passage reading, single word reading, and nonword reading). The masking and reading tasks were completed in four background wavelength conditions. Manipulating the wavelength of the background field affected metacontrast outcomes, which in the long wavelength condition could plausibly be explained as an effect on M-system function; however, the long wavelength background resulted in no observable effects on reading performance. The lack of co-variation in degree of M-system activation and reading performance suggests that a deficit in M-system function either affects reading at the acquisition stage, or is simply a non-causal correlate of dyslexia.

Abstract 151 B2.16

Vastly differing variances in the ratio of red and green cones between female and male human observers
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Three cone types provide the input signals into our color vision. Their respective spectral sensitivities peak at wavelengths of about 430 nm (S-cones), 530 nm (M-cones) and 560 nm (L-cones). L- and M-cones comprise the vast majority of cone types in color-normal human retinae. The ratio between these two cone types - called the L/M-ratio - is found to vary considerably between 1 and 10.
We have recently developed a new method to determine the relative contribution of the three cone types to the perception of brightness in human observers (Teufel & Wehrhahn, JOSA A, 17: 994-1006, 2000). This method provides a fast and robust procedure to determine cone contributions to perceived brightness and includes an estimate of L/M-ratios.
Here we report that color normal female and male observers have very different distributions of L/M-ratios. Specifically female observers show a distribution of L/M-ratios with two peaks, situated at low and high L/M-ratios, respectively. This is opposed to color normal male human observers, whose distribution was found to have only one peak at medium L/M-ratios.
We propose that this difference in distributions is due to a previously unknown genetic mechanism regulating the genesis of retinal cones.

Abstract 152 B2.17

Comparison of color constancy with respect to illumination changes induced by distinct physical processes
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Purpose. Distinct physical processes can change the spectrum of the illumination that impinges on a surface. Here we consider two such changes. The first is a change in the spectrum of the light source that provides the scene illumination (light source change). The second is a change in the reflectance of a surface located near a test surface of interest. Such a change in nearby reflectance can affect the spectrum of light reflected onto the test (reflected light change), even when the light source is constant. A color constant visual system must compensate for changes caused by both of these physical processes. We report measurements of constancy with respect to light source and reflected light changes. Methods. Observers viewed synthetic images rendered from three-dimensional scene descriptions and displayed on a CRT-based stereoscope. They made achromatic adjustments to test surfaces embedded in the images. In the light source condition, the test surface received most of its illumination directly from the light source. In the reflected light condition, it received a large fraction of its illumination from light reflected off a neighboring surface. Within each condition, achromatic loci were measured for five different illuminants, and these five illuminants were matched across the two conditions. One illuminant (D65) was chosen as a baseline and the achromatic loci were used to compute a constancy index for illumination changes with respect to this baseline. Results. Constancy was shown for both conditions, but was better for light source changes than for reflected light changes. In both conditions the degree of constancy varied systematically with the color direction of the illuminant change, and the variation was similar in both conditions. This similarity, as well as the results of other experiments in our lab, suggests that the same mechanisms may play a substantial role in mediating constancy for both types of illumination change.
Support: EY10016

Abstract 153 B2.18

Multifocal chromatic pattern-onset VEPs
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Purpose: Previous investigations have utilized the chromatic pattern-onset visual evoked potential (VEP) to characterize development, maturation, and aging of the chromatic visual

pathways. The utility of the chromatic onset VEP as a sensitive and objective measure of neural function has been demonstrated in both congenital and acquired color vision deficiencies from diseases such as diabetes and optic neuritis. Here we report extension of this technique to include multifocal recordings that provide topographic measures of chromatic response.

Methods: Multifocal VEP recordings were made using the VERIS system. This system employs a binary m-sequence for stimulus presentation and software designed to extract VEP responses generated from different regions of the visual field. Stimuli were chromatic patterns in which colors were modulated along S cone, L-M cone and achromatic axes in the MBDKL color space. Patterns were presented in an onset-offset temporal mode.

Results and Conclusions: Our data indicate that as with achromatic pattern-onset responses the character of the waveforms depends greatly on topographic location. The classic large -positive complex reported for full-field chromatic responses is inverted and reduced in the upper fields as has been reported for achromatic responses. Near the horizontal midline, the responses are partially cancelled and the largest contribution to the classicfull-field negative-positive complex appears to be generated in fact from neurons of the lower visual field. Nevertheless, the robust nature of the waveforms generated throughout much of the visual field suggest that the multifocal onset VEP may be useful for future clinical application and studies of aging.

This work was supported by NIA grants to M.A.C. and J.S.W.

Abstract 154 B2.19

The categorization of colors measured with the Stroop effect.

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Numerous studies have shown that humans classify colors into a restricted number of categories that appear to be universal across cultures. The results of most studies are, however, heavily dependent on the choice of color terms made available to the subjects. Moreover, most studies used monochromatic stimuli, yielding results difficult to compare to those of the electrophysiological literature. We thus designed a new technique to measure the boundaries of color categories, and used it to investigate the classification of colors in a physiologically relevant color space (MacLeod-Boynton). During training, our subjects (N=17) learned to associate a color name with each of four white shapes (square, disc, rectangle, or diamond) presented a dark background. Upon presentation of one of the four shapes, the subjects had to name it as quickly as possible with its associated color name. We measured the subjects' verbal reaction time for the correct naming of the four shapes. For the data collection proper, the task remained the same except that the shapes were presented not only in white (the control condition), but also in various colors (all of equal luminance). The stimuli subtended 1-3 deg of visual angle, had a luminance of 32 cd/m2, and were presented for 150 msec on a background with a luminance of 2 cd/m2. When the color of the stimulus was congruent with its associated color name, the reaction times were shorter than for the control. The reaction times grew proportionally with the difference between the stimulus physical color and its associated color name, similar to the well-known Stroop effect. The curves relating the subjects' reaction times to the color of the stimulus yield estimates of the boundary for each color category tested. These results are compared to those obtained with standard color categorization paradigms, as well as to the color tuning of single neurons in the visual pathways.

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Abstract 155 B2.20

The perception of colour gradients

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Chromatic shading on a surface (spatial gradients in colour) may arise from several physical factors, e.g.: variations in surface pigment concentration, shadows caused by occlusion of a spectrally non-neutral light source, and mutual reflections between surfaces of different spectral reflectance. We have shown that chromatic shading due to mutual illumination can provide cues to object spectral reflectance and scene geometry (Bloj et al 1999). To explore the role of chromatic shading in providing such information, we are investigating the sensitivity of the human visual system to chromatic shading, under varying image contexts. In a simultaneous discrimination task we measure and compare sensitivity to chromatic only and luminance only gradients. On each trial, a reference and test image (each 10 degree square) are presented centrally at a separation of 5 degrees (with side of reference presentation randomised between trials) for 500ms, followed by a static mask for 500ms and then by a neutral full field which remains until observers indicate with a button-press which of the two images contained a larger change in hue or brightness over the extent of the shading. The reference image contains a one-dimensional gradient (vertical or horizontal) in hue or luminance extending over the central 5 degrees, with a 2.5-degree border of a baseline neutral colour. For different image contexts, the edges of the gradient are either gaussian-blurred with the border colour or sharpened by a luminance edge. Within each block, the upper limit of the hue or luminance gradient remains fixed, as does the border colour everywhere, while the lower limit of the gradient is varied between the test images. For blurred-edge gradients, thresholds for discriminating changes in chromatic gradients are lower than for luminance gradients, measured as the just-discriminable difference in total cone contrast between the limits of the gradient. Discrimination thresholds for sharpened-edge chromatic gradients are lower than for blurred-edge chromatic gradients. The results are consistent with the hypothesis that chromatic gradients whose edges coincide with luminance edges are more likely to be due to intrinsic surface properties than to extrinsic shading, and that therefore sensitivity to chromatic gradients in that context is increased.

Abstract 156 B2.21

Hue, saturation and brightness: fundamental properties of color vision derived from dynamic interactions between cortical cell populations

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Opponent and vector models are important, yet incomplete foundations for color theory; they dictate how to compute hue, saturation and brightness, but offer few clues to their neural correlates. Here we derive hue, saturation and brightness from nonlinear dynamic interactions between cortical broadband and narrowband-wavelength selective mechanisms. HUE: Hue opponency can be modeled as a competitive (winner-take-all) interaction between cortical narrowband wavelength selective mechanisms; e.g., blueness-labeled neurons compete with yellowness-labeled neurons for the right to fire, and opponency resides in the fact that only one wins out. This competition opponency reproduces psychophysical opponency and also models some otherwise intractable color behaviors (e.g., Billock et al., JOSA A, 2001). SATURATION & BRIGHTNESS: Another nonlinear dynamic interaction (widely employed in circadian and binding models) is neural synchronization. Coupled neural oscillators can synchronize at a compromise frequency (which lies above or between the uncoupled frequencies). The behavior of the coupled system depends on the nature of the coupling (e.g., excitatory or inhibitory, mutual or asymmetric) and on system nonlinearities. We coupled neural oscillators driven by narrowband hue and broadband luminance mechanisms and identified coupling conditions and nonlinearities that lead to vector-like summation, such as that used in modeling brightness, and to power law functions of signal ratios, such as that used to model chromatic saturation. Competition and coupled oscillators are used extensively in other neural modeling; it is natural to apply them to color theory. Similarly, it is natural to apply binding-like models to saturation and brightness, which are combinations of chromatic and achromatic information. The exciting aspect of these models is that hue, saturation and brightness are emergent properties of physiologically plausible interactions between known cell populations.

Eye Movements

Abstract 157 B2.22

Studying eye movements produced whilst making visual decisions

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In everyday situations we move our eyes around the world 3-5 times every second to obtain visual information. Frequently, the information we require is at different locations in depth within a complex 3-D scene. How do the eyes move in these situations? Does the task being performed influence gaze-shifts? Here, we examine the binocular and monocular eye movements produced by subjects whilst performing different visual tasks using real world objects. Subjects were required to make decisions about small cuboids presented within a purpose-built viewing-box. The cuboids were painted different shades of grey, and varied in size: some were perfect cubes, whilst others had square faces and rectangular sides. On a single trial, subjects performed a 2AFC regarding which of two cuboids was biggest or which had the lightest shade of grey. Viewing was either binocular or monocular. The cubes were laterally separated by 11deg, and were located at either the same distance from the observer or at different distances. Whilst subjects performed the task their eyes were tracked using an infra-red video-based binocular eye-tracking system sampling eye position at 120Hz. Subjects were naïve, and were given no instructions regarding eye movement.

Eye position data were classified into regions of fixations, gaze shifts and local adjustments of gaze. The task (shape vs. grey-level) was not found to influence the number or duration of gaze shifts, fixations, or gaze adjustments. During binocular viewing, vergence changes primarily occurred during saccadic eye movements. Subjects made more fixations, and for longer periods during monocular viewing, although other aspects of the eye movements were comparable with binocular viewing.

Whilst task dependent differences in gaze-shift dynamics have previously been reported (Epelboim et al., Vis Res, 1997, 37, 2597), we fail to find differences in eye movements produced under different tasks or different viewing conditions.

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Abstract 158 B2.23

The role of eye movements and induced motion on the strength of a trajectory illusion.

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Purpose: When viewing transparently superimposed parallel and 'expanding radial' dots, observers perceive the trajectory of some radial dots to be curved when, in fact, all trajectories are straight. The conclusion from prior experiments was that this illusion was a result of induced motion and pursuit eye movements. Observers also reported seeing the illusion when asked to track a horizontally moving (HM) dot in the absence of the parallel dots. The present experiments examine whether this finding is due to a minimal background being present or to a curved trajectory being traced on the retina. This investigation also examines how the strength of the illusion varies as a function of the direction of radial dot motion and the presence of a stationary central fixation (SCF) dot. Methods: The radial dot moved in 1 of 6 directions (clockwise: 0, 45, 135, 180, 225, or 315 degrees), had a straight or curved trajectory, and was embedded into a field of leftward parallel dots or presented alone. Observers fixated on the accelerating radial dot, on the constant-velocity HM dot, on the SCF dot, or were instructed to keep their eyes in the "center" while judging the trajectory of the radial or HM dot. Results: No illusion was reported in either the minimal background or the curved-trace conditions. Observers reported less of an illusion when the radial dot's direction of motion was against the movement of the parallel dots, and reported more of an illusion when asked to keep their eyes in the "center" versus when asked to fixate on a SCF. Conclusion: Results suggest that horizontal motion may

be interpreted as a stable characteristic of the environment. The findings also provide support for the argument that induced motion plays a role in the trajectory illusion. However, the results question previous findings that the perceived shift in the focus of expansion (Duffy/Wurtz illusion) is not due to eye movements, but, rather, to an eye movement compensation mechanism.

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Abstract 159 B2.24

Electrical properties of elements mediating saccadic eye movements within macaque V1: excitability differences between layers

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Electrical stimulation of superficial V1 (layers I through IV) interrupts a monkey's ability to select visual targets appearing in the receptive field region of the stimulated neurons, whereas stimulation of the deep V1 (layers V and VI) tends to drive the eyes toward the target (Schiller and Tehovnik 2001). Given this functional segregation between layers, we performed experiments to assess the excitability of neural elements activated while inducing saccadic eye movements electrically from different cortical layers of V1 in the rhesus monkey. Using cathodal-first stimulation, saccades could not be evoked from the surface of V1 using currents as high as 30 uA. The current threshold to evoke saccades, however, dropped to between 2 and 3 uA as the electrode was advanced between 1.5 and 2.0 mm below the cortical surface. The minimum latency at which saccades were evoked from V1 using suprathreshold currents that were 10 times threshold ranged from 48 to 55 ms. The chronaxies of the directly-stimulated elements mediating saccades in V1 ranged from 0.12 to 0.41 ms, with elements in superficial V1 exhibiting longer chronaxies than those of deep V1. Anodal-first pulses were more effective than cathodal-first pulses at evoking saccadic eye movements from superficial V1, while cathodal-first pulses were most effective at evoking saccades from deep V1. Our chronaxie estimates and the anode-cathode ratio values obtained for evoking saccades from V1 are similar to those reported for elements mediating phosphenes in humans.

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Abstract 160 B2.25

The role of action-relevance in the perception and representation of natural scenes

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Goodman (1980) showed that action schemas influence the retention of visual information within pictures. Here, we investigate whether such schemas can also affect perceptual processing of natural scenes using the standard 'change-blindness' flicker paradigm. Target objects were selected as either of high or low relevance to a salient action performed by an actor within the scene. Time to detect changes which involved surface properties of objects (e.g. colour or swapping with a similar object) was compared to time to detect those which involved object identity (e.g. deletion, swapping with a different object). Eye movements were recorded throughout using a head-mounted eye tracker, and related to the detection of change and relevance of the target object to the action. Observers viewed photographs of natural scenes which displayed one action performed by an actor within them. Four objects in each scene were pre-classified to be of high or low relevance to the action and to the scene. Subjects were required to inspect each scene in order to either (i) recall or (ii) recognise the objects at a later stage. Observers were also requested to react as soon as any change was detected. Time to change detection was found to be related to object relevance as well as to the scene. In general, changes to low relevant objects were detected faster, which suggests that expected items are less attended to. Fixation position was invariably found to be near the area where the change occurred when it was detected. The data suggests that prior knowledge or assumptions about the world, organised in the form of action schemas can affect the eye movement inspection patterns of natural scenes, and the allocation of visual attention within them. These results are consistent with those reported by Hollingworth and Henderson (2000).

Abstract 161 B2.26

Neural correlates of divided orienting in frontal eye field in a search-step task

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We developed a search-step paradigm that combines the classic double-step task with a visual search task to investigate the dynamics of visual selection and saccade preparation in the macaque frontal eye field (FEF). Monkeys were trained to shift gaze to an oddball target among a circular array of distractors. Infrequently, the target and one distractor would swap locations after some variable delay. This delay was adjusted on-line so that half of the search-step trials resulted in a compensated saccade (gaze shift to the final target location which was reinforced) and half were non-compensated (gaze shift to the original target location which was not reinforced). Visual neurons in FEF signal the location of the target whether or not gaze shifts to it (Murthy et al. 2001 J Neurophysiol 86:2634). The current report is based on a neuron-antineuron analysis of activity when the target stepped into or out of each neuron's response field. Two observations were made in compensated target-step trials. First, visual neurons commonly exhibited a transitory period of coactivation during which two separate locations in the visual field were represented simultaneously. Second, the movement neurons producing the compensated saccade commonly became active while the movement neurons producing the noncompensated saccade were still active. These observations are consistent with the hypothesis that when reacting to rapidly changing scenes attention can be allocated to separate locations and more than one saccade can be partially prepared.

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Abstract 162 B2.27

Modulation of responses in mokey V1 by an eye position task

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The integration of retinal and extra-retinal, including oculomotor inputs to the brain is essential for localization of stimuli in space, dynamic stabilization of receptive fields, and for selective attention to a particular object or location to enhance perceptual sensitivity. Neurons in primary visual cortex (V1) are modulated by direction of gaze. It remains unknown whether V1 response can change if retinal inputs and gaze are held constant, depending on task demand. Such a change would define top-down influences reflecting internal state of the animal.

We examined responses to oriented gratings in awake monkey V1 while the animal engaged in performing a fixation task. The fixation spot appeared at three different locations in horizontal plane. The animal was rewarded for maintaining fixation for a period of 1-1.5 sec. with a drop of juice. Single neuron responses to sinusoidal gratings (eight orientations, 2 directions, presented in 10x10 deg. window covering neurons' receptive field) were recorded. Two task conditions were used. In one (randomized trials), trials were presented in a pseudo-random fashion in any of the 3 gaze directions, while in the other (grouped trials) the fixation spot appeared in same gaze direction for 10-15 trials. Our results show that in randomized trials 20% neurons were significantly modulated by the change in gaze direction whereas when trials were grouped, as many as 68% neurons showed gain modulation.

Our data clearly shows task dependent changes in gaze modulation, reflecting top-down influences, such as focal verses distributed attention.
Supported by NIH grants.

Abstract 163 B2.28

Ocular search of simulated roadway displays in drivers with constricted visual fields

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Purpose: Ocular search depends on vision and attention; so does the useful field of view (UFOV).This pilot study aimed to test how UFOV reduction affects visually guided eye movements.
Methods: 34 licensed drivers participated in driving scenarios enacted in the Simulator for Interdisciplinary Research in Ergonomics and Neuroscience (SIREN), which has a 150#730; forward FOV. Driver eye movements were measured with an infrared system (ISCAN Model ETL 500) mounted in SIREN. Eye scanning measures (including frequency and duration of fixations and total scan path length) were recorded for a 166s span across the same geographic location in the drive. 13 drivers had reduced UFOV scores due to cognitive aging (5), retinitis pigmentosa (5), and other causes (3); 21 drivers had normal visual fields. UFOV measurements used the Vision Attention Analyzer 3000(Vision Resources, Chicago). We hypothesized that reduced UFOV would lead to greater fixation duration and lesser total number of fixations, distance between successive fixations, and total scan path length.
Results: Eye movement measures were extracted from the electronic data stream in all drivers. Drivers with visual field constriction did not differ from controls with respect to any of the eye scanning measures ($P>0.05$). Correlations between eye movement measures and the UFOV scores were low (Spearman r's from -0.178 to 0.217; $P>0.34$ all cases).
Conclusions: The UFOV task depends on speed of processing, divided attention and selective attention and taps abilities that contribute to the driving task at attentive and pre-attentive levels. However, reduced UFOV scores did not affect ocular search as predicted. Drivers with severely impaired UFOV did not change their visual scanning strategy to compensate for this loss, raising potential safety concerns. These drivers show decreased ability to extract information from a cluttered scene, even if they visit all scene locations, suggestive of "looking but not seeing."

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Abstract 164 B2.29

Covert shifts of attention precede involuntary eye movements

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It is generally believed that covert attention and eye movements are inexorably linked, such that the planning of an eye movement automatically leads to a shift of covert attention to the saccade target. Previous research demonstrating this link has concentrated on voluntary eye movements. In two experiments, we examined whether covert attention precedes involuntary eye movements made to onsets. The task was to move the eyes to a small uniquely colored saccade target and to identify which of two letters were contained within. At the same time that the target changed color, an irrelevant onset appeared. To measure covert attention, we placed large response compatible or incompatible probes at the location of either the onset or the colored target. Probes were identifiable from central fixation and only visible between the presentation of the target and onset and the initiation of the first saccade. When the eyes moved to the intended color target, only probes at the location of the saccade target affected responses, and no trace of covert attention was found at the location of the onset. When the eyes made an involuntary saccade to the onset, probes at the onset affected response times, indicating that covert attention had preceded the eyes to the onset. However, probes at the color target also affected response times, but not when they were presented during the first 100 ms. This suggests that covert attention first made an involuntary shift to the onset and then made a corrective shift to the intended target, even though this was followed a short time later by an unintentional saccade to the onset. These results suggest that eye movements are a valid measure of the initial shift of covert attention. Consequently, this suggests that previous experiments showing only modest oculomotor capture by onsets are indicative of only modest covert attentional capture.

Results are discussed in terms of a horse-race model between voluntary and involuntary signals.

Abstract 165 B2.30

Localization precedes attention-induced acceleration of visual processing

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The temporal order of a pair of visual stimuli presented in the dark just before a saccade determines their perceived spatial relation: the second stimulus in the pair appears to be shifted in the saccade direction. On the other hand, the positions of these stimuli relative to the focus of attention determine their temporal order: the stimulus on which attention is focused appears to be first even when it is presented several tens of ms later. Here we tested whether these illusions depend on the physical properties of stimuli or their perceived properties. In experiment 1, we presented two 3-ms dots 50ms apart shortly before a 10 rightward saccade and measured perceptions of temporal order and relative position of them simultaneously. One dot was at the site of saccade target where attention would be focused, the other was 3 above it, varying from 1 left to 1 right. The temporal order and relative position of the dots were randomized. The observers' perceived temporal order was inverted when the bottom dot was presented second, but their perceived spatial relation was not affected. This shows that saccadic mislocalization depends on the real order of stimuli. In experiment 2, we changed the dots' location: one dot was at the saccade target position, and the other was at 3 left to it. During the fixation, the right dot, which was presented and perceived at the attentional focus, was almost always perceived to be first. However, when these dots were presented just before the 10 rightward saccade, their perceived position (measured by ocular targeting) shifted to the right so that the left dot was perceived closer to the saccade target position than the right dot. In this situation, the left dot appeared to be first in most trials. This shows that the illusory temporal order depends on the perceived position of the stimulus.
The combined results lead to the conclusion that the brain analyzes the position and the timing of the stimulus serially, and that attention accelerates visual processing after the stage of localization. (Supported by USPHS grant EY-05879)

Abstract 166 B2.31

Is the phantom array an evidence for Discrete-EPI model?

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Introduction: There exists a controversy between two eye-position-information (EPI) models, Damped-EPI model and Discrete-EPI model, about the representation of the objects' positions. The phantom array, which is perceived when we make a saccade across the stimulus flickering at the same position, is considered as counterevidence against Damped-EPI model. The results of the previous studies, which used the relative position judgment, supported Discrete-EPI model (e.g., Jordan and Hershberger, 1994). Many studies, however, showed the validity of Damped-EPI model (e.g., Honda, 1990). Our purpose is to prove that the results in previous studies supporting Discrete-EPI model would reflect method-dependent. Method: A flickering LED for 31 ms was presented near the time of saccades. The onset timing of the flickering stimulus varied. Subjects were asked to localize both endpoints of the phantom array by adjusting localization LEDs to the position of both endpoints. Results: The localization error of the right endpoint of the phantom array was similar with that observed in the single flash stimulation. And the position of the left endpoint of it presented immediately after the saccade onset shifted to the left of the actual stimulus position, which was inconsistence with the perception that the position of the left endpoint was at the actual position. Discussion: We suggest that the phantom array could not be counterevidence against Damped-EPI model. Damped-EPI model is, however, not enough to explain previous studies (e.g., Ross, et al., 1997). The discrepancy between the localization of and the perception of the left endpoint of the phantom array implies the shift of the median plane of the head position with respect to the trunk, which advocates Damped-EPI model.

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Abstract 167 B2.32

Gaze Modulation Of Visual Aftereffects In Color And Depth

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Prior physiological studies indicate that gaze direction modulates the gain of neural responses to visual stimuli (Andersen and Mountcastle 1983). Although several relevant psychophysical reports are available (Kohler, 1964; Leppmann & Wieland, 1966), the gaze modulation of visual aftereffects are controversial (McCullough, 1965; Harrington, 1966) with few exceptions (Meyhew, 1973; Nishida et al., 2001). Here, we test gaze modulation using color and depth aftereffects. Using methods of constant stimuli to derive psychometric functions we measure the intensity of color and depth aftereffects primarily utilizing three paradigms: 1) Classical Retinotopy (Subjects maintain constant fixation throughout adaptation and testing. Adaptation stimuli are always presented on the fovea while test stimuli are presented at varying retinal positions), 2) Balanced Alternating Adaptation (Similar to Mayhew. At regular intervals during the adaptation period, subjects alternate fixation between two loci with opponent adaptation stimuli. For testing, refixation position varies and the test stimuli are presented at the fovea),and 3) Alternating Fixation Adaptation (Similar to 2, except only one of the alternating fixation loci includes an adaptation stimuli). In both color and depth aftereffects we find strong spatial tuning (1) centered at the location of adaptation with significant effect beyond the retinotopic adapted region. Alternating fixation (2,3) shows strong gaze dependent aftereffects for both color and depth. Alternating adaptation paradigms provide a qualitatively different means of testing the spatial tuning of aftereffects and may prove a more sensitive measure of gaze modulation. The results provide strong evidence for (a) gaze modulation of aftereffects, (b) generality of the modulation across two visual

attributes, and (c) perceptual correlates of the modulation of neural activity by gaze direction.

Abstract 168 B2.33

Pursuit eye-movements disambiguate depth order in an ambiguous motion display

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Motion gradients are important cues for depth perception but can be modified by eye-movements. For example, a translating corrugated surface can be specified by combining relative motion (shear) and translation, both of which are needed to determine depth order correctly. During pursuit, however, the eye movement cancels retinal translation so an extra-retinal estimate of translation is required to recover depth order accurately. We examined depth judgements in three conditions to investigate whether extra-retinal signals are used in this way. In condition 1, the eye was stationary and shear combined with retinal translation. In condition 2 the translation was removed. In condition 3, a fixation point moved at the same velocity as the retinal translation. Assuming accurate eye movements, conditions 2 and 3 are retinally equivalent. Stimuli were composed of sparse dot patterns shown on the black background of a screen viewed monocularly in the dark. The shear depicted one cycle of a sinusoidal depth corrugation. Four observers judged whether the top corrugation was concave or convex and whether the stimulus appeared flat or not. In conditions 1 and 3, %concave responses were sigmoidally related to shear. In condition 2, the sigmoidal relationship disappeared. In all three conditions, %flat responses peaked at 0 shear. Depth order was therefore perceived ambiguously in condition 2. In experiment 2, the three conditions were presented separately for 60s. Naive observers indicated if the stimulus appeared concave, convex or flat. Mean number of reversals was 12.55 in condition 2 but 0.28 and 0.16 in conditions 1 and 3, respectively. Moreover, the time spent reporting concavity and convexity was similar in condition 2 but highly-skewed in favour of the correct depth order in conditions 1 and 3. The experiments suggest that extra-retinal estimates of translation are needed to determine depth order correctly during an eye movement.

Abstract 169 B2.34

Peripheral, not fovea, vision detects displacement of a background across saccade

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Purpose: When we make saccadic eye movement toward a target object, which is displaced across saccade, it is easy to detect the displacement. But in the case of the background it is harder to detect its displacement. The visual system seems to consider that the large stimulus extending in the peripheral visual field is stable. In the present study we examined effects of peripheral vision on detecting displacement of a background across saccade.
Methods: We used a multi-colored Mondrian pattern as the background stimulus. The background covered the whole visual field of the subject. The subject made a 16 deg saccade toward the target located in the right side of the fixation point. During saccade the background of the target were shifted in 2 deg either leftward or rightward or not at all. The target and its gray surround of a certain diameter did not shift so that the subject had to utilize the peripheral visual field to detect displacement of the background. The subject responded whether he perceived any change of the stimulus.
Results: We found that the size of the target surround did not influence on performance of detecting displacement of the background. This indicates that the vicinity of the target is not important for detecting displacement of the background, and that the far peripheral visual field might have significant role.
Conclusions: It is likely that our visual system utilizes the peripheral visual field to detect displacement of the background, which means that the peripheral vision may judge the outside world stable.

Abstract 170 B2.35

Initial behavior of the optokinetic response elicited by transparent stimuli

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When two random dot patterns (RDPs) move at different velocities even on the same depth plane (transparent stimuli), observers perceive transparent surfaces sliding over each other on different depth planes. It has been reported that when steady-state optokinetic response (OKR) was elicited by long-lasting transparent stimuli, pursuit eye velocity was modulated by the attention based on the depth perception. To investigate the modulation process of the initial behavior of OKR, we have measured and analyzed horizontal and vertical eye movements elicited by the transparent stimuli.

Seven subjects participated in the experiment. Two RDPs, each subtending 15 deg in diameter, moved in orthogonal or opposite directions on the same plane. The moving speed was 10 deg/s. Subjects were instructed to attend to the near or far surface and report its motion direction.

The mean latency of the initiation of the OKR elicited by the two RDPs moving in orthogonal directions (100 ms) was significantly shorter than that in opposite directions (150 ms) ($p<0.0001$). In the case of orthogonal directions, the distribution of the pursuit direction during the period from 100 to 150 ms after the motion onset biased toward the mean direction of the two stimulus motions. There were two significant effects observed in the statistical analysis of pursuit velocity: the eyes followed the far surface rather than the near one ($p<0.01$) in the period between 170 and 345 ms, and the surface to which the subjects attended rather than unattended ($p<0.01$) after 200 ms. In the case of opposite directions, the OKR was initiated in the same direction of the far surface motion regardless subjects' attention. The significant attentional effect on the pursuit velocity was observed after 235 ms ($p<0.01$). These results suggest that the early phase of OKR is composed of two reflexive components, one reflecting the averaging among stimuli motions and the other reflecting the tendency following far surface.

Abstract 171 B2.36

The effects of eccentricity-dependent image filtering on saccade targeting in natural images

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We investigated the intersection of spatial vision and attentional selection during free viewing of complex natural scenes. Our method involved the use of a gaze-contingent multi-resolutional display (GCMRD) in which high image resolution is placed only at the center of gaze. Photographic GCMRD images were filtered as a function of their contrast, spatial frequency content, and retinal eccentricity, based on a model of visual sensitivity that had previously been tested using sinusoidal grating patches. This enabled us to understand how attentional selection, as measured by saccade targeting, is affected by the interplay between the physical characteristics of an image, its contrast and spatial frequencies, and the reduced resolution of the human visual system with increased eccentricity. Loschky & McConkie (2001) have shown that reducing image resolution in peripheral vision using a GCMRD can decrease the likelihood of sending the eyes there. However, the GCMRD had a discrete resolution drop-off (i.e., a resolution step function). Thus, our study asked 3 questions: (1) Was the observed saccade shortening with discrete resolution drop-off GCMRDs simply due to the eyes being drawn to the texture boundary between the high- and low-resolution areas? (2) If not, can both detection of peripheral filtering and its effects on saccade targeting be predicted by the contrast sensitivity function (CSF) at varying eccentricities? (3) If image filtering affects saccade targeting, what does it remove that is critical to the saccadic system? We used a GCMRD with a continuous resolution drop-off (i.e., smooth image degradation) and found that saccade lengths were still shortened. However, while detection of peripheral filtering was well predicted by eccentricity-dependent CSFs, effects on saccade targeting had a much higher threshold. Furthermore, saccade targeting was not affected until filtering had removed information close to the peak of the CSF at a given eccentricity.
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Abstract 172 B2.37

Speed-accuracy tradeoffs for pursuit and saccades in a luminance discrimination task

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Purpose In models of visual discrimination, sensory evidence accumulates over time, producing a tradeoff between speed and accuracy. To test whether pursuit and saccades obey the same speed-accuracy tradeoff, we measured the accuracy of pursuit and saccade choices over a large range of latencies. Methods Human observers (n=2) initially fixated a central fixation cross. After a random interval, noise strips (0.7 ver x 40 hor) moving horizontally (14 /s) were presented both above and below (± 2) fixation. To elicit a range of latencies, the offset of the fixation cross varied in time (+200, 0, -200 ms) relative to the onset of the noise strips. The luminances of the pixels in the two noise strips were drawn from two normal distributions with different means, but with the same standard deviation. The difference in means was adjusted to produce signal strengths of d' = 0.05 or 0.1. The observers were asked to make an eye movement to and follow the brighter of the two strips. Because the strips moved horizontally in opposed directions and were vertically offset, subjects made a combination of pursuit and saccades on each trial. For each of the two signal strengths, we constructed speed-accuracy curves for pursuit and saccades by plotting cumulative sensitivity as a function of time. Additionally, we measured the sensitivity of pursuit in a 1000-ms perisaccadic interval. Results The trajectories of the speed-accuracy curves for pursuit and saccades were similar – both increased from chance to asymptotic performance by 500 ms. Pursuit reached 95% of its final sensitivity at 44 and 98 ms before the saccade for our two subjects, respectively. Conclusions The similarity in the speed-accuracy tradeoffs for pursuit and saccades supports the idea that choices by both eye movement systems are based on a shared pool of sensory evidence. The perisaccadic enhancement of pursuit sensitivity indicates that this sensory evidence accrues on a similar time scale for both movements.

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Abstract 173 B2.38

Learning to look the other way

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Response latency generally increases as a function of the number of stimulus-response (S-R) alternatives, a relationship described by Hick's law. However, previously we have demonstrated that visually guided saccades (prosaccades) show no increase in latency as the number of S-R alternatives increases in logarithmic steps from 1-8. In contrast, we found that the latencies of saccades directed 180 from the target (antisaccades) rise in accordance with Hick's law. We wondered whether the ability to make responses equally fast regardless of the number of S-R alternatives is unique to prosaccades, or whether such performance can be achieved in other types of saccades through learning. In this experiment, we trained 4 naive observers to make antisaccades for a minimum of 8 sessions. We collected 48 trials for each of the four S-R uncertainty levels (target-set sizes of 1,2,4,8) in every session. In the control condition, we likewise measured response latencies for prosaccades and saccades directed 90 counterclockwise from the target at the start and end of the study. We calculated the slope of the response latencies across S-R uncertainty levels for each session. While the slopes for the control conditions remained constant for the pre- and post-test sessions, the antisaccade latency slopes decreased and approached zero over the course of training. We conclude that prosaccades are not the only type of saccades that be can made with no increase in latency irrespective of S-R uncertainty, as antisaccades can approach and possibly equal this level of performance with sufficient training. This finding suggests plasticity of the stimulus-response pathways involved in the response selection of antisaccades.

Abstract 174 B2.39

Perisaccadic compression of space orthogonal to saccade direction

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Objects flashed before or during a saccade are perceived as shifted towards the saccade target. A possible interpretation is that the target attracts the object. If that would be the case, one would also expect a vertical shift for horizontal saccades. Here we show that a shift in the object's perceived position orthogonal to saccade direction does occur, but only for stimulus positions beyond the target.

Three subjects made horizontal saccades towards a target (20 deg to the right) in front of a red screen. A green dot (1.2 deg) was presented for 12ms before, during or after the saccade. The dot's position was chosen randomly from a 5x5 grid (8x8 deg) centered around the target. After the saccade, the subject reported the object position by setting a mouse pointer. We found that shortly before and during a saccade dots presented left to the target were shifted in horizontal direction. Dots presented to the right of the target, however, were also shifted vertically towards the target position.

In a second experiment we used vertical saccades (20 deg downwards) to test whether transferring information from one hemisphere to the other during remapping or lateralization could account for different results of left and right hemifield. A component of mislocalization orthogonal to saccade direction (i.e. horizontal) occured below the target.

We conclude that the shift towards the target can also have a component orthogonal to saccade direction both for horizontal and vertical saccades. This effect is limited to objects presented in the space beyond the target. We propose that different kinds of visual processing occur for spatial areas before and beyond the target.

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Abstract 175 B2.40

Express saccades: the conditions under which they are realized and the brain structures involved

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Repeated eye movements made to visual targets can yield a bimodal distribution of saccadic latencies the first mode of which was termed express saccades by Fischer and Boch. We have carried out a series of experiments in monkeys to identify the conditions necessary for express saccade generation, the rules involved, and the brain structures responsible. Express saccades are produced to singly appearing targets but not when several stimuli appear at the same time. Learning plays a central role in express saccade generation. What is learned is the vector of the saccade to be produced, not the location of the target is space or the orbital position of the eye. The frequency with which express saccades are made depends on expectation; express saccades seldom arise when targets appear at unexpected locations. Increasing the gap time between fixation spot termination and target onset and decreasing the number of expected target locations increases the frequency of express saccade generation. Express saccades are made with high frequency to the second of two successive targets as long as the vector is one that has been learned. Pre-cuing can increase the frequency of express saccades only within a limited range. Free viewing of natural scenes commonly yields saccades in the express range but the distribution is not bimodal. Lesions of the frontal eye fields, of the medial eye fields, and of areas V4 and MT do not interfere with the generation of express saccades. Neither does the disruption of either the magnocellular or parvocellular systems. But superior colliculus lesions eliminate express saccades; no recovery is evident It appears therefore that the cortical areas involved in express saccade generation send their signals to the brainstem through the superior colliculus.

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Abstract 176 B2.41

Pre-saccade target color influences the perception of its post-saccade counterpart

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When a saccade is generated towards an object in space, the representation of this object’s spatial location in the brain is updated in anticipation of saccade end. We investigated whether a similar updating occurs for the object’s features as well. We designed a psychophysical task in which subjects looked at a central square that disappeared 200 msec after trial onset. After a gap of 200 msec, a peripheral square appeared 17 degrees to the right or left of fixation. Subjects were instructed to saccade to this square and report whether it had the same color as the central square or not. The peripheral square was extinguished 50-150 msec after saccade detection, which happened midway through saccades. A saccade-contingent change in the color of the peripheral square occurred in approximately 50% of the trials. In particular, we had four possible color variations, described by the acronyms: XXX, XYY, XYX, and XXY. In XYX trials, the central square had a color X (first letter in the acronym), the pre-saccade color of the peripheral square was Y (second letter), and the post-saccade color of the peripheral square was X (third letter). The remaining acronyms described square colors in a similar fashion. X was red, yellow, green, or blue, and for each X, the color Y was chosen such that subjects detected a color difference in approximately 70% of all XYY trials. We found that there were significantly more “SAME” responses in XXY trials than in XYY trials, and the effect was strongest approximately 50 msec after saccade end, after which it decayed. The effect was much weaker in XYX trials (subject performance was similar to that in XXX trials) perhaps because of priming of the color X as a result of task requirements. We hypothesize that saccade target properties are enhanced in anticipation of the retinal consequences of a saccadic eye movement and that this effect mirrors dynamic remapping of spatial location in areas such as the lateral intraparietal area (LIP).

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Abstract 177 B2.42

Mechanisms of smooth pursuit eye movements after pursuit initiation

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We investigated the influence of distractors on the control of smooth pursuit eye movements. In a series of experiments distractor velocity, direction of motion and distance to target were manipulated to bias active smooth pursuit. Our results suggest an important role of weighted vector averaging as shown for pursuit initiation (Lisberger & Ferrera, 1997), but with slight modifications. A distractor primarily affected those components of the smooth pursuit involved in tracking the target. This implies that smooth pursuit can be selectively disturbed, depending on the smooth pursuit and distractor motion being composed of either horizontal, vertical or both movements. One smooth pursuit velocity component (vertical or horizontal) is increasing, if the relative velocity component between target and distractor is larger than zero, smooth pursuit velocity component is decreasing if the relative velocity component is smaller than zero. If relative velocity component between target and distractor is zero, smooth pursuit will remain nearly unaffected in this component. The velocity alteration is approximately 10 per cent of target velocity. If a distractor is presented along target trajectories, the quantitative influence is larger than if the distractor is not on target trajectories. Our explanation is that after pursuit initiation visual attention becomes an important rule in controlling active smooth pursuit, so it is not only stimulus triggered. It might be possible that visual attention is averaged along the target trajectories rather than on an equable area around the target, so distractors along target trajectories are more salient than others.

Abstract 178 B2.43

Position-dependent gain adaptation of human horizontal saccades using the double step paradigm

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The visually guided (V-) and memory-guided (M-) saccades acquire different gains (primary saccade amplitude/target displacement) in the same horizontal direction simultaneously, after short-term adaptation using the intrasaccadic target step paradigm. Present study investigates whether the horizontal (vertical) saccade may reach different gains adaptively in the same horizontal (vertical) direction at different vertical (horizontal) directions.

Four subjects participated. In a dimly lit room, the subject traced a small light spot on a screen. We investigated the V-saccade and the M-saccade, separately. Target was displaced 4, 8, or 12 left or right to the fixation along the horizontal line. After 60 test trials, 60 adaptive trials were made along the horizontal line at the +5 level (up), where the target stepped forward during primary saccades to the adaptive direction by 30% of the initial step, thus inducing gain increasing adaptation. Then, 60 adaptive trials were made along the horizontal line at the -5 level (down), where the target stepped back by 50% of the initial step, thus inducing gain decreasing adaptation. These two procedures were repeated five times. Finally, 60 test trials were made at 5, 2.5, 0, -2.5, and -5 , respectively. The same experimental procedures were applied rotating the target displacement by 90 CCW from horizontal to vertical directions with the same target eccentricity.

The V-saccades showed little gain increasing at 5 but clear gain decreasing at -5 , while the M-saccades showed clear gain increasing at 5 and clear decreasing at -5 . Gains at the middle levels took middle values of the gains at 5 and -5 . Selective but mutually interfering adaptations of the horizontal (vertical) saccades in the same direction at different vertical (horizontal) levels were confirmed.

Generally, the gain adaptation in all directions may depend on the initial eye position.

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Abstract 179 B2.44

Visual responses of MT neurons during smooth pursuit eye movements

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MT cells respond to retinal image motion, whether the motion results from stimulus movement or eye movement (Bair and O'Keefe, Vis. Nsci. 1988; Ilg, EBR 1997). But experiments in area MT have identified extra-retinal signals related to eye position and eye velocity (Squatrito and Maoli, J. Neurosci 1997.; Bremmer, et al. J. Neurophys. 1997). These signals suggest that MT cells may modify their visual responses during eye movements. We have therefore studied the way that responses to visual motion in MT cells change during smooth pursuit eye movements.

We recorded responses from direction-selective MT neurons in two rhesus macaques. We measured speed tuning along the preferred-null axis for random texture stimuli presented during both fixation and pursuit. Receptive field stimulation was constant across eye movement conditions. We also assessed the extra-retinal inputs for different eye positions and smooth eye velocities in the absence of receptive field stimuli.

Most MT cells' visual responses did not change during pursuit. In a minority of cells, responses increased or decreased during pursuit, but selectivity for the speed of retinal motion did not change. A few cells also responded systematically to changes in eye velocity or position in the absence of a receptive field stimulus.

The visual response changes we observed in area MT during smooth pursuit were similar in kind, but smaller in both frequency and magnitude than those in neighboring area MST (Chukoskie and Movshon, VSS 2001). These results suggest that although most area MT cells encode retinal image motion veridically, other MT cells may contribute to motion processing in a observer-centered coordinate frame.

Abstract 180 B2.45

Latency of smooth pursuit under conditions of stimulus-response uncertainty

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Hick's law predicts that response latencies increase as a log2 function of the number of stimulus-response (S-R) alternatives. However, earlier findings by our group demonstrate that visually guided saccades (prosaccades) violate Hick's law. Prosaccadic
response latencies do not increase as the number of S-R alternatives rises logarithmically from 1 to 8. In the present study, we investigated the applicability of Hick's law to smooth pursuit eye movements (SPEM). Subjects were asked to pursue a moving dot
which moved from the center of the screen outwards 6 degrees. We varied S-R uncertainty by varying the number of possible movement trajectories the dot could move within a block of trials to either 1, 2, 4, or 8 possible directions. The level of S-R uncertainty was made salient before each trial by presenting 1, 2, 4 or 8 arrows indicating the potential movement trajectories for that particular trial. We found that the latency to initiate smooth pursuit does not depend on the number of S-R alternatives and thus violates Hick's law. Our finding suggests that probabilistic knowledge of target movement direction is not employed by the smooth pursuit system to reduce SPEM latency.

Abstract 181 B2.46

Velocity tuning of short-latency version and vergence eye movements in humans: dynamical limits set by retinal image speed

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Purpose: Short-latency version and vergence eye movements can be elicited by conjugate and disconjugate velocity steps, respectively, applied to large random-dot patterns. We investigated the velocity tuning of both types of eye movements to binocularly symmetric and asymmetric stimuli. Methods: Binocular eye movements were recorded in 3 subjects with the scleral search coil technique. Subjects faced a large tangent screen (80x50°) onto which two identical random-dot patterns (dot diameters, 2°; 50% coverage) were back-projected. Each pattern was restricted to one eye only using crossed-polarizers and its position was controlled by X/Y mirror galvanometers. Viewing was always binocular and horizontal velocity steps (range, 10 to 120°/s) were applied shortly (~50ms) after a centering saccade to one (asymmetric stimulus) or both (symmetric stimulus) patterns. When applied to both, the motion could be in the same (conjugate) or opposite (disconjugate) direction. Results: Conjugate and disconjugate ramps (symmetric and asymmetric) elicited vigorous version and vergence responses, respectively, at similar short latencies (~80ms). Velocity tuning curves (based on the changes in version and vergence over the time period, 80-160 ms) were all S-shaped and peaked when monocular (i.e., retinal) image speeds were ~40°/s, regardless of whether the stimuli were conjugate/disconjugate or symmetric/asymmetric. Plots of version (vergence) responses to symmetric stimuli against version (vergence) responses to asymmetric stimuli were linear ($r^2 \geq 0.9$) when expressed in terms of the monocular (i.e., retinal) image speeds but highly curved when expressed in terms of the binocular (i.e., average or difference) image speeds. Conclusions: Short-latency version and vergence eye movements share very similar dynamical tuning functions when expressed in terms of retinal image speed, consistent with the idea that the dynamical limits are imposed early in the monocular pathways.

Abstract 182 B2.47

Reversed phi motion elicits reversed ocular following at short-latency

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Purpose: Small step displacements of a large random-dot pattern produce vivid percepts of apparent (phi) motion. Reversing the luminance polarity during the steps results in apparent motion in the opposite direction: reversed phi. We recorded the short-latency ocular following responses to step displacements with and without luminance reversals in humans. Methods: Binocular eye movements were recorded with the scleral search coil technique from the 3 authors and 1 naive subject. Subjects faced a large tangent screen (80x50°) onto which random-dot patterns (dot diameters, 2°; 50% coverage) were back-projected. Mirror galvanometers in the light path were used to apply horizontal step displacements (range, 0.1-4.8°), during which the screen was blanked for □ 14ms, shortly (50ms) after a centering saccade (to take advantage of post-saccadic enhancement). On half of the trials, luminance polarity was reversed during the steps by introducing a second image, which was a photographic negative of the pattern, using a second projector. Results: Step displacements without a change in luminance elicited small (<2°/s) but consistent ocular following responses at ultra-short latency (~75ms) in the direction of the displacements. Tuning curves describing the relationship between the change in eye position (over the time window, 80-160ms) and the magnitude of the step resembled the derivative of a Gaussian and were well fit by Gabor functions, peaking with steps of ~0.4° and reaching asymptote at ~1.8°. Reversing the luminance during the steps elicited smaller (by ~50%) tracking responses (latency: ~75ms) in the direction opposite to the displacement steps; spatial parameters of the best-fit Gabor functions were little changed except that the cosine term was phase shifted by ~180°. Conclusions: Initial ocular following is mediated, at least in part, by first-order (luminance) motion-energy detectors.

Abstract 183 B2.48

Visual attention mechanisms are sensitive to manner of occlusion

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We investigated the differences in visual attention mechanisms involved in tracking a moving object when it becomes occluded behind a luminance-defined versus a virtual (illusory) occluder. Previous research suggests that the existence of a virtual occluder does not impair the tracking of moving objects (Scholl & Pylyshyn, 1999). We were interested in subjects' interaction with an object as it moves behind an occluder and then is unexpectedly stopped before re-emerging along its predictable trajectory. We recorded eye movements from adult subjects as they watched a ball move along a predictable trajectory and behind two distinct occluders. In one condition, the two occluders were illusory, whereas in the other they were blue rectangular boxes. In both conditions, subjects tracked the ball's motion which was interrupted at random intervals for two seconds behind one of the occluders. We found that subjects readily tracked the ball as it moved behind both the virtual and luminance-defined occluders. When the ball was stopped behind the luminance-defined occluder, subjects looked for an equal amount of time within the occluder (where the ball was located) and in the anticipation zone (where the ball would emerge). However, when the occluder was virtual, we found that subjects looked significantly longer in the anticipation zone than within the occluder. This finding suggests that manner of occlusion affects the tracking of a moving object and will be discussed in light of divided visual attention between the occluder and the moving object.

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Retina

Abstract 184 B2.49

Measuring and modeling filling-in effects in retinal AMD scotomas

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Retinal scotomas, caused by Age-Related Macular Degeneration (AMD), often damage the center of the visual field, the locus of high acuity, normally used for the detection and recognition of shapes. As a result of the scotomas, the input image is disrupted at the retina level, but the perceived image usually appears continuous, and at the same time distorted in certain ways. Perceptual filling-in phenomena were studied in the past in relation to the blind spot and to artificial scotomas, but not in relation to the large and central scotomas that characterize AMD patients.
In this study we modeled the perceptual effects associated with retinal AMD scotomas. First, we empirically presented to patients a variety of specially designed patterns at controlled locations, and the patients responses were collected and analyzed. Second, we implemented a mathematical model and computer simulation of the observed filling-in phenomena. The model was based in part on neurophysiological evidence regarding receptive field expansion at the level of V1 in and around the scotomas regions. Psychophysically, we found that 1-D patterns such as lines and gratings were completed across large scotomas (up to 7 deg). Gratings completion was better than that of single line and increased with frequency up to 6.28 c/deg. For 2-D patterns, we found completion of dot arrays that improved with density and regularity. Computationally, we found that simulating the filling-in effect by convoluting the image with an adaptive local filter, that simulates the effect of receptive field expansion, achieves good image restoration of highly damaged images, and can account for many of the observed phenomena. The results suggest that the filling-in occurs at several levels of the visual pathway, that together can compensate for large and dense scotomas, and obtain filling-in of both simple and complex patterns.

Abstract 185 B2.50

A combined signals and neurobiological model for predicting P and M ganglion cell responses

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A crucial step towards quantitatively understanding biological vision is to accurately characterize the input/output characteristics of retinal ganglion cells. Building on a modeling framework introduced by J.Victor, we have constructed spiking models of primate P and M ganglion cells. The driving inputs to our model cells are time-varying images. Spike trains are generated as follows: Weighted sums of image intensity values are formed by applying separate center and surround spatial weighting functions. These signals are passed through distinct adaptive temporal filters, and then summed. The combined signal is finally fed to a noisy integrate-and-fire spike generator. Most of the model parameters are estimated from published measurements; the rest are adjusted to bring the model behavior into agreement with a broad range of experimental observations.

Our model serves two purposes. First, it acts as a realistic "front end" for future studies of geniculate and cortical function. Second, it addresses a current controversy: Traditionally, ganglion cell responses are described as sequences of randomly occurring spikes, whose probability of occurrence (rate) varies smoothly with the stimulus. Several investigators have recently challenged this view, arguing that under "natural" conditions, ganglion cells use a sparse code, in which responses consist of long silences punctuated by brief, precisely-timed bursts of spikes.

However, natural images cannot be generically defined—they encompass a very broad range of statistical structures. Accordingly, we hypothesize that ganglion cells use a continuum of encoding strategies. To explore this idea, we have systematically studied the dependence of model spike train structure on the power spectra of artificially generated movies, and video of natural scenes. In agreement with this hypothesis, our model smoothly shifts between "sparse" and "continuous" firing modes, depending on the statistics of the input patterns.

Abstract 186 B2.51

How Do Optical Aberrations and Defocus Affect Retinal Images?

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Purpose: Retinal image blurring results primarily from defocus and ocular optical aberrations and is far more complex than Gaussian blur. We have measured the aberrations of 316 children and young adults in Boston and Beijing. The effects of aberrations on the retinal images of some of these children have been simulated (Thorn et al, 2000). We now extend this work by demonstrating how the effects of wavefront aberrations and different amounts of defocus combine to degrade the retinal image of different types of stimuli.
Methods: Wavefront aberrations were measured using a ray-tracing wavefront sensor. Aberration profiles were described by the first 7 orders of a Zernike polynomial function from which an MTF and point-spread function were calculated. This point-spread function was used to create retinal image simulations for the 40 children examined in Boston (ages 11 to 16 years).
Results: When eyes are in focus, the appearances of simulated retinal images vary from having a slight haziness to image smearing and multiple ghost images. Defocus degrades retinal image quality in the less aberrant eyes as a function of the amount of defocus with plus power inducing a different pattern of degradation than minus power. Highly aberrant eyes show less incremental degradation of the retinal image with defocus although the image's appearance may change markedly. These effects are more noticeable with text than with natural scenes.
Conclusions: Optical aberrations and defocus alter retinal images in complex ways and their effects vary markedly from person to person for different types of stimuli. When creating models of the neural mechanisms underlying vision, researchers must be aware that the stimulus patterns they present to subjects are not the same as those projected onto their retinas and differ from person to person. Thus their models should take the effects of realistic optical degradations into account.
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Abstract 187 B2.52

Improved temporal vision after a color deprivation paradigm: Correlates in retinal ganglion cells

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Can adult visual performance actually be improved by rearing in an altered visual environment? Recent demonstrations of plasticity in neural systems would suggest "yes", however years of monocular deprivation studies suggest "no". In those studies, despite a competitive advantage for the favored eye (resulting in widespread anatomical and physiological dominance in visual cortex), vision in that eye was not improved.

We have taken a different tact by looking at potential competition among neurons comprising different visual channels (e.g., color, motion, form) that co-exist in parallel from retina to cortex. How these pathways develop, and whether experience-dependent competitive interactions may play a role synapse formation (possibly as early as in the retina) have received little attention. This is due, at least in part, to the difficulty of stimulating or inactivating individual components of these parallel pathways.

Our animal model is the tree shrew, which possesses a 95% cone-dominated dichromatic retina. Red light rearing (RLR) deprives its SWS cones, but stimulates LWS cones normally. This in turn produces an imbalance in the activation of a now deprived "color" pathway compared to a normally stimulated "luminance" pathway (driven solely by LWS cones). We recorded retinal ganglion cell responses from optic tract fibers in normal and RLR adult shrews. (RLR shrews were reared from birth to 12- to 25-wks of age under Kodak 1A tungsten illumination, then housed in normal white light.) Receptive fields, the sustained/transient nature of the response, chromatic responsiveness and temporal modulation sensitivity functions (tMSFs) were determined. Our primary finding was that the tMSFs of RLR neurons peaked at higher temporal frequencies compared to normals (23Hz vs 12 Hz, t-test, $p<0.01$). This result held for sustained and for transient type neurons.

Our previous psychophysical testing of RLR shrews revealed enhanced high-frequency temporal vision, paired with poorer color vision. This combination cannot be attributed solely to a deprivation effect, but implies competitive interactions between neurons coding color and motion information during post-natal development. The observed shift in temporal tuning of retinal ganglion cells in RLR shrews argues for a retinal locus of this competition.

Abstract 188 B2.53

Serial stages of gain control

Walter Makous U of Rochester

Goal: to partition the gain changes in the visual system into two serial stages and to measure their relative contribution over a 10,000-fold change of illumination. Rationale and method. Superimposing on the retina two interference fringes of different spatial frequency or orientation (MacLeod, Williams, & Makous, VR, 1992) creates an illusory grating (a distortion product) at a nonlinear stage that probably lies in the outer retina (Chen, Makous, & Williams, VR, 1993). The amplitude of the signal representing a distortion grating is proportional to the product of the amplitudes of the signals representing the two fringes at the nonlinear stage: hence the distortion signal changes in proportion to the square of any gain changes preceding the nonlinearity, but that of a single fringe grating changes only in direct proportion to the gain changes; both kinds of signal change equally with any gain changes following the nonlinear stage. By comparing sensitivities to fringe and distortion gratings (in 3 observers) one can infer how much of the gain changes precede and follow the nonlinear stage. Results. (1) Weber's law holds within 1% for 500 msec fringe gratings presented against steady backgrounds, and also for 2 msec fringes flashed in the dark. (2) As Troland value increases from 10 to 1,000 Td, sensitivity to a distortion product decreases 3- to 5-fold relative to that of a fringe grating

of the same spatial frequency (10 cpd), but the relative sensitivity does not change outside that range. (3) The gain governing sensitivity to 2 msec fringes is completely determined by the energy in the test flash: steady backgrounds from 1 to 1,000 Td have no detectable effect on sensitivity to a 3,300 Td fringe. Conclusions: (1) as total sensitivity varies over a 10,000-fold range, the gain preceding the nonlinear stage is no more than 5-fold; and (2) a 2 msec flash completely predominates over weaker, steady fields in setting gain.
This research was supported by U. S. Public Health Service grants EY-4885 and EY-1319.

Spatial Vision

Abstract 189 B2.54

The study of contrast sensitivity and color vision of the Yellow colored (UVCY) Intraocular Len
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Objective To evaluate the contrast sensitivity and color vision of the yellow colored UVCY Intraocular Len (IOL). This new IOL can reduce the absorption of UV and short-wave length (400-500nm) visible light by adding UV blocking material and yellow coloring dye to ordinary PMMA. Methods ECCE and UVCY IOL implantation were performed for the senile cataract patients in 30 eyes, and the UV-IOL in 36 eyes. Visual acuity, contrast sensitivity measured by SINE WAVE CONTRAST TEST of Stereo Optical Co. and FM-100 color vision were examined at l week, 1 month, 3 months, 6 months after operation respectively. Results The contrast sensitivity and color vision of the patients normalized after they had been performed ECCE and IOL implantation. The yellow colored UVCY-IOL showed significant higher values than ordinary UV-IOL in the low and medial frequency in spatial contrast sensitivity and was above the normal people's level. The subjective sensation was better than UV-IOL in the early postoperative period. Conclusion the yellow colored UVCY-IOL is better than ordinary IOL in spatial contrast sensitivity. Its subjective sensation is also good in the early postoperative period.

Key words: Yellow color, UVCY, IOL, contrast sensitivity, color vision

Abstract 190 B2.55

On Collinear Flanker Facilitation of Contrast Detection
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Facilitation of contrast detection by collinear flankers (Polat & Sagi, 93) has been broadly researched and modeled. Here we report new experimental evidence that would provide further insights into this effect. The stimuli were either collinear Gabor target and flankers or in-phase D6 target and butterfly-shaped sinusoidal grating flankers. Both configurations produce significant facilitation at appropriate target-flanker separations in foveal vision. (1) When a random Gaussian noise was added to the target, facilitation diminished at a low noise level 2-3 times of the noise threshold. The threshold vs. noise functions under baseline and flanker conditions showed mainly a reduction of equivalent internal noise but no change of efficiency, suggesting some neural process, rather than uncertainty reduction, is responsible for collinear facilitation. (2) Collinear facilitation was evident at a stimulus duration as brief as 8 ms, a timing not possible for cortical feedback. (3) We examined the possibility that collinear facilitation is a pedestal effect as a result of receptive fields responding to both the target and flankers. By adding high contrast random noise between the target and flankers to disturb the responses of such receptive fields, we found no disruption of collinear facilitation. Collinear facilitation was still tuned to spatial frequency and thus was irrelevant to potential spatial cuing by the noise. These data question the pedestal-effect explanation of collinear facilitation and favor a longer-range spatial interaction theory. (4) Collinear flanker effects were reported previously to be suppressive in the periphery, which we believe was a result of inappropriate spatial scaling of the peripheral stimuli. On the basis of earlier peripheral scaling data (Yu & Essock, 96), we scaled the target-flanker separation and the length of the flankers separately. At 10 deg temporal periphery, collinear facilitation was evident at low flanker contrasts.

Abstract 191 B2.56

An ideal observer approach to simple visual reaction time
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The ideal observer approach has been used to reveal the causes of human limitations in detecting simple visual patterns at near threshold contrasts. In everyday situations, however, the patterns to be detected often have very high contrasts. We studied the sources of visual inefficiency in detecting high contrast Gabor patches in dynamic Gaussian noise by measuring simple reaction time (RT) and by comparing the results to predictions from an ideal observer model. The ideal observer in a simple RT task must form an estimate of the time of arrival of the signal and hit the button at that time. For an ideal observer, the variance of this time of arrival estimate increases linearly as the variance of the external Gaussian noise increases. The human observer's RT variance behaves in a similar way, but humans have low sampling efficiency and add internal noise.

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Abstract 192 B2.57

Self-cueing contributes to contour detection in noise
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We have shown previously that the ease of detectability of an extended trajectory in noise is because the first segment of the trajectory acts as an automatic cue, alerting the motion system

to subsequent segments of the trajectory. This study investigates whether such a self-cueing process also increases the detectability of static paths in noise. Current research suggests that the detectability of static contours in noise is due to long-range interactions among neurons with similar orientation preference, and to a contrast normalization process that preferentially pools collinear signals. In addition, the cue provided by collinear elements may be a strong component of contour detectability. If the contour cue acts in a similar manner as an explicit cue, it might increase the response gain of similarly oriented elements in the vicinity, and/or reduce the number of potential locations (uncertainty) that the observer monitors. To assess the strength of the contour cue, I measured sensitivity to contrast increments on a test patch placed at various offsets relative to the cueing contour. Noise density and the length of cueing contour were also manipulated. Signal detection theory analysis of the psychometric function provided estimates of the gain and uncertainty parameters associated with each condition. In the presence of noise, observers were best at detecting a contrast increment on a patch that was aligned with the cueing string, but the gain decreased with increasing offset from the aligned position. The estimate of uncertainty at a given noise level did not change with offset, but uncertainty decreased significantly when the length of the cueing string was increased. The high gain for collinear test patches and the ability of the contour to reduce uncertainty at high noise densities is indeed similar to the effect of an explicit cue (e.g., Lu & Dosher, 1998), suggesting that self-cueing contributes to the detectability of contours in noise.

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Abstract 193 B2.58

The spatial frequency characteristics of the Cafe wall illusion

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Purpose: Effects of spatial frequency contents on cafe wall illusion have not been studied extensively except for an isolated report on its disappearance at very high spatial frequencies (Morgan & Moulden, 1986). The main objective of this study is to examine effects of spatial frequency of the square wave part on appearance of the cafe wall illusion in a more systematic fashion. Methods: An 8 (H) x 8.5 (V) deg cafe wall figure with 8 horizontal rows of tiles was presented on a CRT screen. Spatial frequency for the square wave part was varied in 10 steps between 0.25 and 7 c/d. Subjects were asked two questions (1) whether the mortar appeared to be slanted as a whole, and (2) whether tiles appeared as independent trapezoid (see results). Results: At very low (< 0.33 c/d) as well as high (> 3.5 c/d) spatial frequencies, the illusion disappeared and the upper and lower edge of each row appeared parallel. At lower middle spatial frequencies (0.5 - 1.0 c/d), regular cafe wall illusion was observed. The mortars (or the top and bottom edges of the tile rows) were connected and slanted, thus each row appeared as an elongated trapezoid. An intriguing phenomenon was found at moderately high frequencies (1.4 - 2.3) c/d. Each tile appeared as an independent trapezoid instead of connected elongated trapezoid seen with regular cafe wall, thus the top and bottom edges of each row appeared in a saw-tooth shape. Conclusions: It has been argued that the illusion occurs from interactions between the orientations of tile edges and local components of the twisted cords that appear in the mortar part as a result of band-pass filtering within the visual system. The present results support the hypothesis and extend it by defining the limits of such orientation integrations. When the twisted cords' local orientation is excessively slanted, it is impossible to integrate the two orientations into one and each tile appears trapezoidal.

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Abstract 194 B2.59

Covert transient attention does not change the characteristics of a spatial frequency channel

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Directing transient covert attention to the target location enhances sensitivity across the contrast sensitivity function (Carrasco, Penpeci-Talgar & Eckstein, 2001). Using critical band masking to characterize letter identification, Solomon and Pelli (1994) reported that although observers have access to many different bands of spatial frequencies to perform the task, a single spatial frequency channel mediates letter identification. In the present study, we used critical band masking to investigate whether covert attention affects the spatial frequency tuning of the channel mediating letter identification. We manipulated attention using either a peripheral (cue at target location), a neutral-central (cue at fixation) or neutral-distributed (one cue at each of 8 possible locations) cue. All three cues indicated the time of target onset but only the peripheral cue was informative regarding target location. The target letter (N, Z, or X; presented for 40 ms in low or high-pass noise with different cutoff frequencies) followed the cue at one of the 8 locations. Distracter letters (V's) occupied the remaining locations. We measured the energy threshold elevation (using the modified Quest staircase procedure; Watson & Pelli, 1983) at each of the low and high-pass cutoff noise frequencies. To derive frequency-dependent power gain of the inferred filter, we took the derivative of the threshold energy with respect to the cutoff frequency. The peripheral cue doubled sensitivity, however, it did not change any of the characteristics of the channel mediating the task compared to the conditions where the two different neutral cues preceded the display. Having established that attention enhances contrast sensitivity the present results indicate that this enhancement is not a result of a change in the tuning of the spatial frequency channel mediating the task.

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Abstract 195 B2.60

Decruitment effects for magnitude estimates of pattern contrast

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Teghtsoonian et al (Perception and Psychophysics, 2000) report that magnitude estimates for loudness of a very weak tone are much lower when the tone is presented at the end of a slowly and continuously decreasing intensity sweep compared to a presentation at the beginning of a continuously increasing intensity sweep. This decruitment effect was also reported for visual perceived size of a very small disk. Neuhoff (Nature, 1998) proposed that decruitment of loudness and perceived size may promote attention to approaching rather than receding targets. The current experiment attempts to replicate decruitment effects for perceived contrast and examine possible adaptation mechanisms for the effects. Naïve subjects (n=18) used a 100-point scale in a magnitude estimation procedure. Targets were 1.0 and 4.0 cpd stationary squarewave gratings. In each trial, the grating's contrast was increased or decreased logarithmically over a 45 sec sweep, with start or end points of 0.2 and 0.006 contrast. Subjects provided magnitude estimates, cued by a tone, during a sweep for four contrasts (0.1, 0.07, 0.01, and 0.007). Half of the trials presented a single spatial frequency, and half presented a sudden shift in frequency (to 4cpd or 1 cpd) 2 sec before the 0.01 contrast probe. For trials with no frequency shift, evidence of decruitment was observed: magnitude estimates for the 0.01 contrast targets were roughly a factor of two lower ($p<0.05$) when presented in the decreasing compared to the increasing sweep conditions. Similar decruitment effects were observed in the frequency shift condition, suggesting little or no adaptation effects. A second experiment (with frequency shifts coincident with the 0.01 probe contrast) replicated the results of the first experiment, indicating that the absence of adaptation effects was not due to the 2 sec delay prior to probed contrast. The impact of response bias, sensory, and higher-level mechanisms in decruitment will be discussed.

Abstract 196 B2.61

Orientation tuning of vernier acuity in human infants and adults

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Purpose. Differential responses in cortical orientation channels provide critical information for adults' vernier hyperacuity. Developmental studies suggest that young infants can perform simple orientation discriminations but may not use orientation information efficiently in some tasks. Here we used a masking paradigm to ask the question, does orientation information matter in infants' vernier acuity? Methods. We used steady-state visual evoked potentials to measure vernier acuity in 35 4-6-month-old infants, and 4 adults, with no vision abnormalities. In the baseline condition, vernier offsets appeared and disappeared at a rate of 4 Hz in a 1 c/deg vertical square wave grating (40% luminance contrast). Trial length was 10 seconds, during which offset size decreased in log steps from 20 to 1 arc minutes (5-0.2 arc min for adults). The EEG was digitized and filtered to reveal the amplitude and phase of the 4 Hz evoked response; threshold was estimated from average data of 6-8 trials per condition by extrapolating the amplitude vs. offset function to zero microvolts. In the mask conditions, 1-dimensional luminance noise was effectively superimposed with the baseline vernier stimulus using video frame alternation. The 50% contrast mask contained multiple low spatial frequencies (2 +/- 1.5 c/deg). Mask orientation conditions ranged from –40 to +40 degrees from vertical. Each infant was tested on at least 6 different masks; adults were tested with all 17 masks. Results. In adults, all mask conditions elevated thresholds slightly; as with previous data, maximum masking occurred in the 10-20 degree orientation range. Some individual infants had elevated thresholds only in the 40 degree conditions, but mean thresholds showed little overall masking and no orientation-specific masking in infants. Conclusions. Infants do not use the same orientation information as adults do to detect vernier offsets. This may explain infants' poor vernier acuity relative to adults' acuity.
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Abstract 197 B2.62

Spike train analysis reveals cooperation between Area 17 neuron pairs that enhances fine discrimination of orientation

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We examined 22 pairs of neurons in Area 17 of cats that were paralyzed and anesthetized with Propofol and N2O. We studied changes in ensemble responses for small (<10deg, 0.1c/deg) and large (>10deg, 0.1c/deg) differences in orientation (OR) and spatial frequency (SF). Examination of temporal resolution and discharge history revealed advantages in discrimination from both dependent (connectivity) and independent (bursting) interspike interval properties. For 12 pairs with at least moderate connectivity and enough data (>200 stimulus repetitions), we found the average synergy (information greater than that summed from the individual neurons) was 50% for fine discrimination of OR and 20% for SF; and <10% for gross discrimination of both OR and SF. Dependency (Kullback-Leibler "distance" between the actual responses and two wholly independent responses) was measured between pairs of neurons while varying OR (10 pairs), SF (10 pairs) and contrast (9 pairs). In general, dependency was more selective to spatial parameters than was firing rate. Variation of dependence against SF corresponded to variation of burst rate, and was even narrower than burst rate tuning for OR (suggesting that burst length also influences dependency). Since there is no differential modulation of burst rate and average firing rate with contrast, dependency strength matched average firing rate. However, we found a gradual decline (adaptation) of dependency over time that is faster for lower contrasts which is likely a result of the decrease in isolated (non-burst) spikes. The results suggest that salient information is more strongly represented in bursts, but that isolated spikes also have a role in transferring this information between neurons. The dramatic influence of burst length modulation on both synaptic efficacy and dependency around the peak OR (where firing rate remains relatively constant) leads to significant cooperation that improves discrimination in this region.

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Abstract 198 B2.63

Orientation discrimination in foveal and extra-foveal vision: Measuring contrast sensitivity
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Purpose. Sensitivity to orientation differences is influenced by stimulus size, eccentricity of stimulus presentation and stimulus contrast. Mäkelä et al. (1993, Vision Research) studied the effects of size and eccentricity on orientation thresholds. They presented stimuli at a fixed high level of contrast and found that the threshold versus size functions obtained at each eccentricity could be collapsed onto a single function by dividing stimulus size at eccentricity E by F=1+E/E2, where E2 was about 1.95. Sally & Gurnsey (2001, ARVO) found that the recovered E2 was essentially unchanged when stimulus contrast was eliminated as a potential source of variability. Recently, Melmoth et al. (2000, IOVS) demonstrated that size and contrast make different contributions to form discrimination thresholds as a function of eccentricity, and proposed a method to recover these two eccentricity-dependent limitations. The purpose of the present study is to compare previous estimates of E2 for orientation discrimination with estimates obtained using the Melmoth et al. technique.
Method. Stimuli were vertical and tilted (1.5) lines displayed on a high-resolution monitor. Contrast sensitivities were measured for identification of the tilted target as a function of size (0.75 -24) across eccentricities (E = 0 , 2.5 , 5 and 10).
Results. As stimulus size was increased, contrast sensitivities reached the same asymptotic level at each eccentricity. Scaling stimulus size with an E2 of 3.49 provided the best fit to the data.
Conclusions. In this experiment only size limited performance and there was no need to "double-scale" the data. It is possible, however, that contrast scaling may be required for a more challenging orientation discrimination task (e.g., a smaller orientation difference).

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Abstract 199 B2.64

Contrast dependency of orientation filling-in
Yutaka Sakaguchi U. of Electro-Communications, Japan

[Purpose and Background] The author examined the time required for perceptual filling-in when the target and surround were differently-oriented gratings. The previous study (Vision Research, 41, 2065-77) revealed that the time significantly varied dependent on the relation between their orientations. The present study asked how the relation between their contrasts affected the time for filling-in. [Method] Participants observed a color monitor binocularly from 50 cm distance with their head fixed by a chin rest. They should fixate at the center cross throughout a trial. A Gabor patch (diameter: 1.4 deg, eccentricity: 7 deg) was presented on a circular surround region (diameter: 12 deg) filled with a sinusoidal grating. Their spatial frequency and average luminance were 2.5 cpd and 30 cd/m2, respectively, and their orientations were fixed. Participants were told to respond immediately after the target (i.e., Gabor patch) disappeared. In Exp. 1, the target contrast was altered from 0 to 100% with the surround contrast fixed to 10, 25 or 50%, while in Exp. 2, the surround contrast was manipulated with the target contrast fixed. [Result] In Exp. 1, reaction time (RT) was significantly prolonged as the target contrast became higher, while its magnitude was diminished with a higher contrast of surround. In more detail, RT remained almost constant when the target contrast was lower than the surround contrast, but increased for higher target contrasts. In Exp. 2, the surround contrast showed a similar but much weaker effect. It should be noted that higher surround contrasts did not facilitate the filling-in. [Conclusion] The time for orientation filling-in depended on the target and surround contrasts. Target/surround contrast ratio seems a key to explain this dependency, but it alone cannot explain the whole phenomenon. Some non-linear interaction is required to understand its underlying mechanism.

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Abstract 200 B2.65

Contrast, assimilation, and neural edge integration.
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A dark disk surrounded by a bright annulus appears darker as the annulus luminance is increased. Mechanistically, this darkness induction could result either from a direct neural computation of the disk/annulus ratio (for example, by a neural mechanism with center-surround antagonism), or from independent induction effects that originate from the inner and outer borders of the annulus. A recent neural filling-in model of darkness induction (Rudd, 2001; Rudd & Arrington, 2001) postulates that darkness inducing signals originating from separate borders combine linearly to influence disk brightness. We extended this model to include both brightness and darkness induction effects. According to the extended model, the inner edge of the surround annulus induces darkness in the disk (contrast) and the outer edge induces brightness in the disk (assimilation). The magnitude of each induction effect is proportional to the log luminance ratio of the border that generates the effect. We tested this theory and found that disk brightness is determined by a linear sum of independent inductions exerted by the inner and outer annulus edges, as predicted. Two disks were presented side-by-side on a flat-panel monitor. Each was surrounded by a higher intensity annulus. The luminance of the right annulus was varied to modulate the brightness of the right disk. The luminance of the left annulus was fixed. The subject adjusted the intensity of the left disk to achieve a brightness match to the right disk. For each of three observers, the response setting of the left disk varied inversely as a power of the right annulus luminance (power law exponents in the range .54 - .83). These results represent a substantial failure of both Wallach's ratio rule (Wallach, 1948) and any theory of darkness induction based

strictly on local disk border contrast. But the filling-in model gives an exact quantitative account of the data and successfully predicts the log-log slopes (i.e., power law exponents) of the brightness matching curves from a knowledge of the intercepts. The assimilation produced by the outer edge is weakened when the edge is moved farther away from the disk, also consistent with the model. When assimilation is thus weakened, local border contrast dominates and brightness matches follow the ratio rule more closely.

Abstract 201 B2.66

Scaling of both gratings size and contrast is necessary for equalising detection across eccentricities
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We have recently shown that contrast sensitivity for face (IOVS 41, 2000, 2811-19), letter (IOVS 41, 2000, S437) and word (IOVS 42, 2001, S160) recognition can be equalised across eccentricities by scaling face/letter size and contrast according to local spatial and contrast scales of the underlying visual mechanisms. However, sole spatial scaling has been reported to be sufficient to equalise simple grating detection across eccentricities (JOSA A 4, 1987, 1579-82 & 1583-93). Scrutiny of these detection results suggested that scaling of contrast might improve superposition of data curves from various eccentricities. To test this 'double scaling' hypothesis we measured contrast sensitivities in a 2AFC task corresponding to 84% correct correct grating detection as a function of grating size magnification (1.25-20.0 deg) at four eccentricities (0, 2.5, 5, and 10 deg). Extrafoveal detection performance was found to the same as that of the fovea when extrafoveal gratings were magnified and had higher contrast. Sensitivity curves had the same shape at all eccentricities but the curves were shifted along logarithmic size (magnification) and contrast axes, which allowed complete superposition by double scaling. Thus, even contrast sensitivity for simple grating detection can be properly equalised across eccentricities only by scaling both grating size and contrast according to local spatial and contrast scales of the underlying visual mechanisms.

Abstract 202 B2.67

The Poggendorff illusion explained by the statistics of natural scene geometry
Dale Purves & Zhiyong Yang Duke University

One of the most intriguing discrepancies between the perception of a visual stimulus and its real-world source is the Poggendorff illusion. When an obliquely oriented line is occluded by a bar, the continuation of the line across the occluder appears to be shifted vertically, despite of the collinearity of the separated line segments. A great deal of literature on this subject notwithstanding, none of the explanations so far provided (the angle theory and the depth theory are the two major categories) has satisfactorily accounted for all aspects of this effect. Here we have tested a wholly empirical explanation of this illusion. To this end, we acquired a database of natural scenes (including indoor, outdoor and natural scenes) in which the distances of all the objects from the image plane were determined with a laser range scanner. We found the probability distribution of the possible positions of the line segments in the database lying on the 'far side' of an imagined occluder to be shifted vertically compared to the positions obtained by direct extension of the same line segments. This shift was apparent in indoor, outdoor and fully natural scenes, albeit with different magnitudes and variances. Moreover, the magnitude of the shift 1) increased with the width of the occluding bar; 2) increased with a decrease in the (acute) angle of the intersection of the line with the occluder; 3) diminished for the acute angle components of the stimulus, but was maintained for the obtuse angle components; and 4) diminished when the stimulus configuration was rotated. Each of these behaviors has been described in the perceptual responses to corresponding variations in the presentation of the Poggendorff stimulus. We conclude that this otherwise peculiar set of perceptual discrepancies is generated by the probabilistic relationship between the relevant features in the image plane and the probability distribution of the possible underlying sources of the stimulus in the real world.
This work was supported by NIH grant # NS 28610.

Abstract 203 B2.68

Flexible scale use is retinotopically specific
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Humans are able to process spatial scale flexibly depending on task demands and prior knowledge (e.g. Schyns & Oliva (1999) Cognition, 69, 243-265). Could such ability be due to attentional modulation of early visual processing mechanisms such as spatial frequency (SF) channels (Sowden, Özgen & Schyns (2001) Perception, 30, s91)? Consistent with this, a series of experiments in our lab suggested that sensitization to spatial scale is retinal location specific. In a 'sensitization' stage observers were initially shown low or high-passed scenes, combined with noise at complementary SF's (e.g. Low SF (LSF) scene + High SF (HSF) noise), and asked to categorize them (beaches vs. cities, or highways vs. cities). During this stage, one type of sensitization image was consistently presented to each visual field (e.g. LSF scene + HSF noise on the left and HSF scene + LSF noise on the right; or v.v.). In a subsequent test stage, 'hybrid' images were interleaved among the sensitization stimuli. Hybrids combine a low-passed scene from one category with a high-passed scene from the alternative category. Observers showed a bias to report the category of the hybrid component that corresponded to the SF's that they were sensitized to in a particular retinal location. None of our observers reported seeing both components of a hybrid. Such retinotopic differentiation of scale use is consistent with observers having conscious access to spatial frequency channels. We show that our findings can emerge despite an overall low or high bias, and that this varies systematically as a function of the selected HSF and LSF filter cutoffvalues.
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Abstract 204 B2.69

Models of lateral interactions: A failure to generalize
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Several models of contextual effects on apparent contrast (contrast-contrast) have been proposed over the last 15 years, ranging from lightness induction explanations to detailed quantitative models of pooled contrast gain control processes. We tested the generality of several models on data collected in apparent contrast, contrast discrimination, orientation discrimination, and spatial frequency discrimination experiments. Apparent contrast data were gathered in a staircase matching procedure for a center patch of sinusoidal grating viewed alone or in the presence of surrounds that varied in contrast or phase. PSE values were determined for each condition, from which attenuation effects on the apparent contrast of the center patch could be determined. Discrimination data were gathered under similar stimulus conditions in two-alternative signal-detection rating tasks, from which d' values were calculated for the different surround conditions and judgment tasks. Model predictions for the discrimination tasks were generated by adapting models to predict relative d' values by the addition of some assumptions. The results suggest that a) no one model fits all of the data, even qualitatively, and 2) models relying on concepts such as lightness induction or single pooled gain control processes are too simple.

Abstract 205 B2.70

The vanishing disk; a revealing quirk of the scintillating grid illusion
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Take a Hermann grid of gray alleys on a black background and place white disks at the intersections; observers report a striking illusion of transient black spots on the disks (scintillation). There is controversy over whether scintillation is an effect of lateral inhibition or of the cortical processing of repeating patterns. To assess the importance of a repeating pattern, we tested a Hermann grid with a single white disk at one intersection. To our surprise, the disk completely disappeared when distant intersections were fixated. We examined the elements of the grid necessary for this effect to occur and compared them to those that produce scintillation.

Subjects fixated on a computer screen; stimulus patterns were then presented randomly above or below fixation. Stimuli, present for 300 ms to preclude changes of fixation, consisted of either a 4´2 or a 2´2 modified scintillating grid pattern that could include a single disk at one intersection. Disks of various luminances were presented with delays of various duration between the onsets of the grid and the disk.

Disks significantly darker than the grid alleys were detected with near perfect accuracy. As disk color approached alley color, detectability was reduced for disks relatively distant from fixation, while disks nearer fixation showed scintillation. Increasing the delay improved detection of light disks that otherwise would not be detectable, but did not preclude scintillation. The blanking effect apparently decays rapidly after presentation of the grid. The lack of effect upon dark disks demonstrates that this is not a result of inattention or limited visual capability. Both scintillation and complete cancellation of a light disk at an intersection are possible with minimal repetition of a pattern. In contrast, scintillation does not require simultaneous presentation of the grid and disk, implying a somewhat different mechanism.

Abstract 206 B2.71

Effects of contrast on spatial binding and resolution
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The recent finding that a neuron's area of spatial summation can vary depending on stimulus contrast has been interpreted as a trade-off between sensitivity (important in low contrast conditions) and resolution (important in high contrast conditions). In these experiments we examined spatial resolution psychophysically by measuring subjects' ability to discriminate fine orientation differences underlying grouping tasks as a function of contrast. This was done using contour stimuli embedded in distracters (i.e. Field, Hayes and Hess 1993; Kovacs and Julesz 1993). In our task, subjects had to discriminate between a "pure" contour and a "noisy" one that had orientation noise added to the elements. Thresholds were taken as the amount of noise required for subjects to perform the discrimination task at 80% correct levels. We find that when the stimuli were equated for detectability, the low contrast stimuli required the addition of substantially more orientation noise than the high contrast ones in order to be discriminated from a pure (noise free) stimulus. This suggests that judgments on fine orientation structure are less precise at low contrast than at high contrast. This may be due to the internal representation of the stimuli at low contrast being noisier than at high contrast, or because selectivity of the mechanism is reduced at low contrast. These psychophysical results support the physiological findings in suggesting a major re-organization of spatial vision at low contrast.

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Abstract 207 B2.72

Effects of frequency content on the detection of anti-symmetry.
Sandra Mancini, Rick Gurnsey & Sharon Sally Concordia University, Canada

PURPOSE. Mancini et al. (2001, ARVO) measured the detectability of symmetrical patterns defined by checks that were of the same polarity (SP) or opposite polarity (OP) across a vertical axis of symmetry. Stimuli comprised black and white checks having widths of 0.037 to 0.297 degrees visual angle windowed within a circular aperture 9.5 degrees in diameter. The proportion (p) of SP checks matched across a vertical axis of symmetry ranged from 0 to 1. Patches with $p = 1$ are perfectly symmetrical (i.e., SP), those with $p = 0$ are anti-symmetrical (i.e., OP) and those with $p = 0.5$ are random. Results showed that SP and OP stimuli elicited similar thresholds for large checks. However, OP thresholds increased

dramatically as check size was reduced, whereas SP thresholds did not. In fact, for the smallest check sizes, performance on the OP stimuli did not exceed chance even when p = 0. This suggests that the mechanism responsible for encoding OP stimuli works only on low frequency components of the display. We therefore asked if OP stimuli composed of large checks could be rendered undetectable if low frequencies are removed from the display.

METHOD. Stimuli were constructed from black and white checks having widths of 0.297 degrees visual angle. The proportion of matching elements was varied as before to determine threshold. Stimuli were filtered with a high pass Butterworth filter having frequency cutoffs of 0 to 24 cycles/patch. An adaptive procedure was used to find threshold deviations (82% correct in a 2IFC) above and below p = 0.5.

RESULTS. Thresholds were higher for the OP stimuli than SP stimuli for all cutoff frequencies. There was a general trend for thresholds to increase modestly as low frequencies were removed from both SP and OP stimuli. However, high pass filtering did not render the OP stimuli impossible to detect.

CONCLUSION. The hypothesis that only low frequency channels contribute to the detection of OP stimuli must be rejected.

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Abstract 208 B2.73

A de-noising model of contrast adaptation to explain contrast perception

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Background: A computational model that is capable of explaining the effects of contrast adaptation when testing at threshold contrast and at supra-threshold contrast levels is proposed. The model assumes that theeffects of adaptation may be both orientation specific and isotropic. Methods: The model codes for image contrast by the output of spatiotemporal frequency tuned channels whose individual responses are normalized by a summation of individual channel responses present in a neuronal pool (Heeger, Vis. Neurosci., 1992). Each spatiotemporal channel is assumed to have an additive and multiplicative noise component: the multiplicative component arising from an uncertainty in the individual channel weights. With this noise model, the orientation specific component of adaptation is explained by a subtractive de-noising strategy that leads to the familiar rightward shift of the linear filter's contrast response function. The isotropic component of adaptation is represented in the model by a narrowing of the spatial bandwidth and a broadening of the temporal bandwidth of the individual channel weights. Results: The model can explain: (i) why the orientation specific elevation in threshold contrast as a function of adaptor contrast can saturate when the adaptor approaches 10% contrast (Snowden, JOSA, 1994); and (ii) why the isotropic components of adaptation may be described by the two components of signal amplification and division (Ross and Speed, Vis. Res. 1996). Conclusion: The proposed model suggests that the process of contrast adaptation may be viewed as an optimal de-noising strategy. The low level of adaptor contrast at which the elevations in threshold contrast can saturate appears to be inconsistent with the view that the orientation specific effect of adaptation represents a strategy used by the visual system to combat the problem of neural saturation in neuronal response firing rates.

Abstract 209 B2.74

Alcohol reduces simultaneous contrast effects in human vision

Kevin Johnston, Brian Timney, Denise Leung, & Sarah Khan U. of Western Ontario, Canada

Some physiological data suggest that ethanol can reduce inhibitory interactions in the retina (e.g. Backström, 1973; MacNichol & Benolken, 1956). If that is the case, then visual phenomena that rely on lateral inhibition may also be reduced. In a previous study (Johnston et al., 2000) we showed that the apparent contrast of the illusory blobs in the Hermann Grid diminished following alcohol ingestion. In the present study we measured changes in brightness of a target patch using a simultaneous contrast paradigm.

All stimulus generation and data collection were under computer control using a VSG2/3F graphics board. A circular .5 standard patch was superimposed on a circular 2 inducing field. Both were centred 1.5 to the left of a small fixation point. A second .5 comparison patch was located 1.5 to the right of fixation. All stimuli were superimposed on a dark background. Using a double staircase procedure, with a 1s presentation time, subjects adjusted the luminance of the comparison patch to match the brightness of the standard in the presence of the inducer field. Several combinations of inducing and standard luminances were tested.

Participants consumed sufficient ethanol in fruit juice to raise their BACs to 80 mg dl-1. In a second, counterbalanced, session, they received a placebo drink. They were tested when their BACs had reached .06 mg dl-1.

As expected, when the luminance of the inducing field was increased, the perceived luminance of the standard decreased. This simultaneous contrast effect was most pronounced for the lower luminances of the standard, irrespective of consumption condition. Following alcohol ingestion, the brightness reductions were similar when the differences between the inducer and standard were small, but there was a progressively smaller reduction in brightness at the higher inducer luminances.

These data are consistent with an alcohol-induced suppression of inhibitory interactions.

Supported by the Alcoholic Beverage Medical Research Foundation

Abstract 210 B2.75

Hue-selective elevation in luminance contrast detection threshold following adaptation to luminance-varying gabor patches

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Purpose. We have demonstrated hue-selective mechanisms for encoding luminance information at suprathreshold contrast levels (Hardy & De Valois, ARVO 1998). The purpose of these experiments is to investigate the hue-selectivity of luminance encoding at the contrast detection threshold. Methods. Subjects adapted to stimuli of different colors alternating at 1Hz. In one frame of the adapting stimulus, gabor patches were presented to the left and right of fixation (s = .87deg; center-to-center separation = 5.2deg). The phases of the gabor patches were shifted psuedo-randomly at 6Hz. In the other frame of the adapting stimulus, a blank field of the complementary color was presented. Initial adaptation lasted 150sec and top-up adaptation between test trials lasted 6sec. A spatial 2AFC procedure was used. Contrast thresholds were determined using the method of constant stimuli. Post-pattern-adaptation thresholds were compared to thresholds when subjects were adapted to blank, colored fields. Two spatial frequencies of adapt and test patterns were used (2 and 8c/deg). Four colors were used in this set of experiments. These colors correspond to the maximum excursions possible on our monitor in the 0 -180 (L-M axis) and the 90 -270 (tritan axis) directions of MBDKL color space. Mean luminance was set to 20cd/m2 and the white point was set to illuminant C. Results. While significant inter-subject variability was found in post-adaptation threshold elevation, the general pattern of results seems to indicate some hue selectivity of threshold elevation. No significant difference was found between tritan axis and L-M axis color pairs or between 2 and 8c/deg patterns. Conclusions. Hue-selective luminance-encoding mechanisms seem to be operating at luminance contrast threshold. These mechanisms seem to operate equally for colors along both chromatic axes and at both low and high spatial frequencies. Supported by NIH EY00014, NSF IBN-01111059 and an NTT grant.

Abstract 211 B2.76

Equating the "visibility" of luminance- and contrast-modulations

Rick Gurnsey, Sharon L. Sally, & Jeffrey A. Ball Concordia University Canada, Concordia University CANADA, Concordia University Canada

Purpose. Form discrimination thresholds are known to change with stimulus contrast. Therefore, care must be taken when comparing discrimination thresholds for the same property (e.g., orientation) conveyed via different media (e.g., luminance, chromatic or contrast modulations). In recognition of this issue, it is common practice to set stimuli to equal multiples of their respective detection thresholds when the discrimination task is performed. Our purpose is to demonstrate that the multiple of threshold technique embodies a flawed theory of perceptual scaling. We compared orientation discrimination for gratings defined by luminance and contrast modulations.

Method. (i) Detection thresholds were established for luminance and contrast modulations (referred to generally as contrasts). (ii) Contrast discrimination thresholds (JNDs) were determined for the first JND above detection threshold and many suprathreshold contrasts. (iii) A function was fit to the detection threshold and increment threshold data, in order to specify one JND above any given contrast. (iv) Orientation discrimination thresholds were determined for the first 10 JNDs above detection threshold for both luminance and contrast modulations. (v) Results were obtained for two experienced psychophysical observers.

Results. Luminance and contrast modulations that were equal numbers JNDs above their respective detection thresholds were not generally at equal multiples of detection threshold, indicating that the multiple of threshold technique embodies a flawed theory of perceptual scaling. Orientations discrimination thresholds decreased as stimulus contrast increased but the conclusions drawn about the differences between luminance and contrast modulations depended on the scale used (i.e., JNDs vs multiples of threshold).

Conclusions. Setting stimuli to equal multiples of detection threshold does not ensure that they have the same "visibility", "salience", "perceptual impact", or perceptual contrast.

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Abstract 212 B2.77

Isolating the causes of internal noise

Carl M. Gaspar, Patrick J. Bennett, & Allison B. Sekuler McMaster U., McMaster U., McMaster U.

To understand the limits of visual performance, it is critical to determine the causes underlying response variability. One possibility is that response variability is caused by strategies that are based on one's response history, as opposed to the specific stimulus at hand (Green, 1964). We tested this idea using a variation of the double-pass method described by Burgess & Colborne (1988). In the double-pass method, observers are presented with identical stimulus-plus-noise patterns at different times. The relationship between response agreement and response accuracy is an index an observer's internal-to-external noise ratio (I:E).
We measured performance at 5 contrast levels in a 2AFC orientation discrimination task in which observers judged whether a sine wave grating was oriented 1 deg to the left or right of vertical. Gratings were embedded in white Gaussian noise, and identical stimuli were separated by a trial lag of either 1, 2, 4, 8 or 16 trials. We reasoned that if response history strongly influences internal noise, then I:E should vary across different trial lags -- an observer's response on any given trial would likely be influenced by particular trials in the past. Initially, we found differences in I:E across different trial lags. However, these differences diminished by the third session. Our results suggest that, with practice, response history plays only a minor role in producing response variability. We are currently examining the effects of spatial frequency on I:E to determine the locus of contrast-variant noise, as well as the effects of luminance on I:E to determine the influence of photon noise on contrast-invariant noise.

Abstract 213 B2.78

Developing a new quantitative account of backward masking
Gregory Francis Purdue University, USA

Backward masking refers to impaired performance on some judgment of a brief target stimulus when it is followed by a mask stimulus. The effect of the mask often varies with the interstimulus interval (ISI) between the target and the mask, so that a plot of the target percept strength against ISI produces a u-shape. A new general explanation for u-shaped backward masking is analyzed and found to predict shifts in the ISI value that produces strongest masking (the bottom of the u-shape). As mask intensity or duration increases, masking generally becomes stronger and the ISI for maximal masking shifts to smaller values. As target intensity or duration increases, masking generally becomes weaker and the ISI for maximal masking shifts to larger values. Within the model, a calculation of the target's percept strength must be mapped to behavioral responses. Changes in this mapping can modify the overall strength of masking, but do not modify the ISI value that leads to maximal masking. Six sets of masking data that show variation in overall strength of masking are then interpreted by the general explanation according to how the ISI value for maximal masking changes. The data sets explore effects of: practice, eccentricity, light adaptation, flicker adaptation, attention, and a word superiority effect. The resulting interpretations promote the development of a new theory of backward masking that uses the properties of the general explanation. The new theory suggests interpretations of the data that are sometimes novel, often more precise, and sometimes contrary to interpretations that are prevalent in the literature.

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Abstract 214 B2.79

Effects of suprathreshold contrast modulation on crowding
Fatima Felisberti & Michael J. Morgan Dept Optometry & Visual Sciences, City Univ.

'Orientation thresholds of cued targets increase with set size, but only when target and distractors are in close proximity (Morgan et al., 1998; Felisberti & Morgan, 2001). Such impairment is generally called 'crowding' and cannot be explained solely on the basis of spatial uncertainty or lateral masking. Since orientation averaging in a central feature integrator seems to occur during crowding (Parkes et al., 2001), how will the weighting of afferent stimuli be affected by their contrast?

Stimuli were Gabor patches (3.6 c/deg) at 4 deg eccentricity. Observers had to judge whether a patch flanked by 2-4 neutral distractors was tilted clockwise or anticlockwise. The relative contrast of target and distractors was varied as well as the target position, which was either random or fixed to the centre of the array.

Lower orientation thresholds were observed when the contrast of the distractors was lower than the target contrast, and higher thresholds when the contrast of the distractors was higher than the target contrast, independently of whether target position was known or not.

Our results so far indicate that crowding does not depend on grouping-by-contrast, in agreement with Chung et al. (2001) and point to a second-stage averaging process where contrast information from target and distract0rs is weighted by contrast.

Acknowledgement: EPSRC

Abstract 215 B2.80

Distinguishing paintings from photographs
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We present a computational method for automatically distinguishing photographs from paintings. Our approach is based on two types of features: image color and image shape characteristics.

The use of color in this classification task is based on the observation that while intensity edges tend to coincide with color edges in photographs, there are significantly more color edges than intensity edges in paintings.

The second difference between photographs and pictures is at the level of image shape detail, as reflected in the intensity edge structure and texture properties. Intuitively, the bio-mechanical characteristics of the fine hand movements involved in producing the small-scale shape details result in paintings having quite different statistical characteristics than photographs of natural scenes. These characteristics were quantified using a wavelet transforms, and the classification proper was obtained by training a neural network.

The results indicate that whereas each criterion in isolation is a rather weak classifier (65-70% correct) , a conjunction of several weak criteria yields good classification performance.

Abstract 216 B2.81

Colour-luminance interactions in human orientation perception
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A long-standing, though controversial, hypothesis is that colour and form information are segregated early in visual processing. Many colour-preferring cells in primate V1 are insensitive to orientation (Lennie et al., 1990), and there can be a loss of tilt induction at isoluminance (Livingstone and Hubel, 1984).

However, others have found maximum tilt aftereffects for gratings modulated in colour along the principal axes of colour space (Flanagan et al., 1990) and a recent report showed that many orientation-selective cells in primate V1 are responsive to both colour and luminance modulation (Johnson et al., 2001). This prompted us to re-examine interactions between colour and luminance in human orientation perception using the tilt illusion.

We measured the effect of a surround grating oriented at 15º to the vertical upon the perceived orientation of a central test grating. We varied the axis of colour space along which the two (1cyc/º) gratings were modulated; subjects were tested on the three cardinal axes and six non-cardinal axes. At low contrasts (5-20 x detection threshold) we found that some subjects experienced large tilt illusions for subjectively isoluminant stimuli while others experienced none. At higher contrasts (30-40 x detection threshold) all subjects showed tilt illusions of approximately equal magnitudes when test and surround were modulated along a single chromatic axis, regardless of that axis. When the modulation axis of the surround was varied but that of the test was fixed (with contrast equated at 30x or 40x detection threshold), significant tilt illusions were also consistently observed, though the maximum tilt illusion always occurred when test and surround were modulated along the same axis.

These results demonstrate the existence of orientation-selective mechanisms in the human visual system tuned to non-cardinal directions of colour space, and suggest that the processing of colour and orientation are intimately coupled (Lennie, 1998).

Abstract 217 B2.82

Representation of statistical properties

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In everyday scenes, objects rarely appear in isolation. Clustered objects in a scene are less readily identified than objects in isolation. We form a summary representation of the group as a whole. What properties characterize this summary? Likely candidates are statistical descriptors including the mean, the range and the variance. Understanding how these statistics are extracted is one goal for the study of perception. In a series of experiments, we investigated the accuracy of judgments of the mean size of circles. First, participants adjusted a test circle to the estimated mean size of two target circles. Judgments of the perceived mean size followed a power function with an exponent of 0.76, consistent with results obtained by Teghtsoonian (1965). We used this psychological estimate of the mean in the remaining experiments. Next we measured thresholds for discriminating the mean size of a heterogeneous array, and compared them with thresholds for discriminating the size of elements in a homogeneous array, and the size of a single element. We found little difference between these three measures, suggesting that extracting the mean size might be an automatic process. We varied the exposure duration, and found much less Improvement with duration in thresholds for the mean size than in those for single elements or homogeneous displays. There may be internal noise in the averaging process that sets a ceiling on the improvement that is possible. In another experiment, we varied the distributions of sizes (normal, uniform, two peaks, and homogeneous). Thresholds were only slightly higher for comparing the means across two different distributions compared to within the same distribution, confirming that subjects were indeed averaging sizes. Finally, we investigated how many elements participants used in averaging by running a simulation, randomly sampling different numbers of elements. We found that samples of six elements gave the closest match to human performance.

Abstract 218 B2.83

Lateral modulation of contrast discrimination: Flanker orientation and location effects

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Purpose. We showed that collinear flankers facilitate contrast discrimination at low contrasts but impede it at high (Chen & Tyler, 2001, Proc. Roy. Soc. B.). Physiological evidence suggests that the long range interaction is orientation and location specific. Thus, noncollinear flankers may have qualitatively different effects from collinear ones.
Methods. We measured contrast thresholds for vertical Gabor targets superimposed on a pedestal in the presence of flankers. All patterns were 4 c/deg Gabor patches. The pedestal orientation was vertical and the flankers were either vertical or horizontal, placed 1o from the target. ”Aligned” flankers were placed in a vertical line, “side” flankers in a horizontal line through the target and “cross” flankers were the sum of the line and the side flankers.
Results. Without flankers, the target threshold vs. pedestal contrast (TvC) function showed a dipper shape: facilitation at low and masking at high contrast. The vertical line flankers increased both facilitation and masking effect. Compared with the vertical aligned flankers, the horizontal aligned flankers had less effect at low contrast, but had similar effect at high contrasts. The vertical side flankers had less effect at both low and high contrasts. The cross flankers had the same effect as the vertical aligned flankers, suggesting the flanker effects did not sum linearly across space.
Conclusions. We fit a sensitivity modulation model to the data. This model suggests that the target detector received multiplication inputs from other mechanisms in different hypercolumns that modulate its sensitivity to both excitatory and the divisive inhibitory elements of the response function. The best fit parameters reveal that there are two different long-range interactions: one is orientation and location specific and the other is broadly tuned.

Abstract 219 B2.84

WinVis – a novel approach to designing software for psychophysical experiments

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Dramatic improvements in the graphics performance of desktop computers offers a unique opportunity for vision scientists to avoid costly duplication of effort by adopting a platform that

promotes the sharing of software and minimizes hardware costs. To this end we have been developing WinVis, a software platform that uses object-oriented techniques to simplify and expedite the design of psychophysical and physiological experiments. WinVis retains flexibility through multiple levels of user access, from experiments designed over the WEB using standard Internet browsers to lower level programming using Matlab extensions. To promote sharing of ideas and effort, the system provides WEB access to a database of stimulus classes for users to incorporate into experiments. Stimulus classes are easily combined and extended to create new stimulus classes which themselves become database entries. The stimulus classes inherit functionality from one another, a feature of object oriented design. The result is an expanding database, the utility of which increases with use. Trial and experiment classes are also contained in the database for online experiment design. The user provides design criteria (on the WEB), a remote program generator creates a fully executable program that is delivered to the users local computer. The goal is to make it easy for researchers to exchange stimulus/experiment classes via the database to validate and extend each other's research findings. With regular database updates, researchers will be able to view stimuli described in the latest vision science journals. WinVis includes a Matlab extension for performing psychophysical experiments. This extension is integrated with the WEB based stimulus/trial class database system to enhance its functionality. The application of an object oriented design strategy in defining visual stimuli provides an efficient way to build upon existing stimulus objects.

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Abstract 220 B2.85

Dynamics of spatial frequency tuning of macaque LGN

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The dynamics of spatial frequency tuning in macaque primary visual cortex (V1) reveal changes in both selectivity and preferred spatial frequency over the timecourse of the response (Bredfeldt and Ringach, J. Neurocience, in press). We are interested in determining whether these phenomena can be accounted for by the convergence of feed-forward signals from the lateral geniculate nucleus (LGN) onto V1 cells. Here, we measure the dynamic spatial frequency tuning of macaque LGN using the same reverse correlation technique used to measure dynamic tuning in V1. We recorded the responses of individual cells to a rapid sequence of sinusoidal gratings with random spatial frequencies and spatial phases, at a fixed orientation. Blanks were interleaved to provide an estimate of baseline response. We find that when the response to a given spatial frequency is averaged across spatial phases we observe a flat response that is near baseline. This implies that under the conditions of our experiments the input from the LGN to V1 is approximately linear. When we measure the amplitude of the modulation of the response with respect to spatial phase at each spatial frequency, we find that most cells show a fairly stereotyped dynamic pattern. For short time delays, the response modulation is low pass. This initial response decays back to baseline and is followed by a second response that is also low-pass in spatial frequency. A few neurons in our population, however, also showed a transition to a band-pass tuning curve after the initial low-pass response. We are presently using these data to investigate the extent to which the dynamics of spatial frequency in V1 might be accounted for by a model that sums LGN inputs followed by rectification with threshold.

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Abstract 221 B2.86

Revealing and suppressing the visual information for recognition

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*VSS 2002 Student Award

A generic problem in vision is to know which information drives the perception of a stimulus. We address this problem in a case study that involves the perceptual reversal of an ambiguous image (here, Dali's painting the Slave Market with the Disappearing Bust of Voltaire, 1940). Ambiguous images, such as Dali's painting, are perfect stimuli for investigating the information in a stimulus that underlies its perception because the bottom-up information underlying the different interpretations is identical. In Experiment 1, we use Bubbles (Gosselin & Schyns, 2001) to disambiguate the image and to determine the specific visual information that drives each possible perception (here, the nuns vs. the bust of Voltaire). We found that the nature of this information is grounded in different spatial filters analyzing the image. Experiments 2 and 3 validate that this information does determine the selective perception of the ambiguous image. Using dynamic colored noise (computed by randomising the phase angles of the information driving each percept) observers adapted the spatial frequency channels mediating one of the two percepts, globally across the visual field in experiment 2 and locally in experiment 3. In a transfer phase, following global adaptation, we induce a perception of the ambiguous image that is orthogonal to the adapting frequency in experiment 2. Experiment 3 tests the locality of this spatial frequency information by confining it to the region underlying each percept, again observers experience a perception opposite to the adapting frequency. Together, the results of this local frequency-specific adaptation on the perception or recognition of complex figurative patterns suggests a new method to investigate the links between recognition and perception. This highlights the importance of understanding the information contained in a stimulus and how the use of this information modifies perception.

Abstract 222 B2.87

Receptive field structure of monkey V2 neurons for encoding orientation contrast

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Many neurons in V2 are orientation selective, but the possibility that orientation selectivity is not uniform across the

receptive field has received scant attention. To better understand the role of V2 neurons in the analysis of orientation and orientation contrast, we examined the orientation tuning of V2 neurons at different locations within their receptive fields.

Extracellular recordings were made from single neurons in area V2 of anesthetized, paralyzed monkeys. Orientation and spatial frequency tuning functions were measured for each cell with drifting sinusoidal gratings that covered the cell's receptive field. Then, small stationary sinusoidal gratings (~1/3-1/4 of the receptive field diameter) of various orientations were presented, for 40msec each and in rapid succession, at 19 locations in and near the receptive field in a random sequence. The sequence was re-randomized, for both orientation and position, and repeated up to 100 times. The spike train recorded during the stimulus presentation was cross-correlated with the stimulus sequence to assess the spatial map of orientation tuning.

Half of the neurons tested (21 of 42) showed significant spatial non-uniformity in orientation tuning. In many of these cells, there were spatially offset subregions tuned to different orientations that usually were near-orthogonal. The relative positions of subregions varied from cell to cell. The observed non-uniform receptive fields may be useful for encoding orientation contrast and may play an important role in the analysis of image attributes of intermediate spatial complexity, such as corners, angles, curvature, texture, and texture boundaries.

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Abstract 223 B2.88

Center-surround effects on orientation discrimination with visual noise stimuli

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'Physiological and behavioural evidence suggests that responses to a target stimulus can be modulated by context. In the orientation domain, parallel elements in the surround can suppress responses to a center target, whereas orthogonal elements have less or no effect. We investigated the influence of contextual orientation information using a stimulus in which the amount of oriented signal was varied independent of contrast. Oriented elements within the pattern were drawn with a particular grey level for a limited spatial extent, and then randomly switched to a new grey level. Oriented centers (2 deg) were presented in the context of either a parallel or orthogonal surround. The subjects' task was to discriminate oriented centers from unoriented noise centers in a 2IFC task. With a uniform grey surround, only 12% orientation signal was required for accurate discrimination. With a strong parallel surround, twice as much oriented signal was required. This effect was reduced when the orientation strength of the surround signal was reduced or when a gap separated the center and surround. Thresholds were also elevated with an unoriented noise surround. When the surround signal was orthogonal, thresholds were not different from thresholds with a uniform grey surround. These results are consistent with previous physiological and behavioural results that suggest orientation information is pooled across a local spatial region in an orientation-specific manner.

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Abstract 224 B2.89

Spatial integration of second-order orientation

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Humans can discriminate the mean orientation of an array of Gabors. Judging mean orientation may reflect the activity of texture processing mechanisms or pooling of orientation signals. We investigated whether humans can discriminate the mean orientation of second-order Gabors.
Methods: Observers discriminated whether the mean orientation of arrays of 8 or 16 Gabors was to the left or right of vertical. The Gabors were either first-order (luminance modulation of a noise mask) or second-order (contrast modulation of a noise carrier). The arrays could contain, either one type of Gabor, or a combination of half of each Gabor type. The distribution of orientations in an array could be, very narrow (i.e. aligned), very broad (high orientation noise) or half drawn from an orientated distribution and half randomly orientated. We estimated the amount of internal noise affecting the task and the number of samples used. The visibility of the Gabors was matched by measuring the minimum discriminable orientation difference for single Gabors.
Results: Mean orientation thresholds increased with the width of the orientation distribution. Observers' performance was similar for first-order, second-order and combined arrays when the orientation of all the Gabors was drawn from one distribution. Observers' performance with 8 first-order Gabors did not change when 8 randomly orientated second-order Gabors or low contrast first-order Gabors were added but adding high contrast first-order Gabors increased orientation thresholds. Observers performance with 8 second-order Gabors was slightly reduced by adding randomly orientated first-order Gabors and greatly impaired if the observer did not know which type of Gabor held the orientation information.
Conclusion: Observers are able to integrate first and second-order orientation across space. This integration process can, under some conditions, combine first and second-order information.
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Synaesthesia

Abstract 225 B2.90

Synaesthetic photisms and context

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When J an alphanumeric-color synaesthete views black digits or letters, each grapheme is perceived as having a colored overlay or photism. For J these photisms are projected in space,

sitting atop the digit or letter, but conforming to the shape of the grapheme. Previous experiments using Stroop methods showed that viewing black graphemes automatically induces photisms (e.g., viewing a 5 automatically induces a pink photism; viewing an S induces a green photism) Here we used Stroop methods to show that viewing ambiguous graphemes (e.g., a "scoreboard" 5 that can be interpreted as a 5 or an S) automatically induces different colored photisms depending on whether the graphemes are interpreted as digits or letters. Ambiguous graphemes such as a scoreboard 5 were embedded in digit strings (e.g., 3 4 5 6 7) or words (e.g., MUSIC). Each ambiguous grapheme then appeared alone in a video color that J had to name. In the digit context, ambiguous graphemes appeared in colors that were congruent or incongruent with J's photisms for the digit interpretation of the grapheme. In the letter context, colors were congruent or incongruent with J's photisms for the grapheme's letter interpretation. Crucially, what was a congruent trial in one context was always an incongruent trial in the other context (e.g., a pink scoreboard 5 was congruent if a digit, but incongruent if a letter; a green scoreboard 5 was incongruent if a digit, but congruent if a letter). In both the digit and letter contexts, colors in the congruent condition were named significantly faster than colors in the incongruent condition. Because the colored graphemes in the digit and letter contexts were identical, we conclude that the same ambiguous graphemes induced different colored photisms depending on whether they were interpreted as digits or letters. This finding supports a model of alphanumeric synaesthesia in which graphemic form activates meaning and meaning activates color along reentrant pathways.

This research was supported by the Natural Sciennces and Engineering Research Council of Canada.

Temporal

Abstract 226 B2.91

The temporal mechanisms mediating synchrony perception

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Purpose: Previously, we reported that synchrony perception in stochastic displays is tuned for orientation and spatial frequency but not for spatial separation (VSS 2001). Here, we used a masking paradigm to reveal the temporal properties of mechanisms mediating synchrony perception.

Method: Observers discriminated between pairs of synchronous and non-synchronous Gabor elements in a 2AFC task. Spatially, Gabors had a 3 deg horizontal separation and vertical 2.0 cpd carriers with random initial phases. Temporally, each Gabor was driven by a 533 ms waveform that modulated spatial phase over time. This waveform consisted of the linear sum of white Gaussian noise derived from two sources: a synchrony source S common to both elements and an independent masking source M for each element. We separately filtered the S and M components into one of seven 1.2-octave log-Gaussian bands (3.5 to 30 Hz) and measured synchrony thresholds for all 49 pairs of S and M bands. Defining synchrony as the ratio between the variances of S and S+M, we manipulated synchrony and estimated 75%-correct thresholds.

Results: When peak frequencies of the S and M bands coincided, synchrony thresholds remained constant over all frequencies tested. For high-frequency S bands, thresholds decreased as a function of frequency separation between S and M bands. For low-frequency S bands, however, we found little evidence of threshold reduction as we increased frequency separation between S and M bands.

Conclusions: Same-band masking revealed synchrony detection in signals is possible over temporal frequencies spanning a range of at least 3.5 to 30 Hz. Cross-band masking revealed synchrony detection relies on bandpass channels at high frequencies but on broadband channels at lower frequencies. These data, combined with data on the spatial properties of synchrony mechanisms, provide evidence for spatiotemporal association fields that mediate the detection of synchronous events in stochastic displays.

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Abstract 227 B2.92

Visual pattern synchrony as mediated by spatial interactions

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Synchrony is an important factor in binding of visual information, and is also a basic parameter in time perception. Here I report a temporal asymmetry in a synchrony-based perceptual grouping, which demonstrates a notion that synchrony between visual stimuli is mediated by spatial interactions between feature detectors. The stimulus display was a square array of four local patterns each composed of overlapping vertical and horizontal Gabor signals (6 c/deg) whose relative contrasts were sinusoidally modulated out of phase at a certain temporal frequency, producing an orientation alternation. One of the four elements (target) alternated its orientation in a different phase by phi (-180 - 180 deg) from the others. While steady fixating on the center of the array, observers were asked to detect the target element (i.e., asynchrony detection; 4AFC). No motion was seen between elements. The limits of lagged (phi > 0) and advanced (phi < 0) phase differences were measured for various alternation frequencies (TF > 4 Hz) and for various distances between elements (inter-element distance, IED, 0.3 - 1.5 deg). The results showed that both phase limits increased as the TF and IED increased, and that the advanced phase limits were significantly lower than the lagged ones. Thus the target whose orientation changed earlier than the others was easier to detect than the target whose orientation changed later by the same amount. Moreover, the difference between the two phase limits proportionally increased with the IED. This temporal asymmetry, which correlated with the distance in space, can be explained by assuming that visual synchrony is achieved via spatial interactions between local feature detectors, which essentially involve mutual delays of signals that propagate with a finite velocity. A simulation with a simple 4-unit network

gave a quantitative prediction of the results with estimated propagation velocities of 60-130 deg/sec.
Note: supported by JSPS (#7971) and Tohoku University

Abstract 228 B2.93

Visual simultaneity is affected by stimulus depth
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How the simultaneity experienced in visual perception depends on the location of stimuli in three-dimensional space was examined. Two vertical line stimuli (20.8 x 1.2 arc min) were presented at the same level but different depth position by the use of 5.8 arc min of binocular disparity cue; one line was in front of the other line. Pair of mirrors and displays controlled by a personal computer were arranged as a haploscope to present binocular disparity. The viewing distance to the displays was about 45 cm. A fixation point was presented on the display surface 56 arc min below the line stimuli. There were five conditions for depth location of the stimuli; the midway point of the two line stimuli was nearer or farther than the fixation point by 5.8 or 11.6 arc min of disparity, or at the same depth plane with the fixation point. There were seven SOA conditions for the presentation of the two line stimuli, ranging from -64 msec to 64 msec by 16 msec step (positive value of the SOA indicates that the presentation of the nearer stimulus was earlier than that of the farther stimulus). Each condition was presented 20 times in random order. Six observers judged which of the nearer or farther line stimuli was presented later in each trial. We found that the farther stimulus tended to be perceived as presented earlier than the presentation of the nearer stimulus, and that this tendency was more salient in the space nearer than the fixation point. The averaged SOA of the stimulus presentation, which was necessary for the two line stimuli to be perceived as presented at the same time was about 10 msec when the stimuli presented around the fixation point while it exceeded 20 msec when both of the stimuli was nearer than the fixation point. These results suggest that the temporal phenomena, such as simultaneity, in visual perception depend on the location of the stimuli in three-dimensional space.

Abstract 229 B2.94

Temporal integration of visual motion information: Evidence from response times
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Purpose: To investigate the tradeoff between speed and accuracy of perceptual decisions we performed combined measurements of accuracy and response time (RT) in a motion discrimination task. To facilitate comparison with physiological experiments in our laboratory, we used the same random dot stimulus and the same eye movement response paradigm in humans and monkeys. Incorporating measurements of RT provides further constraints on models of temporal integration and allows for links to the underlying physiology.

Methods: Human observers made 2-alternative direction discriminations on stochastic moving dot displays. Difficulty was controlled by changing the percentage of dots moving coherently in a common direction. Subjects indicated their judgment by making an eye movement to one of two peripheral targets.

Results: Psychophysical performance was similar in monkeys and humans. At the highest motion strengths, accuracy was perfect and RT was fastest. At slightly lower motion strengths, accuracy remained near perfect but RT slowed. At motion strengths near discrimination threshold, both accuracy and RT was affected. At the lowest motion strengths, accuracy fell to chance and RT was slowest. These results are consistent with an additive process that accumulates evidence over time about the direction of motion. In contrast, the data are not consistent with the decision being determined by the first occurrence of a suprathreshold event (“probability summation”).

Conclusions: The constellation of accuracy and RT results can be explained by an additive accumulation of evidence bearing on the two alternatives. This accumulation may have a neural basis in the buildup of neural activity observed in the monkey lateral intraparietal area (LIP) during this task.

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Abstract 230 B2.95

Pulse train detection and discrimination in pink noise
G. B. Henning, F. A. Wichmann & C. M. Bird SRU

Much of our information about spatial vision comes from detection experiments involving low-contrast stimuli. Contrast discrimination experiments provide one way to explore the visual system’s response to stimuli of higher contrast. We explored both detection and contrast discrimination performance with sinusoidal and “pulse-train” (or line) gratings. Both types of grating had a fundamental spatial frequency of 2.09-c/deg but the pulse-train, ideally, contains, in addition to its fundamental component, all the harmonics of the fundamental. Although the 2.09-c/deg pulse-train produced on the display was measured and shown to contain at least 8 harmonics at equal contrast, it was no more detectable than its most detectable component; no benefit from having additional information at the harmonics was measurable. The addition of broadband “pink” noise, designed to equalize the detectability of the components of the pulse train, made it about a factor of four more detectable than any of its components. However, in contrast-discrimination experiments, with an in-phase pedestal or masking grating of the same form and phase as the signal and 15% contrast, the noise did not improve the discrimination performance of the pulse train relative to that of its sinusoidal components. In contrast, a 2.09-c/deg “super train,” constructed to have 8 equally detectable harmonics, was a factor of five more detectable than any of its components. We discuss the implications of these observations for models of early vision in particular the implications for possible sources of internal noise.

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Abstract 231 B2.96

Striking Gestalt modulates EEG gamma activity - but not in accordance with the temporal binding hypothesis
Sven P. Heinrich, Ad Aertsen, & Michael Bach University of Freiburg

The binding of stimulus features into the percept of a coherent object is a fundamental task of the visual system. According to the temporal binding hypothesis, this might be coded by neural synchronization. Animal studies suggest gamma-range (30-100 Hz) neural oscillations to be involved in this process. Reports about binding-related oscillations in the human EEG are contradictory, though. Most previous experiments were based on a stimulus-onset paradigm. Thus, the EEG always contained responses to trivial local stimulus changes in addition to binding-related components. We used a new approach with a Gestalt emerging from a continuous movement of stimulus elements without any temporal discontinuances. EEG was recorded from 18 subjects. 3 different stimuli were presented repeatedly in randomized order within each experimental block: a Gestalt consisting of a line grid, the same Grid rotated by 45 , and a stimulus without Gestalt (random line arrangement). Before each block, subjects were instructed to attend to one of the 3 stimuli and indicate its occurrence by pressing a button. For each of the 3 possible tasks a total of about 140 trials per stimulus were recorded. The stimuli produced a striking Gestalt percept and elicited strong event-related potentials with a weak task dependence. Grand-mean 30-100 Hz gamma activity was assessed. An ANOVA applied to 3 perceptually relevant time intervals indicates a significant effect of task ($p<0.05$), stimulus ($p<0.05$), and time interval ($p=0.001$). The effects were small, though, and the characteristics were not as predicted by the binding hypothesis. E.g., differences between both Gestalt stimuli, though perceptually similar, were larger than between Gestalt and non-Gestalt stimuli and occurred mainly before the stimulus had reached a configuration that allowed for perception or identification of a Gestalt. Thus, the striking change of Gestalt is not accompanied by any marked modulations of gamma activity.

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Abstract 232 B2.197

The perceived brightness of a flash can be influenced by temporal properties of its neighbors
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The perceived brightness of an object depends on the spatial relationships it has with its neighbors (e.g., brightness induction). We examined whether perceived brightness of a briefly flashed object depends on its temporal relationships with its neighbors. Two gray disks were flashed on either side of a fixation point: one flash lasted for 14 ms ('brief'); the other lasted for 500 ms ('long'). Observers reported which flash appeared brighter. When the flashes had simultaneous onset against a dark background, subjects report the brief flash dimmer than the long flash, consistent with the Broca-Sulzer effect. However, when the flashes had simultaneous offset, the brief flash now appeared brighter. The perceived brightness of the brief flash increased monotonically and non-linearly with increasing SOA. When the background was made higher luminance than the flashes, results were reversed: now an onset-matched brief flash appeared brighter, an offset-matched brief flash appeared dimmer. When two brief flashes are presented – one aligned with onset, the other with offset of the long flash – a comparison between them bares the same result: the onset-matched flashed is seen as dimmer than the offset-matched flash. Our results suggest that brightness properties of the brief flashes are temporally integrated with the background, and that the integration time window can be shortened by a salient offset signal nearby. Consistent with this explanation, the differential effect was lost when the flashes were isoluminant with a colored background. We present a model of the neural substrate underlying this phenomenon. Further, we ask whether we are aware of certain kinds of brightness changes, or instead only are aware of the result of integrations over these changes. Our results indicate that we are aware of integrations, and that the duration of the integration window may be changed by salient temporal events in neighboring locations in the visual scene.

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Abstract 233 B2.98

Turning it on piecemeal makes it seen faster
Theodore E. Cohn and Khoi Nguyen University of California, Berkeley

In real-world signaling situations, rapid detection of a signal can be vitally important. One such situation involves a following vehicle (FV) that is too close to a lead vehicle (LV). Suppose that the LV could detect the problem. How should the FV be signaled? We studied visual warning signals typical of those used on large LV's, like buses: in this case, an eight-segment 8 CM x 150 CM horizontal array.
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
The endpoint measure was time to react to light onset in the array (RT). The 'standard' signal involved simultaneous ignition of all eight segments at t=0. The 'test' signal delayed the ignition of some segments (first 4,5 @ t=0; then 3,6; then 2,7; then 1,8, each step in the sequence delayed by 50MSEC) producing an apparently expanding pattern. Observers included 6 pre-presbyopic, normal, corrected adults plus 3 corrected adults over 60. Conditions that were varied during testing included adaptation level, array intensity and array size (19 DEG or 1.9 DEG). 25 repetitions of each signal were tested for each condition. Paradoxically, faster RT's occurred with piecemeal ignition. Median RT's were sometimes faster by as much as 50 MSEC and once, by 100 MSEC for individuals, compared to RT's for simultaneous ignition. The difference was due mainly to increased numbers of late RT's for the 'standard'. In nearly every condition, the 'test' signal was seen significantly more quickly than the simultaneous signal. The exception involved a 'wig-wag' signal in which we turned on 1,2,5, &6 then, later, 3,4,7,&8.

The paradox can be explained if one presumes that the standard signal does not stimulate M-neurons (or, some might suggest, 'looming' detectors) as well as does the piecewise-delayed 'test' signal. To determine whether a real-world LV-FV situation can benefit from this knowledge, a delayed test-signal will soon be deployed on a transit bus LV equipped with a radar-based FV detector.

Abstract 234 B2.99

Temporal precision of visual grouping from temporal structure
Randolph Blake & Sang-Hun Lee Vanderbilt University

Correlated change in a dynamic visual property (e.g., motion) among a subset of stimulus elements promotes spatial grouping of those elements within a background of dynamic elements whose changes are uncorrelated in time [Lee & Blake (1999) Science, 284, 1165] What is the minimum time needed for perception of spatial structure created from this kind of temporal structure? To learn the answer, we created animation sequences in which hundreds of small, radial gratings changed their directions of rotation randomly over time. A "figure" region defined solely by correlated change in rotation direction "moved" laterally left or right (a novel form of higher-order motion). Speed of motion was varied to find the value supporting reliable direction discrimination performance on a 2AFC task. The task could be performed at exposure durations as brief as 42 msec, with performance reaching perfection at durations just over 100 msec. In the blink of an eye, human vision can dynamically organize spatial structure from fine temporal structure and exploit that structure to compute higher-order motion.

In a related experiment, contours within many small, randomly oriented Gabor patches changed their directions of motion irregularly over time, with the change times for all Gabors dictated by the same point-process. Over trials, the temporal phase-lag between "figure" and "background" point-process was manipulated, to find the minimum phase-lag supporting accurate shape discrimination. Consistent with earlier findings, shape from temporal phase-lag could be perceived when figure and ground elements differed in their change times by less than 10 msec. Simulations confirmed that these results are not predicted by low-pass temporal filtering [Adelson & Farid (1999) Science, 286, 2231]. These results serve as testimony to human vision's exquisite sensitivity to temporal structure.
NIH EY07760

Texture

Abstract 235 B2.100

The starry night texture and its use to isolate depth cues
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The Starry Night Texture (SNT) is a new surface texture that renders painted objects invisible against a similarly painted background, in static monocular views. Object shape and location become visible when motion parallax or stereo cues are provided. SNT consists of a great many high luminosity spots, each tiny in size, distributed randomly (using the uniform distribution) on an otherwise dark surface. The spots are indistinguishable from point sources when imaged, yielding a Starry Night Image (SNI). A single number (the "densintensity") characterizes the expected number of spots of criterion luminance or brighter, per unit area. To achieve invariance of the image statistics across changes in surface distance, the luminance of the spots is distributed as the square of reciprocal luminance. To achieve invariance across slants, spots are flat on the surface. The resulting Starry Night Image (SNI) is itself an SNT.

In its pure form, SNT contains occasional "supernovas" (very intense stars) and infinitely many dim stars. To use the texture, we therefore adopt upper and lower limits on spot luminances. We justify this by evaluating the probability of encountering SNIs that are missing very bright stars, and we show that the dim star cut-off gives little distance information. We present a rendering method and consider tradeoffs given the dynamic range of the display.

SNT may be of experimental value. Other texture patterns reveal 3D scene structure under reasonable assumptions, whereas SNT reveals no structure. Also, back projection of uniform density random dots onto a scene results in apparently nonuniform dot distributions on surfaces, once scene structure is revealed by stereo or motion. This did not occur with back-projected SNI, suggesting that the perceptual mechanisms used to infer surface patterns on slanted surfaces, and pattern scale at different distances, expected no change of local image statistics from changes in surface slant or distance.

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Abstract 236 B2.101

The central performance drop can be elicited without a backward mask.
Cindy Potechin, Rick Gurnsey, & Francois X. Sezikeye Concordia University, CANADA

Purpose: Studies of the central performance drop (CPD) have shown improved discrimination of textures, comprising left and right oblique lines, as the disparate texture is moved away from the fovea (e.g. Kehrer, 1987). One account of this effect is that processing is faster in the periphery than at the fovea. Therefore, when performance is limited by a backward mask, segmentation processes may have more time to operate in the periphery than at the fovea, leading to impaired central performance (Kehrer, 1987, Spatial Vision). A second account explains the CPD in purely spatial terms (Gurnsey, et al., 1996, JEP:HPP). The "processing speed" account argues that a backward mask is critical to the CPD whereas the spatial account does not. Morikowa (2000, Vision Research) showed that the CPD was not elicited when performance was limited by a simultaneous mask, thus seeming to support the processing speed proposal.

Methods: We employed a different method of degrading performance without a backward mask. Textures always

comprised line segments having mean orientations of 45 and 135 degrees. Texture discrimination was made more difficult by introducing variability about these mean orientations. We refer to this variability as orientation bandwidth. In one task we determined threshold orientation-bandwith as a function of eccentricity. In a second task we measured performance in a four-alternative forced choice task, for a fixed orientation bandwidth, at a range of eccentricities.

Results: In both conditions sensitivity increased significantly as the target was moved from the fovea to about 5.0 to 8.5 degrees.

Conclusion: Consistent with the spatial account of Gurnsey et al. (1996), the CPD can be elicited without a backward mask. We believe that Morikowa's failure to find a CPD with a simultaneous mask reflects the fact that his mask was simply less effective at the fovea than in the periphery.

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Abstract 237 B2.102

Orientation-texture-defined edges: a computational model
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A two-stage model of second order processing is proposed. The model is an extension of the familiar “filter-rectify-filter” scheme. There are two stages; stage 1, filter(1)-nonlinearity-orientation_pooling(1), followed by a second stage applied to each of the outputs of the first stage, filter(2)-nonlinearity-orientation_pooling(2). This unifies second-order processes for the detection of spatial location, orientation of contrast modulations, and texture defined form. The first stage of the model; filter(1) is a bank of linear bandpass filters of equal spatial frequency but different orientations. The non-linearity finds the energy response of each of these first stage filter outputs, which are passed through a Fourier transform, that “pools” over orientation. The magnitude and phase of these Fourier coefficients enables detection of the presence and orientation, respectively, of, eg, lines and edges. Each complex response from the first stage is passed to a separate second stage of processing whose purpose is to detect second-order structure. The second stage; filter(2) is similar to the first, but with the peak tuning frequency reduced by at least two octaves. Two symmetries from the first stage Fourier transform over orientation are examined, E0 and E2. The first, E0, refers to the total energy of the image signal. The second stage processing of this signal leads to the detection of spatial contrast variations. The second, E2, refers to the oriented energy present in the image signal. The second
stage processing of this signal leads to the detection of orientation-texture-defined form. In respect of luminance boundaries, contrast variation boundaries and boundaries of orientation-texture-defined form, the model explains the condition when these boundaries are most salient, it occurs when the phase differences
in the outputs of the first stage across a boundary is at 180 degrees, whether luminance defined, or texture defined.

Abstract 238 B2.103

Orientation- and frequency-modulated textures at low depths of modulation are processed by off-orientation and off-frequency texture mechanisms
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Intuitively it may seem likely that orientation-modulated (OM) and frequency-modulated (FM) textures are processed utilizing the first-order channels that are most responsive to the first-order (luminance) information contained within the textures. This assumption would imply that the detection or segmentation of orientation-modulated or frequency-modulated textures is accomplished by second-order mechanisms that receive their first-order input from neurons tuned to either the center, or to the peaks in the orientation and spatial frequency distribution of the texture. Here we show that at low depths of modulation this is not the case. Using an adaptation paradigm, we show that the first-order filters involved in the perception of OM and FM textures are those which maximize the differential response between the different texture regions. These filters show preferences for orientations and spatial frequencies that are very different from the center and peak orientation/spatial frequency contained in the stimulus. Our explanation of this result is similar to that made by Regan and Beverley (J. Opt. Soc. Am., 73, 1684 [1983], J. Opt. Soc. Am, A, 2, 147 [1985]) for simple grating stimuli. However, we show that whereas Regan and Beverley's results could be accounted for on the basis of the tuning functions of the putative mechanisms involved, our results can be explained in terms of the characteristics of the textures themselves. Our finding has some important implications. For example, the distribution of activity across texture mechanisms with differing first-order tuning functions may be used to determine the nature of a texture modulation.

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Tracking

Abstract 239 B2.104

Is multiple object tracking affected by three-dimensional rigidity?
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Scholl, Pylyshyn & Feldman (2001) has discussed "objecthood" in the context of a multiple object tracking (MOT) task. In their experiment, the target and distractor were merged by line segment or by drawing the convex hull of the two items (target merging technique). It was demonstrated that the participant's capacity to track multiple items destructed when items were merged, compared to the separate condition when items were not merged. This indicates that the target merging technique created difficulty in attending to each target item. One of the reasons for this might be because the merged items were treated as a single object. Another possibility, however, is that the merged items formed non-rigid and unnatural object, and this could have created the difficulty in

attending to "part" of the object. In this study, a three-dimensional display was used to test this possibility, and to examine the effect of depth on merged MOT. Participants viewed a split display through a haploscope and perceived three-dimensional or two-dimensional stimuli. Merged and separate items were presented either two or three dimensionally. The three-dimensional rigidity was also controlled. As for the results, the tracking accuracy was higher in the 3-D condition than in the 2-D condition. This result is consistent with Viswanathan and Mingolla (in press). The rigidity of the items improved the participant's performance, and was an effective cue on 3-D MOT. However, both the 3-D and 2-D merged item conditions showed significantly lower accuracy than the separate item condition. It was concluded that this difficulty stems from the fact that the three-dimensionally merged items were treated as a single object.

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Abstract 240 B2.105

Object tracking in ecologically valid occlusion events

Jonathan A. Slemmer & Scott P. Johnson Cornell University

Tracking of multiple moving targets has been found to be largely unaffected by the presence of narrow occluders, implying that the object tracking system is immune to brief occlusion events (e.g, Scholl & Pylyshyn, 1998). Object tracking across occlusion was robust when occlusion occurred as an accretion/deletion along a fixed contour relative to the object's path of motion. Movements were random except for the stipulation that object paths would never cross. The objects therefore influenced each other's direction of motion.

The purpose of the present study was to examine whether the tracking system treats all occlusion events the same, with two new conditions. First, we used a shadow occluder whose edges were semi-transparent gradients instead of fixed contours. The total amount of occlusion area remained the same, but time to become occluded was prolonged, relative to the accretion/deletion event. We reasoned that the tracking system might have difficulty following objects whose occlusion time was extended. Second, motion paths were independent, and objects occasionally occluded each other. We reasoned that extra occlusion events might pose additional challenges to the tracking system, resulting in a decrement of performance.

When no occluders were present, subjects accurately identified 89% of targets, replicating the original Scholl and Pylyshyn results. Performance in the shadow event was similar to our other occlusion events (luminance and virtual borders), implying that the tracking system is robust to shadow occlusions as well as accretion/deletion occlusions. However, performance was far worse (between 78 and 81%) than no-occluder events, and worse than results reported by Scholl and Pylyshyn. Tracking through occlusion is thus more difficult when objects can also occlude each other, but only when static occluders are also present. The tracking system may be unable to individuate objects effectively when occlusion events are made more ecologically valid.

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Abstract 241 B2.106

The effect of a secondary monitoring task on Multiple Object Tracking

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Previous research has shown that observers are able to track at least four moving targets among identical distractors. According to Pylyshyn's account, tracking uses a preattentive mechanism called a Visual Index (or FINST). Several people have challenged the assumption that MOT is preattentive. Treisman (1993) showed that a simultaneous task of monitoring color changes at the screen border results in poorer performance on both tasks. We hypothesize that a task that involves indexing an additional visual object (e.g., the border) may interfere with tracking, but that a task that involves an already-indexed object might not. Subjects performed a MOT task with 4 targets as well as a simultaneous task involving monitoring the occurrence of a specific color change at one of four locations: on a target, non-target, border, and fixation. Both tracking and monitoring performance were recorded. The results showed that tracking was not significantly affected by the monitoring task regardless of its location (although the trend was in the expected direction, with the best performance occurring when the monitored change was on the target and the worst when on the border). There were, however, significant differences in reaction times to the secondary monitoring task, as well as differences in the frequency with which the monitored events was missed. The longest RT occurred when the change was at fixation and the shortest when it was on the border. An attempt is made to reconcile these findings with the general assumption that MOT requires attention. Among the relevant factors that are considered is the difficulty of the tracking task and the possible role of inattentional blindness and nontarget inhibition.

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Abstract 242 B2.107

Effect of object discriminability on multiple object tracking

John L. Dennis & Zenon W. Pylyshyn Rutgers University Center for Cognitive Science, USA

In the Multiple Object Tracking (MOT) paradigm observers track a designated set of (typically 4) objects that move independently and unpredictably among an equal number of identical distractors. It has been shown (Scholl, Pylyshyn & Franconeri, 1999) that, consistent with Pylyshyn's Visual Indexing Theory, a change in the color or shape of a tracked objects is not encoded during MOT. Even if properties are not encoded, it might still be easier to track targets if some properties distinguished targets from nontargets. However, if targets were consistently different from nontargets, selecting the targets at the end of a trial could be accomplished without actually tracking. Consequently, we developed a paradigm for investigating whether a distinctive property of objects (e.g., their color) would improve tracking even when the property

could not be used directly to pick out targets without tracking them. In this paradigm the color of each object was always distinct from the color of every other object, but it did not remain fixed, and therefore targets could not be tracked merely by recalling their color. The method involved selecting 8 equispaced points on a color circle and rotating all 8 selections around the circle in a continuous manner. Three conditions were compared: (1) Colors of objects were always distinct but continuously changing, (2) colors of all objects were always the same but changed continuously in synchrony, and (3) colors of objects were identical and fixed. Results showed that that performance in these three conditions were significantly different, with (1) being best and (3) being worst. The improvement in tracking arising from maintaining distinct colors is discussed in terms of two possible explanations: Reduced confusability of target-nontarget pairs that came close to one another during a trial, and use of color differences in an "error recovery" stage.
Acknowledgement: Supported in part by NIMH Grant 1R01-MH60924

Abstract 243 B2.108

The processing of untracked objects during multiple object tracking
Hirokazu Ogawa & Akihiro Yagi Kwansei Gakuin U., Japan

Purpose: Numerous studies reported that observer could track 4 or 5 moving targets among identical moving distractors. Pylyshyn (1988) proposed the existence of individuating indexes that were assigned to tracked objects. While Yantis (1992) claimed that the importance of grouping processes for tracked objects. We showed that the processing of distractors in multiple object tracking (MOT) was also important, using contextual cueing procedure (Chun & Jiang, 1998). Method: Ten white circles were presented and five of these circles were flashed, designating them as the target objects. Then all objects began to move independently in random directions. Seventeen naïve observers were asked to track five moving target objects for 5 s and indicate the five targets using the mouse after the tracking. The two main variables were spatio-temporal pattern (Consistent vs Distractor-Variable vs All-Variable) and epoch (1-5). The Consistent set of motion pattern consisted of 5 randomly generated patterns in which the trajectories of the all objects were consistent through the experiment, presented once per block. The Distractor-Variable (DV) set consisted of 5 different patterns which only the target trajectory were repeated. The All-Variable (AV) set consisted of 5 different patterns that were newly generated for each block. Each pattern for Consistent and DV was repeated 15 times through the entire experiment. After MOT session, observers asked to perform the recognition task for consistent motion pattern. Result: The MOT performance showed significant contextual cueing effect, which was greater for consistent patterns than DV patterns. Besides the performance in the recognition task did not show any significant difference from chance level. Conclusion: The spatio-temporal information of distractors served as the implicit contextual information and facilitated tracking performance. This suggests the importance of the information that was not explicitly processed during MOT.
This research was supported by Grants of the MEXT and the NEDO.

Abstract 244 B2.109

Can indexes be voluntarily assigned in multiple object tracking?
Vidal Annan, Jr. & Zenon W. Pylyshyn Rutgers University - Center for Cognitive Science

In Multiple Object Tracking (MOT), an observer is able to track 4 – 5 objects in a group of otherwise indistinguishable objects that move independently and unpredictably about a display. According to the Visual Indexing Theory (Pylyshyn, 1989), successful tracking requires that target objects be indexed while they are distinct -- before tracking begins. In the typical MOT task, the target objects are briefly flashed resulting in the automatic assignment of indexes. The question arises whether indexes are only assigned automatically or whether they can be assigned voluntarily in a top-down manner. This study compares several ways of specifying which of 8 items are the targets to be tracked. In the Flash condition the target items were flashed, in the Nonflash condition the targets were the items not flashed, and in the Number condition the targets were specified by number (e.g., items numbered 1-4). The results showed no difference between the three conditions, suggesting that tracking was possible with either voluntary or involuntary indexing. The second experiment tested the hypothesis that voluntary indexing is possible only if the target items are visited serially. The conditions were the same as experiment 1 except that the time available for index assignment was too short to allow targets to be visited serially. In this experiment, targets flashed only once (or, in the Numbers condition, remained visible for about 400 ms). The results showed a decrease in tracking performance for the Number condition, but the Flash and the Nonflash conditions did not differ, suggesting that as long as the designation of targets was done rapidly, the observer did not have to visit each target serially in order to index it. These results suggest that indexing can occur both automatically and voluntarily, and without serially visiting them, so long as the items are successfully specified.

This work was supported by NIH Grant 1R01-MH60924 to ZWP and an Institutional NRSA Postdoctoral Training Fellowship to VA (Grant NIH T32-MH19975).

Saturday PM Talks (North Hall)
Attention and Memory I

Moderators: Marvin Chun & Cathleen Moore

Abstract #	Time	Authors
245	1:30	Triesch, Sullivan, Hayhoe, Ballard
246	1:45	Rensink
247	2:00	Marois, Todd, Chun
248	2:15	Moore, Lleras
249	2:30	Scholl, Feldman
250	2:45	Pylyshyn

Abstract 245 1:30 PM

Transient visual representations: a change blindness approach

Jochen Triesch, Brian T. Sullivan, Mary M. Hayhoe, & Dana H. Ballard UC San Diego, USA, U. of Rochester, USA, U. of Rochester, USA, U. of Rochester, USA

Experiments on change blindness, or the inability to notice scene changes that occur during saccades or other transients, reveal the limited extent of visual representations. It is thought that only the attended parts of a scene are represented and retained in visual memory. The present study reveals that even attended information may not be maintained in memory, and that what is represented at any moment may be only a very limited subset of the visual properties of an attended object that depends on the current task demands. We used a Virtual Reality environment, where subjects pick up and place virtual objects using two haptic force-feedback devices. Subjects moved bricks of two different sizes onto two different conveyor belts, according to different criteria that manipulated the relevance of brick size. Between the pick-up and put-down, brick size sometimes changed by 20%. When subjects pick up the large bricks first and were required to place them on a specific conveyor belt, they were quite likely to notice the change (53%). However, if all blocks had to be placed on the same belt regardless of size, then only 24% of changes were detected. One way to explain the result is that size information might not be maintained after picking up the brick in this condition. In the first condition size remains relevant at put-down, so observers must either maintain this information or recompute it at put down. Finally, when bricks could be placed in any order, even fewer changes were noticed (17%). Sometimes changes went unnoticed even though the subjects visually tracked the object as they moved it toward the belt. In conclusion, subjects often fail to notice changes even when attending to an object if the changed stimulus feature is not task relevant at that moment. These results underscore the dynamic and task specific nature of visual computations, and the fragmented nature of attention.

Supported by NIH/PHS research grants P41 RR09283 and EY05729.

Abstract 246 1:45 PM

Failure to see more than one change at a time

Ronald A. Rensink U. of British Columbia, Canada

The ability of observers to detect the presence of more than one change at a time was tested using a sequence of displays that always contained two simple items (e.g. rectangles) with constant locations. Each feature that was examined (orientation, color, and size) had two possible values for each item: A or A' for item 1, and B or B' for item 2. On half the trials the display sequence was such that only one change occurred at a time (e.g. AB, A'B, A'B', AB'); on the other half, it was such that a pair of changes occurred on every other transition (e.g., AB, A'B', A'B, AB'). The task of the observer was to determine whether the display sequence in a given trial contained any change pairs. Brief (100 ms) blank fields were presented between displays so that changes could not be detected via transients, but instead required focal attention (Rensink et al, 1997). Since only two items were present in any display, and since attention can be given to 3-5 items at a time, this technique allowed a determination of the extent to which change can be perceived at any moment, even when all items are attended.
Detection accuracy was measured as a function of display duration. For displays shorter than 200 ms, detection of change pairs was always poor. This is consistent with the temporal resolution needed to perceive simultaneous feature pairs (Holcombe & Cavanagh, 2001). For longer displays, an interesting pattern emerged: whereas performance improved considerably with display duration for changes made to different kinds of feature (e.g., color and orientation) or to the orientation of separated items, it remained poor for other kinds of changes, even for display durations exceeding 600 ms. This therefore appears to be a new form of induced blindness, in which--at least for some kinds of changes--observers cannot see more than one change at a time.

Supported by NSERC Canada and Nissan Motor Co.

Abstract 247 2:00 PM

The impact of reaching visual short-term memory capacity on the attentional blink

René Marois, James J. Todd, & Marvin M. Chun Vanderbilt Vision Research Center and Vanderbilt University, USA

When subjects search for two targets presented among a rapid sequence of visual distractors, they are severely impaired at detecting the second target (T2) if it occurs within 500 ms of the first one (T1). Models of this 'attentional blink' (AB) suggest that it reflects limitations in consolidating target representations into visual short-term memory (VSTM). However, the relation between the AB and capacity limits of VSTM has not been directly established. Here, we tested the specific prediction that if the AB is subject to the capacity limits of VSTM, then T2 performance should 1) decrease as the number of encoded T1 items increases, but 2) level off after the number of T1 items reaches VTSM capacity. We tested this prediction in 11 subjects where the T1 task consisted in encoding a variable number (1-6) of letters briefly displayed around an imaginary circle, and the T2 task consisted in detecting a large X shown inside the imaginary circle at

variable SOAs after T1. To provide converging estimates of VSTM capacity, we employed both partial and whole report procedures for the T1 task. Both types of report demonstrated that subjects encoded more objects as T1 setsize increased, but only up to setsize 4, when their capacity leveled off even with further increase in the number of objects displayed. Reciprocally, T2 performance decreased as T1 setsize increased, but again only up to setsize 4, and leveled off thereafter. To rule out the possibility that these findings were due to verbal working memory interference between T1 and T2, an additional 16 subjects performed a similar experiment but with a purely perceptual T2 task that required detecting a gap in a square (Landolt figure). The results were identical to the first experiment.

These findings suggest that the AB is tightly coupled to the limited capacity of visual short-term memory.

Supported by NSF Grant BCS-0094992.

Abstract 248 2:15 PM

Object substitution masking and object-token individuation

Cathleen M. Moore & Alejandro Lleras Pennsylvania State University, USA

A recently reported form of visual masking--known as Object Substitution Masking (OSM)--occurs when a minimal mask (e.g., four single-pixel dots) is presented simultaneously with the target (e.g., a Landolt-C). When the mask lingers in the display following target offset, severe masking can occur (e.g., Enns & DiLollo, 1997). This is true despite there being little opportunity for contour interference between the mask and target. Using apparent motion to manipulate the representation of the object-token that is associated with the target, we have shown that it is the lingering of that object token that is critical to the masking effect, rather than the lingering of any particular stimulus at the target location. In fact, a mask need never appear at the target location and can be as minimal as a single dot that is much smaller than the target itself (Lleras & Moore, submitted). As long as the spatio-temporal characteristics of the mask are consistent with it being the same object as the target, OSM occurred. These and related results suggest that OSM may be caused by a failure to individuate the mask and target with separate object tokens, before the target offsets. If true, then OSM may provide an index of those processes that normally serve to link previous states of an object with its current state as it moves through space and time. Under this view, the relationship of OSM to this updating process is like that of visual illusions to normal perceptual processes; it is a limitation that occurs under unusual conditions and that can reveal characteristics of the system as it functions under normal conditions. Here we present experiments supporting this interpretation of OSM and its potential as a tool for studying updating processes in object perception.

Abstract 249 2:30 PM

The temporal dynamics of object formation in object-based attention

Brian Scholl & Jacob Feldman Yale University, USA, Rutgers University, USA

Much recent research has suggested that the units of attention are often discrete whole objects, and has further revealed some of the factors that mediate what can count as an 'object'. Here we address a new question: How fast do these object representations form? This question is difficult to address with standard cueing or divided-attention paradigms, since these tasks themselves require strict timing parameters. Here we employed the 'multiple object tracking' task, in which subjects had to track a set of unpredictably and independently moving targets in a field of featurally-identical moving distractors: e.g., a subject might have to track 4 out of 8 moving line segments. 'Target merging' manipulations were then employed to frustrate this tracking: each target was merged with a distractor via various types of grouping cues ('connectors'); e.g., two line segments might simply be joined into a single long line, of which subjects must continue to track one end. We have found in earlier studies that such manipulations cause the target-distractor pair to be treated as a single object (i.e. to 'merge'), which prevents tracking of only the targets. In the current study these connectors appeared for only a short time during the tracking interval: they onset after the motion had begun and then disappeared before the motion ended. The critical variable was the duration for which the connector was visible. Observers were able to successfully track the targets through connector durations of up to about 300 ms; at longer durations, tracking was drastically impaired. The critical duration beyond which tracking suffered varied with the particular grouping cue used, and also with the method by which the connector appeared (suddenly vs. gradual fading-in vs. growing from each end). Such results reveal the speed with which the objects of object-based attention form in various conditions, at least in a situation with a high attentional load. (BJS was supported by NIMH 1-R03-MH63808-01. JF was supported by NSF SBR-9875175.)

Abstract 250 2:45 PM

Tracking multiple identical moving objects: Analysis of recent findings

Zenon W. Pylyshyn Rutgers Center for Cognitive Science

We have been using a Multiple Object Tracking (MOT) paradigm (Pylyshyn & Storm, 1988) to explore people's ability to track a number (usually 4 or 5) of designated visual targets when these are intermixed among a number of nontargets, all of which are identical and move independently in unpredictable ways. This paper will summarize some recent unanticipated results, several of which are being reported at this conference. Here I will discuss one such result in greater detail: the finding that observers can track the set of targets accurately while losing track of which one is which (in terms of some unique identifier assigned to them at the start of a trial). In other words target ID performance drops more rapidly with time than tracking performance. This result is puzzling because correct tracking logically requires that observers keep track of each individual item and trace it back in time to a particular item that was made briefly distinct at the start of the trial (in other words, a "correspondence problem" must be continuously solved for each target). Recent studies have suggested that the more rapid drop in ID performance relative to tracking performance may arise because observers more easily confuse targets they are tracking with other targets that they are also tracking than with nontargets that they are systematically ignoring. We found that

targets that come close to other targets during a trial frequently switch identities, whereas targets that come close to nontargets are more readily kept distinct. Possible reasons for this are explored, including the proposal that nontargets are inhibited during tracking. Data are presented showing that under certain conditions nontargets may indeed be inhibited. The implications of such an inhibitory mechanism will be discussed. The various phenomena associated with MOT will be illustrated with animated demonstrations.

This work was supported by NIH Grant 1R01-MH60924 to ZWP

Saturday PM Talks (North Hall)
Scene Perception and Memory I

Moderators: John Henderson & Russell Epstein

Abstract #	Time	Authors
251	3:30	Li, VanRullen, Koch, Perona
252	3:45	Hollingworth, Henderson
253	4:00	DiMase, Oliva, Wolfe
254	4:15	Christou, Thornton
255	4:30	Epstein, Graham, Kanwisher, Downing
256	4:45	Walker, Malik

Abstract 251 3:30 PM

Detection of objects in natural scenes with minimal or no attention

Fei Fei Li, Rufin VanRullen, Christof Koch & Pietro Perona
Caltech, Caltech, Caltech, Caltech

Attention plays a critical role in modulating visual information that eventually reaches our visual awareness. What can we see when we do not pay attention? Change-blindness experiments have demonstrated that one can be "blind" even to changes in major aspects of a natural scene. The only tasks that need minimal or no attention appear to be those carried out in the early stages of the visual system. Contrary to this common belief, we report that subjects can rapidly detect highly variable objects (e.g. animals or vehicles) in briefly presented novel natural scenes while simultaneously performing another attentionally demanding task (a five-letter form discrimination task). By comparison, they are unable to discriminate large 'T's from 'L's or a bisected two-color disk from its mirror image under the same condition. This ability does not depend on the fact that our subjects are extensively trained on this type of categorization task. Some of the subjects learn to perform a dual-task involving a given target category (e.g. "animal" or "vehicle") and are subsequently tested using another target category. The pattern of results obtained in that case is comparable. We conclude that some visual tasks associated with "high-level" cortical areas may proceed in the near absence of attention.

(This research is supported by NSF, NIH, the Kech Foundation and McDonnell Foundation.)

Abstract 252 3:45 PM

Sustained insensitivity to incremental scene rotation: A dissociation between explicit change detection and visual memory

Andrew Hollingworth & John M. Henderson Yale University, USA, Michigan State University, USA

The visual system is often faced with small discrepancies between consecutive views of a scene (introduced, e.g., by motor inaccuracies in eye movements), yet it typically does not attribute such events to changes in the world. In this study, we introduced a series of small discrepancies to a scene image by rotating it in 1 intervals in a flicker paradigm. Two stimuli were used: a living room scene that rotated in depth around the viewing position, and a top-down view of a desk that rotated in the picture plane. First, we considered whether, through the incremental addition of small rotations, participants would come to consider a significantly different view as an unchanged continuation of the original view. This was indeed the case. Participants required an average of 31 and 50 of rotation before detecting the change to the living room and desk scenes, respectively. Control experiments, in which participants reliably detected much smaller total rotations made in a single step, eliminated the possibility that this insensitivity derived from failure to represent the scenes in memory or to compare consecutive views. Second, we considered the relationship between explicit change detection and visual memory. Participants' extended insensitivity to the 1 rotations suggests that, despite the absence of explicit change detection, visual memory was incrementally updated with each change to reflect the most recently available scene information. Thus, comparison processes from one view to the next operated over representations of consecutive views, even though the current and immediately prior views were often significantly different from the original view. These results demonstrate an important dissociation between explicit change detection and visual memory. Following a change, visual memory is updated to reflect current perceptual information, even if the change was not detected.

Supported by NSF grants SBR 9617274 and ECS 9873531.

Abstract 253 4:00 PM

Taking a picture apart: Memory for backgrounds and objects in scene photographs

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After viewing thousands of images presented for a few seconds apiece, an observer can successfully distinguish old images from new ones (Standing, 1973). How is this accomplished? Do observers remember a list of objects? Do they remember the background (e.g. a beach)? In a variation of the standard picture memory experiment, we created photorealistic scenes of

natural settings, urban places and indoors spaces. These consisted of a background and three added objects consistent with that background. Subjects were presented with 60 of these scenes for 3 seconds each, and then immediately tested for their memory. Test stimuli could have the same background, a similar background (e.g. a different beach with a similar spatial layout), or a different background. The 3 objects, too, could be the same or all different. Subjects made two responses; one about the novelty of the objects, the other about the background. Even though these stimuli resemble each other more than the usual picture memory stimuli, overall performance was quite good (objects: 74% correct, d' = 1.37, backgrounds: 68% correct, d'=1.15). Poor performance was found in very specific situations. Whenever objects were incorrectly classified, performance on the background task dropped to chance. Whenever observers reported that an old background was new, they were poor at distinguishing old from new objects (d' = .41). These results would be consistent with observers simply forgetting some scenes entirely. However, when observers erroneously reported that a new background was old, classification of objects remained quite good (d'=1.02 or 0.85 depending on the type of new background). Clearly, observers can recall the global background and the local objects in a briefly presented scene. These sources of information interact asymmetrically. Forgotten objects predict a forgotten background, but a forgotten background may accompany remembered objects.

Supported by NIMH MH56020.

Abstract 254 4:15 PM

Boundary extension as a function of viewpoint in a virtual scene

Chris G. Christou & Ian M. Thornton UMIST, Manchester, UK, Max Planck Institute, Tuebingen, Germany

Subjectively, human perception of complex scenes appears to be fast and accurate but recent demonstrations of change blindness show that scene perception is not as complete as we think. Memory distortions have also been reported suggesting that the basis of apparent richness of our experience are perceptual schemas that allow fast perception of a scene without having to accurately encode everything in it. One such demonstration is Boundary Extension (BE; Intraub & Richardson 1989; JEP:LMC, Vol.15, pp179-187) in which observers appear to remember a greater expanse of a scene than was actually shown. For instance, if they are shown a close-up photograph of a child sitting on the stairs, they will later identify a wider-angle view of the scene as the original; suggesting the use of top-down extrapolation. The wider field of view apparent in BE is also consistent with an overestimation of viewing distance to the main subject of a scene. In our experiments we use interactive computer graphics in order to determine the origins of BE in 3D scenes. Subjects fixate one of 12 computer generated 3D representations of common objects that can be situated within a richly decorated setting of 3D virtual room. Initial 1s presentations depict these objects from one of three viewing distances (close-up, middle-distance and long-distance). After a 5s retention interval subjects are allowed to recreate their original view of the objects using a 3D joy-stick. Analysis of settings suggests that a perceptual schema explanation is too restrictive. Subjects' recreated views are a function of the original simulated viewing distance with under-estimation when the original view was long-distance and over-estimation (BE) when the viewing distance is close-up. Furthermore, results are also affected to differing degrees depending on whether the objects are initially viewed within the 3D setting and whether the setting is visible during subjects' recreation of the original view.

Abstract 255 4:30 PM

Scene representations in the parahippocampal place area are viewpoint-specific

Russell Epstein, Kim S. Graham, Nancy Kanwisher & Paul Downing MRC Cognition & Brain Sciences Unit, UK; MRC Cognition & Brain Sciences Unit, UK; MIT, USA; University of Wales, UK

Parahippocampal cortex has been strongly implicated in the processing of visuospatial information. For example, fMRI studies have demonstrated that the "parahippocampal place area" (PPA) responds significantly more strongly to visual stimuli that convey information about surrounding space (e.g. pictures of scenes and houses) than to stimuli that do not (e.g. pictures of faces and objects). However, many questions about the nature of the underlying representations in the PPA are unanswered, including the critical question of whether the PPA represents scenes in egocentric or allocentric spatial coordinates. We used an event-related fMRI adaptation paradigm to examine this issue. Subjects viewed events consisting of two successively-presented tabletop scenes which could have three possible relationships to each other: (1) they could be the same scene but containing different objects; (2) they could be the same scene shown from different viewpoints (egocentric-only spatial change); (3) they could be different scenes but containing identical objects (egocentric+allocentric spatial change). Based on previous results, we expected that the regional event-related fMRI response to each scene-pair would be greater if the two scenes differed along an informational dimension processed by the region than if they did not. The PPA response to egocentric-only spatial changes was equal to the response to egocentric+allocentric spatial changes. In contrast, response in the fusiform face area (FFA) and lateral occipital complex (LO) to object changes was greater than response to either kind of spatial change. These results demonstrate that (1) scene representations in the PPA are viewpoint-specific; (2) the PPA and more lateral fusiform regions such as the FFA and LO are differentially involved in processing spatial vs. object information within a visual scene.

Abstract 256 4:45 PM

When is scene recognition just texture recognition?

Laura L. Walker* & Jitendra Malik University of California, Berkeley, USA
*VSS 2002 Student Award

It remains unclear whether humans recognize scenes by using "diagnostic objects" or by using global attributes of the scene. Based on our work, we argue that not all scenes are created

equal and that varying levels of information are needed for recognition at different category levels. We hypothesize that there is a time course to scene processing. Global scene information may be accessed early and can be used for superordinate-level categorization, but recognition of "diagnostic objects" takes longer and is necessary for basic-level categorization. EXPERIMENT ONE: Subjects were asked to divide grayscale images into multiple sub-groups based on global visual similarity, while ignoring the object and scene content of the image. We found that the resulting sub-groups could be categorized at the superordinate-level as natural or man-made scenes, but categorization beyond that level was not achieved. EXPERIMENT TWO: Subjects were shown grayscale images of scenes, followed by two basic-level category choices. The task was to select the category that best described the image. When subjects were allowed to view the images for 150ms, they demonstrated nearly perfect performance. When the viewing time was reduced to 30ms, subjects made more errors categorizing man-made scenes than natural scenes. The distribution of errors revealed a higher level of confusion among indoor scenes. EXPERIMENT THREE: A simple texture-based classifier was tested and compared to human performance at 30ms. The classifier made similar errors, but was outperformed overall. Based on this result, it is clear that subjects are using more than just global texture to do basic-level scene classification in 30ms. CONCLUSIONS: Global properties of a scene, such as texture and shape, may be instructive in the early, superordinate-level categorization of scenes. Basic-level categorization may require more time and more information, such as the processing of "diagnostic objects".

Saturday PM Talks (South Hall)
Motion I

Moderators: Delwin Lindsey & David Burr

Abstract #	Time	Authors
257	1:30	Sperling, Lyu, Kim
258	1:45	Cormack, Stevenson
259	2:00	Lindsey, Denys, Brown, Orban
260	2:15	Burr, Ross
261	2:30	Shim, Cavanagh
262	2:45	Melcher, Morrone

Abstract 257 1:30 PM

Motion standstill in first- and second-order motion

George Sperling, Sonhee Lyu, & Hyungjun Kim University of California Irvine

Motion standstill is a phenomenon in which the pattern, color, texture, and depth of a rapidly moving stimulus can be perceived, but the stimulus appears to be standing still--the motion system fails while the other systems are still functioning. Motion standstill previously has been observed in various types of third-order motion displays, such as color motion (Cavanagh, Tyler, & Favreau, 1984; Lu, Lesmes, & Sperling, 1999) and stereo motion (Julesz & Payne, 1968; Tseng, Kim, Gobell, Lu, & Sperling, 2001). To discover motion standstill of first- and second-order motion, we used moving luminance and moving contrast-modulated-texture sine gratings. They were presented either centrally or peripherally, with various spatial and temporal frequencies (fx, ft). Gratings were slanted either +45 or -45 deg, moving either up or down (90 deg/frame). Centrally viewed gratings were circular discs whose edges were smoothly windowed to remove terminators' effect on motion judgments. Peripheral gratings were circular annuli with similarly windowed edges. In the second-order (contrast-modulated) displays, first-order (luminance) motion components were removed by individual calibration for each observer. Observers made both slant-discrimination and motion-direction judgments on each trial.

For each observer, with both first- and second-order stimuli, we found combinations of fx and ft that lead to phenomenal reports of motion-standstill. Forced-choice slant judgments were close to 100%-correct, whereas motion-direction judgments were at chance. Incidentally, we also found some spatiotemporal frequencies in which slant judgments were nearly perfect whereas motion direction judgments were significantly below chance-level, indicating motion-aliasing. The main standstill results further confirm Lu et al (1999) that pattern systems extract a single, stable representative view from a moving stimulus, a process that probably begins in the complex cells of visual cortex V1.

Supported by Air Force Office of Scientific Research, Human Information Processing Program.

Abstract 258 1:45 PM

Illusory reverse-motion from contrast modulation

Lawrence K. Cormack & Scott B. Stevenson U. of Texas, USA, U. of Houston, USA

Purpose: When a drifting grating is contrast modulated over time, a strong illusory percept of reverse motion occurs when the stimulus is near zero contrast. The purpose of this study was to demonstrate and understand this illusion. Methods: The primary stimuli used to explore the illusion were rotating radial gratings. The perceived motion of a contrast-modulated test stimulus was matched with a constant-contrast comparison stimulus containing adjustable motion reversals. We did several experiments exploring the effects of contrast modulation and contrast masking on the illusion, and we measured perceived speed as a function of contrast for test stimuli of constant contrast. Various qualitative observations were also made with other stimuli including radial noise that was uncorrelated across temporal contrast cycles. Results and Conclusions: The illusory percept builds over time but is inconsistent with a traditional motion aftereffect; the percept builds very quickly, and square-wave contrast modulation produces no illusion. An extrapolation of perceived speed vs. contrast functions does not provide a reasonable explanation for the illusion either. Decreasing the depth of the contrast modulation by changing either the maximum or minimum contrast attenuates the illusion. The temporal phase of spatially-interleaved, high-contrast masking noise strongly affects the illusion with

maximum attenuation occurring at pi-phase. Noise that is uncorrelated across temporal cycles produces a strong illusion, which obviates an explanation based on phase ambiguity across temporal cycles. The presence of a delayed negative afterimage additively interacting with the stimulus can qualitatively account for many of the observations, but the delay required is much longer than that typically reported between populations of cell types early in the visual pathway.

Abstract 259 2:00 PM

fMRI correlates of isoluminant motion perception
Delwin T. Lindsey, Katrien Denys, Angela M. Brown & Guy A. Orban Ohio State University, USA, K.U. Leuven, Belgium, Ohio State University, USA, K.U. Leuven, Belgium

We examined with fMRI (Siemens MAGNATOM Sonata, 1.5T) the proposal by Lu et al. (PNAS, 1999) that L- and M-receptor-mediated motion perception at isoluminance is due to a tracking-based motion processing mechanism. According to this theory, isoluminant gratings appear to move when differences in the relative salience of the alternating stripes of the moving grating produce features that can be tracked over time. Operationally, relative salience can be manipulated by varying the saturation of a greenish grating that is modulated isoluminantly in spatial antiphase with a 1.0 contrast red grating. We measured the BOLD response to monocularly viewed, eccentrically placed (5.0 deg. nasal visual field), Gaussian windowed (sigma x = 1.25 deg.; sigma y = 2.5 deg.), 0.5 cycle/deg. horizontal gratings that moved either up or down (3.75 Hz) or were stationary. We compared BOLD responses for moving vs. stationary low-, medium- and high-green-saturation gratings and for a luminance-modulated red/black control grating. Isoluminance for each saturation condition was determined in situ by motion photometry. All four motion conditions led to enhanced BOLD responses in contralateral V1 and bilateral V5+, relative to those obtained from their stationary stimulus counterparts. We also obtained a saturation-dependent variation in relative BOLD response in V5+: response was greater for low- or high- saturation than for moderate- saturation isoluminant gratings. These variations in motion-induced V5+ activation at isoluminance parallel the psychophysical findings by Lu et al. under similar isoluminant motion conditions.

Supported in part by NSF BCS-007-9277 to DTL and GOA 2000/11 to GAO.

Abstract 260 2:15 PM

Direct evidence that 'speedlines' aid perception of motion direction
David C. Burr* & John Ross Istituto di Neurofisiologia del CNR, Italy, University of Western Australia, Australia
*VSS 2002 Student Award

Geisler (Nature, 1999) proposed that streaks left in the wake of a moving object may be detected by orientationally selective mechanisms (with appropriate temporal integration) and used to help disambiguate motion direction. We have measured thresholds for discriminating the direction of motion of a field of moving dots superimposed on orientationally-filtered noise, oriented either parallel or orthogonal to the dot motion. Orthogonal noise had little effect on direction discrimination thresholds, while parallel noise raised them by a factor of about 8. The detrimental effect decreased with increasing orientation-bandwidth for the parallel noise, and increased with bandwidth for the orthogonal noise. Parallel noise specifically impeded motion direction discrimination, having virtually no effect on either contrast thresholds or speed discrimination. We also measured direction discrimination thresholds for random fields of dot pairs, that were oriented either coherently to form Glass patterns, or at random. Motion direction thresholds were considerably higher when the dot-pairs were oriented coherently and near the direction of motion than when they were oriented randomly. Similar results were obtained for motion along a spiral trajectory. The results provide direct evidence that motion traces, efectively 'speedlines', give information about motion direction that is used by the visual system. The presence of oriented masks, either in the form of orientation-filtered noise or coherent Glass patterns confounds this information source, either by reducing sensitivity to the motion traces or by producing false traces that mislead motion mechanisms.

Abstract 261 2:30 PM

Illusory displacement of flash location depends on the perceived direction of bistable quartet motion
Won Mok Shim & Patrick Cavanagh Harvard University, USA

Purpose: Motion can influence the perceived position of a nearby static flash (Whitney & Cavanagh, 2000) but these experiments used drifting luminance gratings that strongly activate passive, low-level processes. To investigate whether high-level processes also contribute to the position encoding of stationary objects, we measured the shift in perceived location of a test flash as a function of the perceived direction of a bistable quartet. Methods: Two flashes were briefly presented just outside the square defined by the four corners of the quartet display. The flashes were placed midway along two opposite sides (either left and right sides or top and bottom sides). The tests were presented in every second ISI so that the same direction of motion would be seen at each presentation. Subjects judged whether the direction of the quartet's motion was vertical or horizontal and then, over repeating cycles, adjusted the relative position of the flashes until they appeared aligned. Results: When the perceived motion of the quartet was vertical, the two horizontal flashes (to the left and right of the midpoint of the square defined by the quartet) were adjacent to the motion paths and showed a considerable vertical misalignment in the direction of the motion. However, when the perceived direction of motion was horizontal, along the top and bottom sides of the quartet, there was no illusory displacement for these same flashes. In contrast, the vertically aligned test flashes were displaced when the perceived motion was horizontal but not when it was vertical. Conclusion: Even though there was no change in the physical stimulus, the position shift of the test flashes was determined by the perceived direction of motion — as the motion organization changed, the direction of illusory location shifts followed. This result indicates that high-level motion processes can influence the position encoding of stationary objects.

Abstract 262 2:45 PM

Retinotopic temporal integration of motion across saccadic eye movements
David Melcher & Concetta Morrone U. Vita-Salute San Raffaele

Perceptual judgments of motion require information to be integrated over time. During integration, however, the visual input may be temporarily interrupted by occlusion from other objects, or suppressed during saccadic eye movements. We examined whether motion integration continued across saccades, or whether eye movements halted or otherwise interfered with the integration of motion across separate fixations. Observers viewed a motion 'patch' (8 deg) containing two motion intervals (translation, 10 deg/sec, limited lifetime dots) embedded in a stream of random noise, and made a directional discrimination judgment. Signal-to-noise sensitivity was measured for the two separate motion signals and compared to presentations of a single motion signal. The results indicated that the signal and noise periods were integrated over a period of hundreds of milliseconds up to one second. When a saccadic eye movement (2 deg) within the boundaries of the patch was made during a period of random noise, or during a blank background, there was still integration of the motion signals (and noise) from before and after the saccade. Saccades were always orthogonal to the direction of motion. In a further test, the entire motion patch (8 x 4 deg) was displaced immediately to the new fixation position before the saccade (4.1 deg). There was no spatial overlap of the two motion patches. Nonetheless, the motion signals from the two patches were integrated when the patches were in identical retinotopic positions. These results suggest that motion signals, unlike many other forms of visual information, can be retinotopically combined across fixations. Trans-saccadic motion integration, combined with the suppression of motion perception during saccades, may play an important role in the perceived stability of the world across eye movements. Acknowledgements: HFSP and COFIN-MIUR

Saturday PM Talks (South Hall)
Synesthesia/Binding

Moderators: Phillip Merike & James Enns

Abstract #	Time	Authors
263	3:30	Enns
264	3:45	Paul, Schyns
265	4:00	Arnold, Clifford
266	4:15	Ramachandran, Hubbard, Butcher
267	4:30	Butcher, Hubbard, Ramachandran
268	4:45	Merikle, Smilek, Dixon

Abstract 263 3:30 PM

Illusory feature binding in the standing wave illusion
James T. Enns University of British Columbia, Canada

When two video-frames are alternated at the appropriate rate, one with a central shape and the other with two flanking shapes, the central shape becomes invisible. An intriguing phenomenal aspect of this illusion is the mislocalization of visual features (shape, color, texture) in the central shape to the flanking shapes. Psychophysical experiments examined the spatial and temporal factors underlying these mislocalizations. Systematic explorations of contour proximity, frame duration, cycle time, and inter-frame interval revealed that (1) target visibility depends on relative frame duration, but that (2) feature mislocalization depends critically on a brief blank interval between two video-frames. This indicates that masking (target visibility) and binding (feature mislocalization) are separable aspects of the standing wave illusion. These findings are interpreted within the framework of masking by object substitution.

Abstract 264 3:45 PM

Attention modulates perceptual asynchrony in binding.
L.Paul & P.G.Schyns U. of Glasgow, U. of Glasgow

Researchers have reported a perceptual asynchrony when vision binds two separate sources of information to form a unitary perception. However, the determinants of binding remain unsettled. Here, we investigated whether spatial attention modulates the perceptual asynchrony between two sources of information to be bound (shape and color). If binding was fixed in early vision, the temporal asynchrony to bind color and shape would itself be fixed (Moutoussis and Zeki, 1997). In contrast, temporal asynchrony between the information sources should be found if spatial attention modulates binding.
We report a new method that directly manipulates the physical asynchrony between two information sources (source 1: alternation of red/green; source 2: alternation of square/circle) to determine when they are in perceptual synchrony vs. asynchrony. When the sources are perceptually synchronous, the observer perceives the alternation of the red square/green circle stimuli. When the sources are perceptually asynchronous, a new perception emerges (red circle vs. green square).
In each trial of a 2AFC discrimination task, a fixation cross appeared for 1 s, followed by one row of 6 linearly positioned colored shapes (e.g., all red squares) equally distributed left and right of the fixation cross. We manipulated attention with a non-predictive white cue presented for 67 ms above the middle left or middle right positions. All six stimuli would then alternate to, e.g., green circle, but in one randomly chosen position, information would be asynchronous (as described above). We tested 7 physical lags from 13 to 93ms between the two sources, to derive the critical lag required for the 75% correct discrimination of the emergent stimulus (e.g., red circle vs. green square).
Contrary to a fixed binding hypothesis, we found that attention to left and right positions modulated the perceptual asynchrony required to bind identical colors and shapes in discriminable perceptions.

Abstract 265 4:00 PM

Temporal dynamics of colour and motion perception
Derek H. Arnold & Colin W.G. Clifford Macquarie U., Australia. U. of Sydeny, Australia

When a stimulus oscillates in both colour and direction of motion, changes in colour must lag behind changes in direction if they are to be seen as concurrent1. It has been argued that this perceptual lag arises as a consequence of asynchronous neural activity1,2 with changes in colour being processed more rapidly than those in direction. This is a contentious proposal3, not least because an asynchrony of this form appears to contradict physiological evidence that suggests motion should be processed faster than colour. Here, we demonstrate that the extent of the perceptual lag is influenced by the prevailing stimulus conditions. The apparent asynchrony is greatest if the stimulus is composed of opponent directions of motion and is reduced if the angular difference between the directions is reduced. We believe that this pattern of results suggests that asynchronous neural activity arises as a consequence of differential levels of inhibition within relatively independent cortical structures. A further implication of this data is that the time course of neural processing may correlate directly with that of perceptual experience without any necessary mediation by subsequent interpretive processing. Of course this proposal does not explain how the time course of activity in distinct cortical structures might be introspected and contrasted so that temporal judgments can be made. To do so seems to require self-awareness and, while at this point we do not know how this might arise, assuming a singular temporal processing system does not necessarily clarify the issue.

1: Moutoussis, K. & Zeki, S. A direct demonstration of perceptual asynchrony in vision. Proc. R. Soc. B 264, 393 - 399 (1997). 2: Arnold, D.H., Clifford, C.W.G., & Wenderoth, P. Asynchronous processing in motion: Colour leads motion. Current Biology 11, 596 - 600 (2001). 3: Johnston, A. & Nishida, S. Time perception: Brain time or event time? Current Biology 11, R427 - R430 (2001).

Abstract 266 4:15 PM

"Higher" and "lower" forms of synesthesia may arise from cross-wiring at different cortical stages
Vilayanur S. Ramachandran, Edward M. Hubbard, & Peter A. Butcher Ceter for Brain and Cognition

Although synesthesia ("seeing sounds" or seeing letters and numbers tinged with specific colors) has been known for over 100 years, only recently has progress been made towards understanding its underlying mechanisms. We have previously demonstrated that synesthesia is a perceptual phenomenon, and suggest that, in some synesthetes, it may be caused by cross-wiring between V4 and the number grapheme area, both of which lie in the fusiform gyrus (Ramachandran & Hubbard, SFN 2000; 2001, VSS 2001). Roman numbers and subitizable clusters of dots did not evoke colors, suggesting that the visual grapheme is critical for the experience of colors. To explore this further, we presented graphemes in unusual fonts, in lower case, or made from unusual forms (i.e. a drawing of three cats to make up the form of an "A"). Synesthete JC reported that he still experienced the appropriate synesthetic colors, but lighter and "shinier." These results further show that the visual grapheme is critical for the experience of colors. However, we have also identified a second group of "higher synesthetes" in whom the colors are driven by the numerical concept (e.g., by Roman numerals). For these synesthetes, the experience of colors does not change depending on visual properties such as font. We propose that in this group of synesthetes, cross-wiring may occur near the angular gyrus, where higher color areas and more abstract number areas lie. Intriguingly, in some of these synesthetes, even days of the week and months of the year are colored. We therefore suggest that the angular gyrus may be involved in representing abstract sequences or ordinality, and this would explain why numbers, days of the week and month of the year are colored in these synesthetes. This heterogeneity has often led researchers to avoid studying synesthesia. Our results suggest that there may be an underlying logic to the phenomena, and may help to guide further research into the neural basis of synesthesia.

Supported by NIMH 1 RO1 MH60474 to V.S.R and NIMH 1 F31 MH63585-01 to E.M.H.

Abstract 267 4:30 PM

Top-down influences affect the experience of synesthetically induced colors.
Peter A. Butcher, Edward M. Hubbard & Vilayanur S. Ramachandran Center for Brain and Cognition

Some otherwise normal individuals experience sensations in one sensory modality when a second modality is stimulated. For example, a synesthete may see any given number as always tinged a certain color (e.g. 5, may be green and 6, may be red). We have previously shown that synesthetically induced colors can influence perceptual grouping, can lead to pop-out and are not affected by crowding (a form of blindsight). This suggests that synesthesia is a sensory phenomenon caused by cross activation of brain maps corresponding to color (V4 or V8) and graphemes, which lie adjacent to each other in the fusiform gyrus (Ramachandran and Hubbard, SFN 2000, 2001 VSS 2001). We now present evidence that top-down influences can also affect synesthetic colors. We find: 1) When presented with hierarchical figures (e.g., a large 5 composed of small 2's) the colors depend on where a synesthete focuses his attention (the exact experience differs depending on whether letters or numbers are used) 2) For synesthetes who experience letters in color, unitization (for example, missing the "f"s in "of") can affect whether or not a synesthete experiences colors for letters and 3) Most synesthetes report that imagining a grapheme evokes the corresponding color more strongly than actually seeing it. We tested two synesthetic subjects (JC and ER) on a variant of the Perky experiment, in which mental imagery interferes with visual perception. Subjects made a 2AFC identification of colored letters or numbers while imagining either consistent or inconsistent graphemes. When their performance with and without imagery were compared, synesthetes showed a much greater increase in threshold for detecting the presence of a grapheme when they were imagining another grapheme then did normals (a larger Perky effect). We therefore conclude that although synesthetic colors arise early in perception, they can also be influenced by top-down influences.

Supported by NIMH 1 RO1 MH60474 to V.S.R and NIMH 1 F31 MH63585-01 to E.M.H.

Abstract 268 4:45 PM

Synaesthetic photisms and memory
Philip M. Merikle, Daniel Smilek, & Mike J. Dixon U. of Waterloo, Canada, U. of Waterloo, Canada, U. of Waterloo, Canada

We describe a case study of C, an alphanumeric-colour synaesthete, who has an extraordinary memory for digits. When C views a black digit, it elicits a highly specific colour (i.e., photism) that is experienced as an overlay which conforms to the shape of the digit. In an initial experiment, we evaluated how C's synaesthetic photisms influence her immediate and delayed recall of digits. C and seven non-synaesthetes were presented with three matrices of 50 digits. One matrix consisted of black digits, and two matrices consisted of colored digits. One matrix of colored digits contained digits that were colored to be congruent with C's photisms for the digits, whereas the other matrix of colored digits contained digits that were colored to be incongruent with C's photisms for the digits. The results showed that C's immediate recall of the incongruently colored digits was considerably poorer than her recall of either the black or the congruently colored digits. Similar differences in the recall of the digits from the three matrices were not shown by any of the seven non-synaesthetes. Furthermore, when immediate and delayed (48 hours) recall of the black digits was compared, C showed no decrease in recall over time, whereas each of the non-synaesthetes showed a significant decrease in recall over time. In a subsequent experiment, we sought to rule out the possibility that C's superior delayed recall of the black digits simply reflected a general, above average memory ability. In this experiment, C and seven non-synaesthetes were presented with matrices of shapes that do not elicit color experiences for C. The results showed that unlike her superior delayed recall of black digits, C's delayed recall of shapes was no different than the delayed recall of the non-synaesthetes. Taken together, the findings clearly demonstrate C's extraordinary memory for digits and show that C's synaesthetic photisms influence her immediate and delayed recall of digits.

This research was supported by the Natural Sciences and Engineering Research Council of Canada.

Sunday

Sunday AM Talks (North Hall)
Attention and Memory II

Moderators: Steven Luck & David Irwin

Abs #	Time	Authors
269	9:00	Brockmole, Wang, Irwin
270	9:15	Becker, Pashler
271	9:30	Vogel, Woodman, Luck
272	9:45	Angelone, Levin
273	10:00	Luck, Woodman, Schmidt, Vogel, Vecera
274	10:15	Alvarez, Cavanagh

Abstract 269 9:00 AM

Properties of memory-percept integration
James R. Brockmole*, Ranxiao Frances Wang, & David E. Irwin U. of Illinois, USA
*VSS 2002 Student Award

The current research investigated whether visual memory and visual percepts can interact such that information from each source can be integrated to form a single representation. Two dot arrays were serially presented within a grid leaving one space empty which subjects identified. Past research has shown that when the delay is very short (<100 ms), the arrays are perceptually integrated and performance is excellent. Our goal was to determine if integration can also occur at longer delays where perceptual integration is not possible. Specifically, we investigated whether subjects could generate a visual memory of Array 1, retain it across the delay separating the arrays, and combine it with information obtained from Array 2. To test this, array separation ranged from 0 to 5000 ms. After a drop in accuracy from 0 to 100 ms due to backward masking, performance improved, reaching asymptote after 1500 ms as a memory for Array 1 was generated which could be combined with Array 2. Strikingly, accuracy after 1500 ms approached that when the arrays were perceptually integrated and reaction times indicated memories and percepts were integrated at the same speed that two percepts are integrated. The insertion of a probe-discrimination task showed that during the delay subjects assigned spatial attention / memory to the locations occupied by Array 1 as responses to the probe were faster when it appeared at a location previously occupied by Array 1 compared to when it appeared elsewhere. This assignment of attention or memory, however, was not strictly bound to the arrays' physical or spatial properties. Subjects were able to identify the location of the missing dot even when the arrays were presented at different locations and sizes. Thus, the memory trace of Array 1 can be transformed during the delay between the arrays to match the expected properties of Array 2. Implications of a memory-percept integration process on theories of visual memory will be discussed.

Abstract 270 9:15 AM

Volatile visual representations
Mark W. Becker & Harold Pashler University of California San Diego, USA

“Change Blindness” results suggest that visual representations may be sparse and volatile, providing no cumulative record of the attended items in a scene. However, these studies failed to control attention. Thus they cannot completely rule out the possibility that the visual representation of a scene contains a cumulative record of previously attended objects. Subjects may nonetheless fail to detect many changes because the changes involve items that were never attended to. In two experiments subjects saw 12-digit arrays and identified either the highest digit in the array (Experiment 1) or the lowest digit not in the array (Experiment 2). Subsequent change detection tasks revealed that subjects often failed to detect changes that involved the same digits they had identified in order to successfully perform the digit tasks. Results provide direct evidence against the cumulative record hypothesis and provide additional evidence that accessible visual representations are relatively impoverished and volatile.
Research supported by NSF (SBR#9729778), NIMH (MH45584) and a UC San Diego Faculty Fellowship.

Abstract 271 9:30 AM

The rapid time-course of visual working memory consolidation
Edward K. Vogel, Geoffrey F. Woodman, & Steven J. Luck University of Oregon, USA, University of Iowa, USA, University of Iowa, USA

'How long does it take to form a durable representation in visual working memory? Several theorists have proposed that this consolidation process is highly limited in capacity and very slow –taking upwards of 500 ms per item. However, these estimates of the "slow" consolidation process have been inferred from dual-task paradigms, and these paradigms may overestimate the duration of consolidation by including processes other than consolidation. In the present study, we sought to measure the time-course of the encoding process more directly, using a procedure in which consolidation is interrupted at various time points. This procedure allowed us to quantify the rate of information accrual in visual working memory. Specifically, observers performed a variation of a common change detection task, in which they were asked to remember an array of simple objects (colored squares) and compare them with a subsequent array. Shortly after the presentation of the first array, pattern masks were presented at the locations of each of the memory items. The masks were intended to disrupt representations that had not yet been consolidated, and the timing parameters were adjusted so that the initial identification of the squares was not impaired by the masks. Performance on this memory task revealed that encoding larger memory arrays required longer amounts of uninterrupted processing time than smaller arrays to reach asymptotic levels, which supports the general proposal that consolidation is highly capacity limited. However, the specific rate of consolidation was calculated to be near 50 ms per item, which is approximately an order of magnitude faster than previous estimates. These results indicate that forming a durable visual working memory representation is actually a relatively rapid process, and they pose a challenge to "slow" consolidation models.

This study was supported by grants from the National Institute of Mental Health (MH56877), the National Science Foundation (SBR 98-09126), and the Human Frontier Science Program (RG0136).

Abstract 272 9:45 AM

Visual short-term memory load and detecting feature changes
Bonnie L. Angelone & Daniel T. Levin Kent State University

Observers may demonstrate change blindness while having nonetheless represented the changing details. In our previous experiments, we found that observers who did not detect changes to actors in brief videos were sometimes able to recognize the actors in a lineup just as accurately as observers who did see the change. In the current experiment, we explore the hypothesis that this pattern of results can be observed when attention is directed at the changing actors while keeping visual short-term memory relatively free of the need to represent visual detail. Observers searched for simple (low VSTM load) or complex (high VSTM load) visual targets in a video depicting a conversation between two actors. Observers were also told that the cues may or may not appear on the body of one of the actors. Consistent with previous experiments, the task of searching for the cue increased change detection compared to situations where the task does not focus the subjects on the changing features. In addition, observers who searched for the complex cue detected significantly fewer changes than observers who searcher for the simple cue (45% vs. 64%). On the recognition test, observers in the complex cue condition were more accurate when they saw the change while observers in the simple cue condition were equally accurate whether they saw the change or not. This pattern of results suggests that the need to retain the visual details of a complex cue in VSTM can preempt representations of extra, noncompared, visual details that would otherwise allow successful recognition in the face of change blindness.

Abstract 273 10:00 AM

The effects of attentional capture on visual working memory
Steven J. Luck, Geoffrey F. Woodman, Brandon K. Schmidt, Edward K. Vogel, & Shaun P. Vecera University of Iowa, USA

Under some conditions, visual transients will automatically capture an observer’s attention. This has been demonstrated primarily in experiments that emphasize rapid perception. For example, reaction times are faster for a target stimulus that is preceded by a brief cue stimulus than for a target that is not

cued, even if the cue does not provide any information about the location of the target. The present experiments were designed to explore the effects of nonpredictive visual transients on the transfer of perceptual representations into working memory. In one set of experiments, we assessed whether objects accompanied by transients are more likely to be stored in working memory than objects that are not accompanied by transients. Under a variety of conditions, we found that transients significantly increased the probability that an existing perceptual representation would be transferred into working memory. In a second set of experiments, we assessed whether the effects of a transient would interact with the perceptual organization of the sensory input. Under a variety of conditions, we found that working memory performance was increased for objects that were perceptually grouped with an object that was accompanied by a transient. That is, when one element of a perceptual group was selected for transfer into working memory, other parts of the same group were also automatically transferred. In both sets of experiments, the transients were effective even if they occurred shortly after the to-be-remembered information, indicating that transients can automatically lead to the transfer of existing perceptual representations into working memory as well as influencing the formation of new perceptual representations.

Supported by grant MH63001 from NIMH and grant SBR 98-09126 from NSF.

Abstract 274 10:15 AM

The capacity of visual short-term memory is set by total information load, not number of objects

George Alvarez & Patrick Cavanagh Harvard University, Harvard University

Purpose: Is the capacity of visual short term memory limited by the number of objects that can be stored (4, Luck & Vogel,1997) or by the total amount of information? To address this question we estimated the memory capacity of a variety of materials using change detection and the information load of these same materials using visual search. Method: 6 subjects were tested on five stimulus classes (colors, polygons, Chinese characters, shaded cubes, and letters). In the change detection task, 1-15 items from one class were presented for 500 ms, followed by a 900 ms blank interval, and then by the test array. On half of the trials one item changed identity. The number of items yielding 75% correct detection of a change was used as the capacity estimate for that stimulus class. In the visual search task, a target item was presented for 500 ms, followed by a 900 ms blank interval, and then by the presentation of 4, 8, or 12 items of the same class, including the target on half the trials. The slope relating reaction time to set size for target-present trials was taken as the estimate of processing rate, and therefore information load per item, for each class. Here we assume that the more information that must be analyzed per item, the slower the search rate. Results: Memory capacity varied significantly over the 5 stimulus classes, ranging from 3.5 to 7 items. Visual search rate also varied markedly but in the opposite direction. Processing rate strongly predicted (r = .996) the inverse of capacity in each class. Conclusion: Memory capacity was not a constant in terms of number of objects but decreased as the information load (as indexed by search rate) of the items increased. Consequently, the capacity of visual short term memory is not fixed in terms of the number of objects, it is fixed in terms of the total amount of information (the product of the information load per item and the number of items that can be stored, minus a baseline capacity). Supported by NEI EY09258, Harvard Graduate Prize Fellowship.

Sunday AM Talks (North Hall)
Attention and Brain

Moderators: Brad Motter & Patrick Cavanagh

Abst #	Time	Authors
275	11:00	Motter
276	11:15	Rolls, Aggelopoulos, Zheng
277	11:30	Battelli, Cavanagh
278	11:45	Riddoch, Humphreys
279	12:00	Bonneh, Pavlovskaya, Soroker
280	12:15	Legge, Lee, Owens, Cheung, Chung

Abstract 275 11:00 AM

Crowding and object integration within the receptive field of V4 neurons

Brad C. Motter VA Medical Center - Syracuse NY, USA

Target detection is constrained during active visual search and during letter crowding studies by the proximity of neighboring stimuli to the target. Eccentricity (E) dependent spatial interactions between stimuli occur over a range of ~0.5 E. Cortical receptive fields (RF) capable of integrating across this range are first encountered in area V4. We investigated the impact of flanking stimuli on the responsiveness of V4 neurons to a stimulus centered in the RF. Fifty-five V4 neurons with RFs centered within 10 degs of the fovea and differentially responsive to a letter-like set of stimuli, 0.75 to 2.5 deg in length, were studied in monkeys. Attention was directed to the fixation point and not at the stimuli. Flanker spacing varied over a 0.0 to 6.4 deg range. Response interactions occurred only when flanking stimuli were within the classic RF. Interactions were not simple summations, and can be classified as either crowding suppression or integrative fusion. Crowding suppression occurred as soon as flanking stimuli entered the RF. The flanker(s) typically suppressed the response below that elicited by the centered stimulus when presented alone. The degree of suppression observed did not correlate with the difference in responsiveness observed for the center and flanking stimuli when presented alone. An integrative fusion, that reduced or reversed the suppression, could often be observed when physically identical flanking and center stimuli were separated by less than 0.5 deg. Sensitivity to stimulus size and shape could limit the degree of fusion observed. Stimuli that differed in color did not fuse. A series of flanking stimuli were chosen such that when they fused with the center stimulus a different member of the letter-like set was formed. Integrative fusions of this subset (spacing < 0.5 deg) could produce dramatic changes in responsiveness. Interactions were translationally

invariant within the RF. Supported by the Veterans Affairs Medical Research Program.

Abstract 276 11:15 AM

Reduced receptive field size of inferior temporal cortex neurons and reduced effects of attention when objects are selected in natural scenes

Edmund T. Rolls, Nikolaos C. Aggelopoulos & Fashan Zheng
U. of Oxford, England, U. of Oxford, England, U. of Oxford, England

To investigate how information is passed from the inferior temporal cortex (ITC) to other brain regions to enable stimuli to be selected from natural scenes for action, we analysed the responses of single and simultaneously recorded ITC neurons to stimuli presented in complex natural backgrounds. The macaques had to search for two objects on a screen, and a touch of one object was rewarded with juice, and of another object was punished with saline. The magnitudes of the responses of the neurons were similar when the (9x7deg) object was at the fovea in the real scene and with the plain background; but typically the receptive field sizes were much smaller in the real scene (36 deg) than in the plain background (65 deg). Simply introducing a second 10 deg stimulus into the experiment produced some of the effect produced by a complex background (with the receptive field reduced from 65 to 42 deg). In addition to these effects produced purely by introducing a background or second stimulus, attention also influenced the responses. When two stimuli were present in the plain background, the receptive field size was larger (42 deg) when a stimulus was a target for action than when the stimulus was not a target for action (24 deg). Interestingly, the effects of object-based attention were less marked when a complex background was
present. When smaller objects (4.5x3.5 deg) were used, the receptive fields became even smaller (e.g. extending less than 10 deg beyond the stimulus). Thus a reduction in receptive field size of inferior temporal cortex neurons is produced by a complex background, and this contributes to facilitating the read-out of information about objects from the inferior temporal cortex, with only a small additional role for object-based attention (see Rolls,ET and Deco,G, 2002, Computational Neuroscience of Vision, Oxford University Press).

Research supported by the Wellcome Trust and the MRC IRC for Cognitive Neuroscience.

Abstract 277 11:30 AM

Bilateral deficit of transient visual attention in neglect

Lorella Battelli & Patrick Cavanagh Harvard University, USA

Purpose: We have previously shown that right parietal patients are impaired at performing attentive tasks of apparent motion in both visual fields, not just the left field where they show other attention-related deficits. We hypothesized a loss in how their transient attention processes object appearance and disappearance. Method: To test this possibility we devised an experiment where six squares (three in each visual field) were flickering at the same temporal frequency and the target to be detected was flickering out of phase. The stimuli were reversed sinusoidally at temporal frequencies varying from 2-9 Hz. We used the method of adjustment and varied the temporal frequency progressively until the subject reported the target correctly. Results: Neglect patients showed a severe loss in both hemifields, while left parietal patients performed like age-matched controls. In experiment 1 the onsets and offsets of the target stimulus were always 180? shifted out phase with the distractors. Therefore the appearance and disappearance of the target and the distractors were aligned in time. In a control experiment we shifted the phase of the flicker in the test relative to the distractors such that the onsets and offsets were not aligned (the phase of the target's flicker was shifted 90?). The performance of neglect patients improved dramatically. Conclusion: Since these same patients detect flicker normally, we conclude that the deficit affects a higher level of processing possibly where attentional mechanisms assign transient onsets and offsets to the appearances and disappearance of objects.

Abstract 278 11:45 AM

Between-object action coupling influences visual selection: Neuropsychological evidence

Jane Riddoch & Glyn W. Humphreys U. Birmingham, UK; U. Birmingham, UK.

Visual extinction, associated with unilateral parietal damage, occurs when a patient can report a single unilateral stimulus but fails to report the same stimulus under bilateral presentation conditions. Prior studies have shwn that extinction can be reduced if bilateral stimuli group to form parts of a single object. In this study we demonstrate that extinction can also be reduced in parietal patients when separate objects fall in appropriate spatial relations for action. We failed to find similar reductions in extinction when stimuli were associatively but not action-related, and we failed to find effects of action relations when words rather than objects were presented to patients. The evidence suggests that action coupling can be used to 'glue' objects together for visual selection.

Abstract 279 12:00 PM

Slow binocular rivalry in hemispatial neglect

Yoram Bonneh, Marina Pavlovskaya, & Nachum Soroker
Neurovision Inc., Israel, Loewenstein Rehabilitation Hospital, Israel, Loewenstein Rehabilitation Hospital, Israel

Hemispatial neglect is considered to be a disorder, which is primarily related to space. Inability to allocate attention properly to spatial-coded stimuli is of its essence. Recent evidence shows that hemispatial neglect might incorporate impairment in temporal attention as well as in spatial attention. For example, it was found that extreme elongation in time of the "attentional blink" affects the perception of visual stimuli in midsagittal position in neglect. Here we show that the temporal deficit previously demonstrated with rapid perceptual events, is also reflected in a slow perceptual switching in binocular rivalry, a phenomenon that does not involve any perceptual load and is considered to be "automatic". Three groups of observers - normal controls, patients with left-hemisphere

damage without neglect, and patients with right-hemisphere damage with neglect, were tested on three aspects of binocular rivalry – alternation speed, contrast dependency and orientation preference. Observers monitored the perceptual alternations induced by two patches of orthogonal (horizontal and vertical) gratings presented to different eyes at varied contrast levels. Overall, neglect patients (right-hemisphere damage) had (1) much slower perceptual alternations (7-15 sec) as compared with normal (1-3 sec) or non-neglect patients (4-7 sec), (2) were more sensitive to contrast differences, with small changes in contrast altering both the suppression and dominance phases, and (3) had preference for horizontal gratings. We further found that the recovery from neglect correlated with shortening of the switching intervals. These results demonstrate a non-spatial fundamental disturbance in neglect: impairment in the temporal organization of the switching mechanisms, which seems to be crucial for proper environmental monitoring. At the same time, it demonstrates the critical role of attention in binocular rivalry.

Abstract 280 12:15 PM

Visual span: A sensory bottleneck on reading speed
Gordon E. Legge, Hye-Won Lee, Dan Owens, Sing-Hang Cheung, & Susana T. L. Chung U. of Minnesota, USA, U. of Minnesota, USA, U. of Minnesota, USA, U. of Minnesota, Indiana U., USA

PURPOSE. Visual span profiles are plots of letter-recognition accuracy as a function of letter position left or right of the midline. We hypothesize that the size of the visual span, summarized as the area under the profile, limits reading speed in normal and low vision. We tested this hypothesis by measuring the correlation between size of the visual span and reading speed for variations in the contrast, size and retinal eccentricity of letters.

METHOD. In one experiment, visual-span profiles and RSVP reading speeds were measured for 5 normally sighted subjects for letter contrasts ranging from threshold (1.5%) to 92%. In a second experiment, similar measurements were made for 3 subjects for letter sizes ranging from the acuity limit (4') to 4º. Finally, similar measurements were obtained from our previous published work for retinal eccentricities from 0º to 20º.

RESULTS. For all 3 data sets, reading speed covaried closely with the size of the visual span, with high correlations between log reading speed and area under the visual-span profiles. Both rose sharply at low contrast and leveled out at high contrast (individual correlations from .97 to .99). For character size, both peaked for middle values with a decline for small and large letters (individual correlations from .75 to .99). For eccentricity, both declined in peripheral vision (group correlation = .98).

CONCLUSIONS. Our findings are consistent with the view that reduction of the size of the visual span limits normal reading speed near the acuity limit, near contrast threshold, and in peripheral vision. Because most reading deficits in low vision are associated with losses in acuity, contrast sensitivity or field, our findings suggest that a reduced visual span is a key factor in limiting low-vision reading.

Supported by NIH grants EY02934 and EY12810.

Sunday AM Talks (South Hall)
Spatial Vision

Moderators: Preeti Verghese & Kathy Mullen

Abst #	Time	Authors
281	9:00	Beaudot, Mullen
282	9:15	Scharff, Ahumada
283	9:30	Baldassi,Verghese
284	9:45	Sowden, Ozgen, Schyns
285	10:00	Levi, Klein
286	10:15	Tse, Smith, Augath, Trinath, Logothetis, Movshon

Abstract 281 9:00 AM

Orientation selectivity in luminance and color vision assessed using 2-d bandpass filtered spatial noise
William H.A. Beaudot & Kathy T. Mullen McGill University, Canada, McGill University, Canada

Purpose. We evaluate the orientation selectivity of red-green and blue-yellow chromatic mechanisms using an external noise paradigm that allows the assessment of the internal orientation noise, the relative sampling efficiency, and the orientation bandwidth of the underlying orientation-tuned mechanisms.

Methods. The task required the measurement of orientation acuity (detection of orientation change) in a temporal 2AFC staircase method. Stimuli were patches of orientation noise defined in the Fourier domain multiplied by a Gaussian envelope in the space-time domain (σ_x = 1 deg, σ_t = 500 ms). Orientation acuity (σ_0) was measured as a function of peak frequency, spatial bandwidth, and stimulus bandwidth in orientation (σ_e). Internal orientation noise (σ_i), relative sampling efficiency (N), and orientation bandwidth $\sigma_e(\text{knee})$ of the underlying mechanism were derived by fitting the data with a noise model:

$$\sigma_0 = \sqrt{\left(\sigma_i^2 + \left(\sigma_e^2/N\right)\right)}$$ and

$$\sigma_e(\text{knee}) = \sqrt{N} \cdot \sigma_i$$

Stimuli were cardinal, isolating each of the three postreceptoral mechanisms, and matched in multiples of detection threshold.

Results. We find that orientation bandwidth and internal orientation noise are significantly greater in the chromatic than the achromatic systems. Preliminary results indicate that red-green orientation selectivity depends on the spatial properties of the stimulus (peak frequency and spatial bandwidth).

Conclusions. We conclude that color vision (red-green and blue-yellow) has a moderate deficiency in orientation selectivity. This may account for the small differences we have found between color and luminance vision on contour integration and shape discrimination tasks (Mullen et al, Vis. Res. 40, 2000; Mullen & Beaudot, Vis. Res., 2002).

Supported by CIHR Grant MOP-10819

Abstract 282 9:15 AM

Identification of filtered letters in filtered noise
Lauren F. V. Scharff & Albert J. Ahumada Stephen F. Austin State University,USA, NASA Ames Research Center, USA

Several researchers have investigated the effects of filtering letters and/or added noise on letter identification (e.g. Legge, Pelli, Rubin & Schleske, 1985 (letters filtered but no noise added); Parish & Sperling, 1991 (noise filter matched letter filter); Solomon & Pelli, 1994 (noise filtered but letters unfiltered)). This study compares the combined effects of high and low pass filtering on both letters and noise. Letters (Arial font, 24 pt) that were unfiltered, high- or low-band pass filtered (sharp cut off frequency of approximately 4 cycles per capital letter height) were presented in unfiltered, high- or low-band pass filtered noise (9 combinations). Three participants made 26-alternative, forced-choice responses for each of the 9 conditions (counterbalanced, blocked presentation) for both upper and lower case letters. For each condition, three replications of 30 trial threshold estimations were run, in which letter contrast was adjusted by a Quest algorithm. Averaged thresholds showed that for a given noise, unfiltered letters (the sum of the high- and low-pass letters) led to better recognition than either component filtered letter alone. However estimates for summation indexes in the different noises were strikingly different. In the wide band noise, summation was between linear and Euclidean. In high-pass noise, the summation was quite linear. But, for low-pass noise, there was no summation. Adding the low-pass letter component did not improve performance; high-pass letters in low-pass noise led to better performance than unfiltered letters in low-pass noise. The results qualitatively support a moveable single filter model where the filter band was moved most in the low-pass noise and least in the high-pass noise.

Supported by NASA RTOP 548-54-12.

Abstract 283 9:30 AM

Effects of cueing on the tuning function for orientation
Stefano Baldassi & Preeti Verghese The Smith-Kettlewell Eye Research Institute

Several studies suggest that attentional modulation can act very early on the visual system by changing the properties of units tuned to targets and/or distractors. If attention acts as early as in V1, either by enhancing the gain of the units seeing the target or by reducing the spread of the tuning function of such units, or both, then the signature of the responsible mechanism(s) can be revealed by using a masking paradigm. We devised a task that mixes the classical Posner and masking paradigms. The test was a vertical Gabor patch varying in contrast displayed in one of two intervals (2IFC) and in one of two locations on either side of fixation. The mask, a 'barcode' patch varying in contrast and orientation, was presented in both locations and overlapped the test. Attention was summoned through peripheral cues signaling the location of the test patch in the signal interval, and a random location in the noise interval. Comparing thresholds for parallel, orthogonal and no mask in the two attentional conditions showed a significant difference only with a parallel mask, which disrupted performance strongly. When the mask is orthogonal or absent, there was no difference between cued and uncued conditions. We then measured a tuning function by systematically varying the orientation of the mask. Interestingly, the width of the tuning function is unaffected by the attentional condition, whereas sensitivity increased by 50% when the cue signaled the test location. The results indicate that uncertainty plays little or no role in our task, as the cue is effective only under particular angle relationships between test and mask. Comparing the tuning functions under the two attentional conditions suggests that attention produces a pure signal enhancement. In fact, the width of the tuning function does not differ in the two conditions, showing a spread of about 40º, similar to previous physiological estimates.

This work was made possible by a NEI grant R01EY12038 to PV.

Abstract 284 9:45 AM

When a plaid is not a plaid: attentional modulation of spatial frequency processing
Paul T. Sowden, Emre Ozgen, & Philippe G. Schyns U. of Surrey, UK, U. of Surrey, UK, U. of Glasgow, Scotland

When an observer is cued to detect a sinusoidal grating presented at one SF their detection of an unexpected SF is impaired compared with when the same SF is expected (Sowden & Schyns, 2000, Perception, 29, s24). Further, these 'expectancy' effects are SF tuned consistent with their origin being top-down directed monitoring of early SF processing channels (Sowden, Özgen & Schyns 2001, Perception, 30, s91). These findings support the possibility that the task dependent selection of spatial scale in perception of faces and scenes (Schyns & Oliva, 1999, Cognition, 69, 243-265) also results from attentional modulation of spatial frequency (SF) processing.

Here we explore a direct analogy to the latter effects. Can expectancy effects cause orthogonal perceptions of the same plaid stimulus? In a sensitisation block observers were required to report the direction of tilt of a briefly presented (120 msec) single frequency grating (±30˚ relative to vertical) presented at luminance contrast threshold. The SF of the grating was either 0.5 or 8 c/deg. Prior to each trial an auditory cue signalled the SF of the forthcoming grating. Next in a test block, unknown to observers, plaid stimuli were randomly interleaved with sensitisation stimuli (1:3 ratio). The plaids were composed of the two single-frequency grating components combined orthogonally at the two different orientations (±30˚). We found that observers tended to correctly report the direction of tilt of the cued plaid component (71% of trials). Importantly, observers never reported

perceiving a two-component plaid but always perceived a single frequency grating.

Our finding of orthogonal perceptions of exactly the same plaid stimulus provides further evidence of top-down driven attentional modulation of SF processing.

This work was supported by BBSRC Grant No. 90/S13186 awarded to Paul Sowden & Philippe Schyns.

Abstract 285 10:00 AM

Noise provides new signals about the spatial vision of amblyopes

Dennis M. Levi & Stanley A. Klein UC Berkeley

Amblyopia results in a loss of contrast sensitivity, and position acuity. However, the nature of the neural losses is not yet fully understood. Here we report the results of experiments using noise to try to better understand the losses in amblyopia. In the first experiment, we used noise to measure efficiency for detecting a target and for discriminating its position in normal and amblyopic observers. Our results show a loss of efficiency for both detection and position in observers with amblyopia. To determine whether the loss of efficiency was a consequence of a mismatched template, we derived classification images for both tasks. We found that some amblyopic observers show markedly abnormal classification images for the position task, and moderately abnormal classification images for the detection task. The amblyopic position template, like that of the normal parafovea, is a low spatial frequency template, reflecting a shift in the spatial scale of analysis. Reduced efficiency in the amblyopic visual system may reflect a high level of intrinsic noise, a poorly matched position template, or both. To assess the level of internal noise we used a "double pass" technique, in which observers performed the identical experiment twice. The amount of disagreement between the two provides an assay of the observer's intrinsic noise, since the signals and the external noise are identical. Simulations enable us to parse the intrinsic noise into random noise and consistent noise, due to a poorly matched template. For normal observers, for both tasks, about 30% of the noise was random, and 70% consistent noise. Amblyopes show a much higher proportion of random intrinsic noise noise. We conclude that the loss of efficiency in amblyopia is due in part to a poorly matched template, but to a greater degree, to high levels of random intrinsic noise.

Supported by grants R01EY01728 and RO1 EY04776 from the National Eye Institute.

Abstract 286 10:15 AM

Using Glass Patterns and fMRI to identify areas that process global form in macaque visual cortex.

P. U. Tse, M. A. Smith, M. Augath, T. Trinath, N. K. Logothetis, J. A. Movshon *Max Planck Institute for Biological Cybernetics, Tuebingen 72076, Germany; +HHMI and Center for Neural Science, NYU, NYC, NY, USA; #Dartmouth College, Dept. of Psychological and Brain Sciences, Hanover, NH 03755 USA

We have used functional imaging methods to locate areas of the macaque brain involved in processing global form. For this purpose, natural objects are not ideal stimuli because their form-defining characteristics are difficult to isolate and control. Glass patterns, created by pairing each dot in a random texture with another at a specified spatial offset (Glass 1969, Nature), are useful because form is defined in patterns with identical local statistics purely by the global arrangement of dot pairs. Wilson et al (1997, VR) showed that concentric Glass patterns are processed more efficiently than other patterns, suggesting that there exist higher-order 'grouping' filters tuned to particular patterns of activation among local filters.

We generated different Glass patterns (concentric, radial, translational, and random) and used these to activate visual cortex in anaesthetized monkeys. We measured the resulting BOLD fMRI signals in a 4.7T scanner; voxel volume was 0.5x0.5x2mm. We collected 13 horizontal slices of the entire brain using multi-shot T2* weighted gradient-recalled EPI sequences.

All Glass patterns produced substantial BOLD activity in V1 and V2, and in favorable cases also in more anterior areas including V4. Further analysis suggested that despite their identical local statistics, different patterns produced different degrees of activation in some cortical areas, with concentric patterns usually producing greater activation than other patterns. This difference was most marked in anterior extrastriate cortical areas including V4, and suggests that these areas contain neurons selectively
sensitive to different global forms.

Sunday AM Talks (South Hall)

Stereo

Moderators: Bruce Cumming & Suzanne McKee

Abst #	Time	Authors
287	11:00	Read, Cumming, Parker
288	11:15	Cumming
289	11:30	Hayashi, Maeda, Tachi, Shimojo
290	11:45	Albert, Nakayama
291	12:00	McKee, Norcia
292	12:15	Vreven, Verghese, McKee

Abstract 287 11:00 AM

Simple cells can show non-linear binocular combination

Jenny C. A. Read, Bruce G. Cumming, & Andrew J. Parker National Institutes of Health, USA ; National Institutes of Health, USA ; University of Oxford, UK

Current models of binocular simple cells assume that input from left and right eyes is initially combined linearly. Model cells of this type underlie the successful energy model of disparity-tuned complex cells (Ohzawa et al., 1990, Science 249:1037). An alternative hypothesis is that input from each eye is passed through a threshold non-linearity prior to

binocular combination. This is physiologically entirely plausible – for instance, it would occur if some binocular simple cells receive input via monocular simple cells rather than directly from the LGN – and explains a number of observations. (i) We have shown previously (Read et al., 2000, Abstr. Soc. Neurosci. 26:1845) that using simple cells of this form in the energy model yields disparity tuning curves whose amplitude is reduced when the stimuli are anti-correlated, in agreement with experiment. The energy model predicts the same amplitude for anti-correlated as for correlated. (ii) For some cells, comparing monocular and binocular responses suggests that the input from one eye is always suppressive. This is hard to explain if binocular combination is linear. (iii) If the input from both eyes is excitatory, the pattern of the cell's response to disparate drifting gratings shows a distinctive dependence on interocular phase, changing from one burst of firing per stimulus cycle to two bursts at a particular interocular phase. Observation of such "frequency doubling" would be a strong indication that the postulated cells actually exist, but has never been reported. This may be because no one has looked for it, compounded by the difficulty of discerning such behaviour in data from awake animals. A study of our data revealed several simple cells which showed disparity-dependent frequency-doubling, supporting the view that binocular combination is non-linear in some cases.

This research was supported by the US National Institutes of Health and the Wellcome Trust.

Abstract 288 11:15 AM

Receptive field structure and disparity tuning in primate V1

Bruce G. Cumming LSR, National Eye Institute, NIH.

The disparity energy model successfully accounts for many properties of disparity selective neurons in the primary visual cortex. According to this model, the shape of the disparity tuning curve should reflect the shape of the underlying monocular subunits. For complex cells,the Fourier amplitude spectrum of the disparity tuning curve should be closely correlated with that of the monocular RF. Two previous studies found only a weak correlation between preferred monocular spatial frequency and the peak in the Fourier transform of the disparity tuning curve (disparity frequency). The extent to which this was the result of sampling variation was not assessed. A systematic comparison of monocular selectivity to spatial frequency and disparity tuning was therefore undertaken. Circular patches of sinusoidal luminance gratings were
presented monocularly to each eye at the preferred orientation. Disparity selectivity was measured with binocular random dot patterns, and the disparity was applied in a direction orthogonal to the preferred orientation (along the axis for which spatial frequency tuning was measured).

For many cells, the data fit well with the predictions of the energy model. However, the majority showed significant differences between the spatial frequency tuning and the Fourier transform of the disparity tuning. Most commonly the disparity tuning curve contained more power at low frequencies than was observed monocularly. In many cases a bandpass tuning response to monocular gratings was associated with a Gaussian (low-pass) disparity tuning curve. Also, many cells had disparity frequencies which were significantly lower than the preferred spatial frequency for gratings.

These data show that the existing form of the energy model cannot account for the disparity tuned responses of all V1 neurons. An initial stage of disparity energy detectors, followed by an appropriate combination of their outputs, could produce the results observed here.

Supported by the NIH.

Abstract 289 11:30 AM

A computational model of stereopsis that produces depth from interocularly unpaired points as well as binocular rivalry

Ryusuke Hayashi, Taro Maeda, Susumu Tachi, & Shinsuke Shimojo U. of Tokyo, Japan, U of Tokyo, Japan, U of Tokyo, Japan, Caltech, USA / NTT Com. Sci. Lab.s

Half-occluded zones (visible from only one eye) are found at every depth discontinuity in daily visual scenes. Even though such zones have no counterpart in the other eye (thus no disparity defined), they are perceived at a certain depth behind the occluding surface rather than causing binocular rivalry. Here we propose a mechanism detecting interocularly unpaired zones in each eye modeled after physiological responses of disparity selective cells and show a stereo algorithm that reconstructs 3D structures from not only interocularly paired but also unpaired points. In our model, we assume left and right unpaired point detection cells in addition to depth detection cells. These 3 types of cells cooperatively interact with each other depending on physical constraints (uniqueness, smoothness, occlusion) to estimate depth and determine which zones are unpaired. Moreover, since it is contradictory for monocularly visible zones to be visible in both eyes, we introduce mutual inhibition between left and right unpaired point detection cells. When input images including unpaired zones satisfy occlusion geometry, the model outputs the depth of the zones. The interesting finding is that when we input two different images to the eyes, the model shows an unstable output that alternates between interpretations of monocularly visible zones for the left and the right eyes, thereby reproducing binocular rivalry. Our results suggest that binocular rivalry is an erroneous output of a stereo mechanism that estimates the depth of half-occluded points. There are two general theories for what the rivals are in binocular rivalry: the two eyes, or representations of two different stimuli. We propose a new hypothesis that bridges these two: interocular inhibitions between representations of monocularly visible zones cause binocular rivalry. Unlike the traditional interocular theory, the level of the inhibitions here is after binocular convergence, thus open to a stimulus-specific mechanism.

Abstract 290 11:45 AM

Stereo thresholds for binocularly-matched opposite-contrast edges are close to those for same-contrast edges
Marc K. Albert & Ken Nakayama U. of Southampton, UK, Harvard U., USA

Recent models of human stereopsis include the constraint that binocularly matched edges must have the same contrast-polarities in the two eyes (Marr & Poggio, Pollard et al., Ohzawa et al.). The psychophysical evidence supporting this constraint is based on studies in which interocular reversals of edge-contrast were created by reversing the relative luminances of image regions (Treisman, Kaufman & Pitblado, Cogan et al.). These studies thus confound edge contrast-polarity with the relative luminance of adjoining surface regions. Here we simulate a common real-world viewing situation in which background surfaces are differentially occluded in the two eyes (Da Vinci stereopsis). In this situation, interocular reversals of edge-contrast can occur without changing the relative luminance of visible surface regions in the two eyes. Although 'qualitative' stereopsis has been previously reported using opposite-contrast edges, the stereo thresholds reported for opposite-contrast edges are roughly ten times larger than for same-contrast edges, leading to the view that opposite-contrast edges are processed by coarser mechanisms. Using our stereograms, however, we obtain stereo thresholds for opposite-contrast edges that are close to the smallest previously reported thresholds for same-contrast edges. We also show that the quantitative gain in depth as a function of binocular disparity is similar for our same-contrast and opposite-contrast stimuli. Matches between opposite-contrast edges in our stereograms could be signalled by tuned inhibitory cells (Poggio, 1995), or by cells sensitive to reversed contrast-phase in the two eyes, as reported by Anzai, Ohzawa & Freeman (1999). We also show that the ecologically-valid constraint of interocular consistency of relative surface lightness can be critical for stereopsis.

Abstract 291 12:00 PM

Dynamic topography of the response to monocular and binocular misalignment
Suzanne P. McKee & Anthony M. Norcia Smith-Kettlewell Eye Research Institute, USA

We mapped the global evoked response to monocularly- and binocularly-viewed contour misalignment, using a Geodesic Sensor Net equipped with 128 electrodes that completely blanketed the scalp. The monocular stimulus consisted of randomly-spaced vertical bars each containing multiple segments that were repetitively aligned and misaligned at a rate of 1 Hz. We paired the oscillating bars in one eye with static vertical bars in the other eye; the static bars were either straight or had large fixed offsets corresponding to the oscillating segments in the other eye. When fused binocularly, the observer saw rows of bar segments oscillating in depth interspersed with static segments. The Sensor Net measurements to the monocular oscillation showed a large response near the occipital pole, peaking at about 160 msec after the break in alignment. Over time, this monocular response spread to adjacent electrodes in front of and lateral to the occipital pole, so that by 250 msec after misalignment, activity was visible over two thirds of the scalp. When the monocular oscillating bars were paired with the static straight bars (creating a small disparity), the early occipital response was nearly identical to the monocular response. However, the late response in the lateral and frontal electrodes was greatly diminished. Binocular pairing with the offset static bars (creating a large disparity) virtually abolished the late response, leaving the early occipital response almost unchanged. While contour misalignment affects many cortical regions, the response to a disparate target is brief and confined to early visual areas. Movies of the development of the monocular and binocular responses will be shown.
Support: EY06644 to SPM; EY 12348 to AMN

Abstract 292 12:15 PM

Configuration effects in the stereoprocessing of 3D surfaces
Dawn Vreven, Preeti Verghese, & Suzanne P. McKee Smith-Kettlewell Eye Research Institute,US, Smith-Kettlewell Eye Research Institute, US, Smith-Kettlewell Eye Research Insitute, US

Recently (ARVO 2001) we showed that stereoacuity in 3D surfaces was affected by shape(flat vs. curved) and by the spatial distribution of disparity signals across the stimulus surface (disparate contours vs. random-dot stereograms). For equivalent amounts of disparity, curved uniform-luminance surfaces with disparate contours had much higher thresholds than flat uniform-luminance surfaces or curved random-dot surfaces. One explanation for this result is that spatially continuous disparity signals cause disparity detectors to interact. If an interaction does occur, it should be possible to measure its vertical and horizontal spatial extent. To this end, flat and curved 3D surfaces (2.3o sq.) were generated using vertically-spaced horizontal lines. Flat surfaces were depicted with up to 19.6' of standing disparity to equal the disparity of the most curved surface. Disparity thresholds were measured using observers' judgments of whether a line probe with variable disparity was in front of or behind the center of each surface. The vertical extent of interaction was estimated by varying the vertical spacing between the lines. The horizontal extent of interaction was estimated by replacing solid lines with segmented lines. The duty cycle was fixed at 50% while the segment length varied. Thresholds for surfaces with large curvature disparity were a factor of 2 higher than those for flat surfaces with equivalent standing disparity when lines were vertically separated by .5 deg. Thresholds for curved surfaces decreased dramatically, however, when line segments were horizontally separated by ~ .5 deg. These thresholds were indistinguishable from those for a random dot stereogram with the same overall luminance, ruling out disparity averaging to explain high thresholds. The spatial distribution the disparity signals has a profound effect on sensitivity. Disparity detectors respond optimally to signals separated by at least 1 deg vertically and .5 deg horizontally.

Sunday Posters Session: Visual Short Term Memory; 3D Shape; Binocular; Biological Motion; Classification Images; Event Perception; Illusory Contours; Imagery and Brain Systems; Lightness; Motion

Visual Short Term Memory

Abstract 293 B3.01

Capacity of short term implicit memory is larger than visuospatial working memory in visual search
Takako Yoshida, Hiroshi Ashida, & Naoyuki Osaka Kyoto Univ. & JSPS, Kyoto Univ., Kyoto Univ.

In visual search tasks using pop-out stimuli, memory of the target features and positions in the past trials affects the present search performance. This is called “priming of pop-out” or “repetition effect in visual search” in which facilitation for the repeated and inhibition for the changed lasts over the following three to eleven trials. It has been suggested that the number of trials the effects persist reflects the capacities of a memory system mediating the effect (Yoshida, et al., 2000, Jpn. J. Psychon. Sci.: Maljkovic & Nakayama, 2000, Vis. Cogn.). To compare the capacities and the stored representations between visuospatial working memory and the memory system, we used a modified visuospatial n-back task (Carlson, et al., 1998, Cereb. Cortex) concurrently with the visual search task. Observers’ task was to quickly respond to the shape of an odd-colored target in a display, and to judge whether the instructed one characteristic (color or position) of the current target was the same as the target that had been presented n trials before. Observers successfully performed color n-back task or position n-back task with the visual search task at most to the 2 or 3 trials back. This number implies capacity of the visuospatial working memory to the target characteristic. During each types of the n-back task, the reaction time in the visual search task showed robust priming effects lasting three to twelve trials with respect to “both” target color and position, showing there were three to twelve memory traces to the past target events and the memory contained several target characteristics independently of the n-back task’s demand. So representations which one can consciously store and update in visuospatial working memory are limited to past a few targets and to the task-relevant aspect of them, even though reaction time indicates our visual system represents more objects and their multiple characteristics.

Supported by JSPS to TY

Abstract 294 B3.02

Capacity limits in the detection and identification of change have implications for models of visual short term memory
Patrick Wilken & Jason B. Mattingley California Institute of Technology, USA, University of Melbourne, Australia

Observers typically have trouble reporting salient changes between two visual displays if they are presented in alternation, separated by a short blank interval. This phenomenon, commonly known as 'change blindness', suggests that the visual system maintains a relatively sparse representation of the world. Work in a number of research areas -- transsaccadic memory, visual-tracking, and visual short-term memory -- suggests that visual processing capacity is limited in many tasks to approximately 4-6 items. Here we report findings from an experiment in which observers were asked to detect and identify change in an array of coloured forms. In separate blocks of trials subjects were asked to detect and identify either a colour change (e.g., 'red' to 'blue') or a form change (e.g., 'L' to 'T') to one of the items in the array. As expected, the probability of detecting or identifying change in the form condition was much worse than in the colour condition. However, a lawful relationship was found between detection and identification rates in both conditions. These findings are inconsistent with a model in which limitations in the detection and identification of change are the result of a single underlying process, operating on a limited number of coherent objects held in a high-level working memory store. Instead, we suggest that detection and identification of change are separate processes that share a common low-level informational bottleneck.

Abstract 295 B3.03

Motion severely reduces capacity and life of object visual working memory
Jun Saiki Kyoto University, Japan

Visual working memory is said to hold a set of four coherent representations of objects (object files). However, their spatiotemoral characteristics are largely unknown. Using a paradigm called multiple object-permanence tracking (MOPT), which measures memory for feature-location bindings, this study revealed that “life” and capacity of object files critically depends on objects’ motion. Observers were asked to detect any color switch in the middle of regular rotation of a pattern of multiple colored disks behind a windmill-shaped occluder. Experiment 1 examined the effects of disks’ motion by manipulating the angular velocity of the disks using relative motion of the pattern and occluder, keeping the exposure and occlusion durations fixed. The color switch detection performance dramatically declined with the rotation speed. Experiment 2 evaluated the life of object files, by examining the effect of occlusion duration. The estimated life (.75 threshold) of four object files decreased from 1158 ms with the stationary pattern, to 56 ms with 126 deg/s angular velocity (about 1/3 r.p.s.). Experiment 3 evaluated the capacity using MOPT with target cueing used in multiple object tracking. Target disks selected from a set of 6 were cued by flash, and observers were asked to track only the targets. The estimated capacity declined from 5.1 disks in the stationary condition, to 2.1 disks in the 126 deg/s condition. Velocity and the number of targets affect the performance independently, which is inconsistent with the view that processing cost takes effects only above the capacity limit. The data could be accounted for by a probability summation model, where the number of targets and velocity independently affect the threshold. The characteristics of visual working memory dramatically change with spatiotemporal factors, and cognitive predictability is of

little use. The MOPT paradigm is a useful tool to quantitatively evaluate such dynamics. Supported by JMESC grants (11610075, 13610084) and JSPS-RFTF99P01401.

Abstract 296 B3.04

Serial position effects in visual short term memory
Andrea Reinecke & Jeremy M. Wolfe University of Leipzig, Brigham and Women's Hospital, Harvard Medical School

After being briefly presented with an array of simple items, observers seem to be able to retain a small number of these (~4) in a visual short-term memory (e.g. Luck & Vogel, Nature, 199, 390, 279). We looked for serial position effects in this type of memory by endogenously cueing a subset of items and then probing for memory of one of those items. In Experiment One, subjects viewed 20 colored spots. On each trial, 3, 6, or 8 of these spots were cued by a luminance increment. Items were cued, one after another, every 50, 150 or 300 ms. After the cue sequence, a single item was masked and subjects were asked to make a 5AFC decision about the color of the now hidden item. On 90% of trials, the probed item was chosen from the cued set. Ss responded at chance levels to the 10% of uncued probed items but at above chance level at all cued locations. Results show a strong "recency effect" with the last two cued items recalled more accurately than the other cued items. However, performance was above chance even for items that were early in strings of 8 Cues. There was no significant "primacy" effect favoring the item cued first. A visual memory capacity can be estimated by multiplying overall accuracy by the length of the string of cues. Estimates approach the "magic number" of 4, especially for longer strings at slower SOAs. We obtained comparable results in a second experiment using real objects in composed scenes. This supports the assumption that integrated objects, not merely single features are stored in visual short term memory. In an additional control experiment, verbal labeling was prevented by a distraction task. Results were similar, suggesting that verbal recoding is not the basis for the pattern of results.

3D Shape

Abstract 297 B3.05

PARAFOVEAL LIMITS OF SIMULTANEOUS AND SEQUENTIAL STEREO-SLANT DISCRIMINATION
Zhi-Lei Zhang, Ellen M. Berends, Yasuto Tanaka, & Clifton M. Schor U. of California at Berkeley, USA

This study compares stereo-slant discrimination thresholds of vertically separated random dot surfaces viewed either with or without saccadic gaze shifts. How is the stereo-slant perception affected by retinal eccentricity? Do eye movements lower thresholds even though they produce vergence fluctuations that introduce additional noise?
Stereo-slant discrimination was tested using random dot patterns (V 1.5 x H 8 deg). Yaw-slant was produced by horizontal magnification of one ocular image. Reference and test patches were presented for 167 ms each, either simultaneously or sequentially (ISI = 400 ms). The reference patch was centered at the fixation point and the test patch was presented at retinal eccentricities ranging from 1 to 16 deg above the reference. Condition 1: simultaneous targets were viewed with fixation maintained on the reference surface. Condition 2: sequential targets were also viewed with steady fixation. Condition 3: gaze was shifted between sequentially presented targets.
In conditions 1 and 2, thresholds were lowest for the smallest target separation, and remained constant over a small range of target separations. The threshold was lower for the simultaneous than sequential stimulus presentation. At larger target separations, threshold increased proportionally with the square of the retinal eccentricity. The knee where the constant and rising portions of the function meet occurs at a smaller retinal eccentricity for the simultaneous than sequential condition. This knee describes the retinal eccentricity at which position uncertainty exceeds the noise sources that determines threshold at the fovea. The function for condition 3 was flat and similar to the foveal threshold for the sequential condition 2. It indicates that noise introduced by vergence fluctuations associated with saccadic gaze shifts is smaller in comparison to the other noise sources limiting threshold.

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Abstract 298 B3.06

Screen cues to flatness do affect 3d percepts
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3d displays on digital media are often perceived as different from the portrayed object or scene, even when the display creates the “correct” 2d retinal images. In principle, there are at least three depth cues created by digital displays that could contribute to such distortions: 1) inappropriate focus cues, 2) pixelization, and 3) inappropriate motion parallax during head movements. We measured the contribution of these inappropriate screen cues to perceived slant by varying independently the slant specified by the computer graphics algorithm (“computed slant”) and the physical slant of the CRT on which the stimuli were presented (“screen slant”). Planes with different computed and screen slants were presented (tilt = 0 deg) and observers indicated the amount of perceived slant. Precise spatial calibration ensured that retinal-image shapes, texture gradients, and disparity gradients were determined by only the computed slant. Observers were unaware of the screen slant from trial to trial. Across different experiments, we examined the influence of display type (monocular vs. binocular), screen distance (30-200 cm), head stabilization (bite bar, chin rest, and free), amount of slant, and conflict between computed and screen slant. Screen slant had a significant effect on perceived slant in a wide variety of conditions. The effect was larger in monocular than in binocular viewing conditions, at short distances, with head unstabilized, and at large screen slants. We used regression analyses to determine the effective weight given inappropriate screen cues across the various conditions. These results show that inappropriate screen cues can have a significant effect on 3d percepts and that the size of the effect depends strongly on viewing condition.

Abstract 299 B3.07

3-D Structure in global flow stimuli

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A 3-D spiraling cylinder can be perceived when viewing a random-dot cinematogram (RDC) in which dots are assigned new directions of motion from a distribution spanning 90 deg because local motions consistent with an actual transparent 3-D spiraling cylinder are present in each frame of the display (Williams & Phillips, unpublished). We examined the effect of local motion duration on the strength of this 3-D percept.

Observers viewed RDCs comprised of 150 dots, each assigned a direction from a uniform distribution of directions spanning 90 deg (frame rate=100 Hz). Each trial, observers reported the perceived depth using a scale ranging from 0 (no depth) to 9. Individual dots changed their direction of motion after the number of frames specified by the duty cycle had elapsed. Exp 1 varied stimulus duration for duty cycles of 1 (direction change each frame) and another equal to the stimulus duration (no direction change). Exp 2 tested many duty cycles with duration fixed at 100 frames. Exp 3 varied direction distribution sampling resolution for duty cycles of 1 and 100 (duration = 100 frames). For each condition in a trial block (10 trials/condition), we computed a mean depth rating. Ten mean depth ratings per condition were collected for each subject in Exp 1 and 2, and 5 mean depth ratings per condition in Exp 3.

Overall, depth ratings increased with duration but perceived depth was lower for a duty cycle of 1. Perceived depth systematically increased with duty cycle, reaching asymptote at 10-13 frames. Sampling resolution of the direction distribution did not affect perceived depth. Our results suggest that local motion signal strength is critical to perceiving depth in these displays. The longer a dot travels in a consistent direction, the greater the strength of the local motion signal. The perceived-depth asymptote at duty cycles of 10-13 frames (100-130 msec) reflects the “strongest” local signal, consistent with motion detector cell integration times.

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Abstract 300 B3.08

Role of 3D Shape in Contrast Detection of Luminance Gratings

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Purpose: Studies on binocular contrast sensitivity have predominantly focused on flat, two-dimensional gratings. The underlying hypothesis of such studies is that contrast sensitivity is determined at the early stages of visual processing and is not influenced by the process of 3D shape recovery. However, it can be argued that contrast detection involves identifying changes in albedo of a 3D surface rather that strictly determining the presence of 2D luminance changes (Knill & Kersten, 1991). Therefore, if a sinusoidal grating aligns with a stereo-specified sinusoidal corrugation, it should be harder to detect than an identical grating that does not align with a corrugation. In effect, in the first case the grating would be interpreted as a shading pattern produced by illuminating a Lambertian corrugated surface, whereas in the second case the grating would be interpreted as a spatial modulation of the reflectance properties of the surface.
Method: Subjects were presented with random-dot stereograms representing 3D sinusoidal corrugations superimposed on low frequency luminance gratings. Gratings and corrugations were frequency-matched. The corrugation was either aligned with the grating, orthogonal to the grating, or flat. The task was to discriminate the presence of the grating from a uniform gray field.
Results: We analyzed the average difference between the measured d' for detecting the grating superimposed on the corrugated surfaces and the d' for detecting the grating on the flat surfaces. Consistent with our hypothesis, this difference was positive in the orthogonal case and negative in the aligned case.
Conclusion: Our results suggest that contrast detection does not exclusively rely on early detection of 2D luminance changes but that it involves later stages of visual processing concerned with 3D surface reconstruction.

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Abstract 301 B3.09

Surface-slant-from-texture discrimination: Effects of slant level and texture type

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The problem of surface-slant-from-texture was studied psychophysically by measuring the performances of five human subjects in a slant-discrimination task with a number of different types of textures: uniform lattices, randomly displaced lattices, polka dots, Voronoi tessellations, orthogonal sinusoidal plaid patterns, fractal or 1/f noise, "coherent" noise and a "diffusion-based" texture (leopard skin-like). The results show: (1) Improving performance with larger slants for all textures. (2) A "non-symmetrical" performance around a particular slant characterized by a psychometric function that is steeper in the direction of the more slanted orientation. (3) For sufficiently large slants (66 deg) there are no major differences in performance between any of the different textures. (4) For slants at 26, 37 and 53 degrees, however, there are marked differences between the different textures. (5) The observed differences in performance across textures for slants up to 53 degrees are systematic within subjects, and nearly so across them. This allows a rank-order of textures to be formed according to their "helpfulness" - that is, how easy the discrimination task is when a particular texture is mapped on the surface. Polka dots tended to allow the best slant discrimination performance,
noise patterns the worst up to the large slant of 66 degrees at which performance was almost independent of the particular texture chosen. Finally, our large number of 2AFC trials (approximately 2800 trials per texture across subjects) and associated tight confidence intervals may enable us to find out about which statistical properties of the textures could be responsible for surface-slant-from-texture estimation, with the ultimate

goal of being able to predict observer performance for any arbitrary texture.

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Abstract 302 B3.10

Neural correlates of judging 3D structure from motion
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Motion is an important cue in elucidating 3D-structure of complex objects. Previous fMRI work comparing 3D rotating and 2D translating line patterns in passively viewing subjects indicated that an occipito-parietal network, including hMT/V5+, may be involved in extracting depth-from-motion (1). In the current fMRI-study, discrimination tasks were used to test to what degree these regions were involved in processing 3D shape rather than 3D motion contained in the displays. Stimuli consisted of rotating, randomly deformed, textured spheres and featural attention was directed to either shape-from-motion, to motion (judging rotation axis) or to the texture by means of a same-different task performed on each of these attributes. Two control conditions in which either central or peripheral luminance dimming (present in all conditions) had to be detected were also included to control for visuospatial attention effects. Random effects analysis on fMRI data from 12 human subjects revealed shape specific activation in a bilateral lateral occipital area, posterior and superior to hMT/V5+. A bilateral inferior satellite of hMT/V5 was also specifically activated in the shape task, while shape and motion tasks activated bilateral hMT/V5 proper equally. Shape also engaged right anterior fusiform cortex, which was also active in texture, but not motion. Activation in the dorsal parietal cortex common to motion and shape was observed in two sites: one posterior along the intraparietal sulcus was slightly more active in shape and one anterior and lateral from IPS was slightly more active in motion. These results show that attention to 3D shape extracted from motion activates a subset of the passive viewing network together with ventral regions.
1 Orban GA, Sunaert S, Todd JT, Van Hecke P, Marchal G (1999) Human cortical regions involved in extracting depth from motion. Neuron, 24:929-940.
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Abstract 303 B3.11

Eye movements and lateral translation disambiguate the perceived direction of kinetic depth rotation
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Purpose: The rotation of a kinetic depth (KD) figure in parallel projection is perceptually ambiguous. Additional information, i.e., binocular disparity, can disambiguate the perceived rotation. As recent work suggests eye movements have a role in depth assignment in motion parallax, we wondered if eye movements might also disambiguate the perceived rotation of KD figures. That is, for motion parallax, retinal motion in the same direction as the eye movement is assigned to near depth while motion in the opposite direction is perceived as farther than fixation. If this were to apply to KD, then a KD figure translating from left to right should be perceived as rotating "front to right" and translation to the left generating rotation "front to left".
Method: Stimuli were rotating, random-dot KD figures. The task was to report the figure's perceived direction of rotation. Direction of rotation (front to right/left) and direction of translation (left/right) varied between trials. In the first and third conditions (C1 & C3) observers used LCD glasses and frame sequential presentation to view "stereo" KD figures. In conditions two and four (C2 & C4) observers viewed KD figures monocularly. Observers fixated a stationary spot just below the figure's path in C1 and C2, and fixated a point translating along with the figure in C3 and C4. Trials from C3 and C4 were randomly interleaved in an attempt to obscure to the observers the covariation of translation and rotation predicted in the KD trials.
Result: Binocular disparity was effective for disambiguating KD rotation: 91% with stationary eyes (C1) and 96% with eye movements (C3). Eye movements were equally effective in disambiguating KD rotation: 98% in C4. It was unexpected that translation of the KD figure, without eye movements, was almost as effective: 90% in C2.
Conclusion: Eye movements and lateral translation disambiguate KD rotation as well as binocular disparity. The actual effect of each remains to be determined.

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Abstract 304 B3.12

Processing shape, motion, and three-dimensional shape-from-motion in the human cortex
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Primate visual cortex is segregated into at least two functionally discrete pathways - one that processes motion information and one that processes shape information. However, object motion is a powerful cue for the perceptionof three-dimensional (3D) shape, implying that the two types of information - motion and form - are well integrated.We conducted a series of fMRI experiments aimed at identifying the brain regions involved in inferring 3D shape-from-motion cues. For each subject, we identified regions in occipital-temporal cortex that were activated when perceiving: (1) motion in unstructured random-dot patterns, (2) 2D and 3D line drawing shapes, and (3) 3D shapes defined by motion cues (shape-from-motion, SFM). We found non-overlapping, adjacent areas activated by random motion and line drawing shapes. In addition, we found that SFM stimuli significantly increased activity in only one of the areas identified with either the random motion or line-drawing stimuli, the superior lateral occipital (SLO) region, indicating this area may be important for integrating motion and form information. Closer analyses suggest that SFM and line drawings are processed in separate but closely located sub-regions in SLO. Expanding the

analysis to the entire cortex identified a parietal area that had overlapping activity to SFM and line drawings and increased activity to 3D versus 2D shapes. We suggest this area is important for integrating shape information from cue-dependent lateral occipital regions. We also observed significant activity reductions in primary visual cortex (V1) when visual elements (motion vectors and line segments) were grouped into objects, suggesting that activity in early visual areas is reduced as a result of grouping processes performed in higher areas.

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Abstract 305 B3.13

The effect of a reference on eye-movement-induced distortions of motion-defined shapes

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In ARVO 2001, we showed that the perceived shape of a spatiotemporally-defined 2D object reflected the content of the retinal rather than physical image during pursuit eye movement (i.e., a rectangle appeared as a parallelogram). Would the presence of reference patches surrounding the target rectangle improve shape perception? If shape perception were to utilize the relative position information of the references, the perceived shape should be a rectangle rather than a parallelogram. We manipulated both the contrast of the reference patches as well as their distance from the target. Subjects tracked a dot moving horizontally over a rectangle which was defined by the occlusion of a vertically moving bar, and they reported the perceived shape of the target by adjusting a comparison shape. In a separate session, subjects also reported the position of the top/bottom side of the target relative to the references. Both shape distortions and positional biases in the direction of pursuit were observed even with the reference patches. However, the amount of shape distortion and positional error decreased as the reference patches increased in contrast and became closer to the target. Interestingly, when there was no gap between target and reference, shape distortions were observed even though there were no localization errors. These results imply that the visual system uses object-relative information to improve shape perception, and that the shapes of spatiotemporally defined objects are processed independently of the position of the local elements comprising the objects.

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Abstract 306 B3.14

Texture synthesis for 3D shape representation

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If we could design the perfect texture pattern to apply to any smooth surface in order to enable observers to more accurately perceive the surface's shape in a static monocular image taken from an arbitrary generic viewpoint under standard lightingconditions, what would the characteristics of that texture pattern be? In order to gain insight into this question, our group has developed an efficient algorithm for synthesizing a high resolution texture pattern (derived from a provided 2D image, e.g. from the Brodatz album) over an arbitrary doubly curved surface in such a way that both seams and projective distortion are practically eliminated, and, most importantly, the orientation of the texture pattern is constrained to follow an underlying vector field over the surface at a per-pixel level. We are using this algorithm to generate stimuli for a series of experiments investigating the effects of various texture characteristics, including orientation, on surface shape judgments. The results of earlier studies that we conducted using a more restricted class of uni-directional texture patterns seemed to support the hypothesis that shape perception is most severely impeded when the texture pattern consists of lines that turn in the surface, and that shape perception is not significantly different in the case of a texture pattern consisting of lines that are locally aligned with the first principal direction than in the case of an isotropic texture pattern of similar spatial frequency. Our new texture synthesis method enables us to extend these studies to a much broader class of textures, including patterns that contain 90-degree rotational symmetry, which is useful in enabling us to maintain continuity in a principal-direction oriented pattern as it passes through umbilic points where the first and second principal directions switch places. Images are available at www.cs.umn.edu/~interran/texture. Upon publication, our software will be made available via the web.

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Abstract 307 B3.15

Perceptual asymmetry in solid shape perception

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Iso-perspectival solids are physically distinct 3-D objects which project to the same image, e.g. a cube at eye height is iso-perspectival to a family of shapes created from it by applying a shearing affine transform along the line of sight. Griffiths & Zaidi (2000) found that cubes sheared away from the observer were misperceived as regular upright cubes, but cubes sheared towards the observer were perceived veridically. We hypothesized that the percepts were influenced by the ground plane, and we now investigate the effects of stimulus contact with neighboring surfaces.

Stimuli were sheared cubes, presented at eye level so that the closest edge to the observer was either vertical, or oriented towards or away from the observer. Stimuli were mounted either on top of a horizontal planar "floor", underneath a "ceiling", or were "free-floating" without a visible support. Gauge measurements of the perceived orientation of the closest edge of these stimuli were used as estimates of perceived shape.

Stimuli with vertical edges were perceived veridically. For other stimuli, the closest edges of free-floating stimuli were consistently perceived as vertical, independent of stimulus shape. Floor-mounted and ceiling-mounted stimuli exhibited bistable percepts in which the perceived edge orientations fluctuated between slants towards or away from the observer. Slant was underestimated by up to 50%. However, stimuli in

which the mounted face was farther from the observer than the opposite face were more likely to be perceived veridically. Under perspective projection, the edges of the physically closer top or bottom face of these sheared cubes will be wider in the image than those of the farther face. If the leading edge is inferred to be vertical, the perceived shape will be wider at the top or bottom. It appears that observers accept a prior assumption that edges are vertical for shapes which contact a surface at their widest edges, but reject it for the opposite configuration.

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Abstract 308 B3.16

A mechanism in striate cortex for coding shape from motion

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PURPOSE: We have shown (ARVO 2001) that some simple cells in striate cortex of cat have space-time response domains whose orientation changes across space. This implies that the optimal stimulus for these cells is an accelerating or decelerating bar moving broadside. Here we propose a possible mechanism for this selectivity and compare model measurements with those of measured cells. METHODS: We modulated luminances at 16 receptive field positions, simultaneously and independently with 3-level "white noise". We computed linear space-time responses and 2-bar nonlinear interactions from extracellular responses. We also modeled the linear responses of cells showing acceleration or deceleration selectivity by choosing two inseparable filters from a motion energy model, but with different slopes in the upper and lower regions of the receptive field. We tested both simple cells and models with a stimulus array of mean-velocities vs delta-velocities that covered a wide range of accelerations and decelerations. RESULTS: A simple model with two velocity selective subunits, each followed by a soft threshold, was capable of mimicking the linear selectivity of a cell for accelerating or decelerating stimuli. Whether the model preferred acceleration or deceleration depended on the spatial order of the subunits. When 2-bar interactions were computed for the two models with different spatial order, each model showed the same selectivity as in two simple cells each that preferred acceleration or deceleration. Selectivity for acceleration or deceleration agreed between the linear and nonlinear measures of both models and cells.
CONCLUSIONS: A possible
mechanism for decoding shape from motion in single cortical cells is for a receptive field to have a small number of subunits with progressive differences in preferred velocity across space. Even two subunits capture both the linear and nonlinear signature of some simple cells in responding to accelerating or decelerating stimuli.

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Abstract 309 B3.17

The influence of object size on shape from stereo

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The perception of shape from binocular disparities is often not veridical (e.g. Johnston, 1991). We investigated the generality of this result for objects which varied in size and surface shape. Observers performed a shape judgement task for 3 differently shaped surfaces and 5 different sizes. Stimuli were random-dot stereograms. The shapes were a) elliptical hemi-cylinders, b) triangular ridges and c) frontoparallel rectangles, all horizontally oriented against a random dot background. All had a constant width but varied in height. Stimuli were presented with a range of depths and observers were required to judge whether the depth was less than or greater than the half-height. For the hemi-cylinder this was equivalent to judging whether it appeared squashed or stretched compared to a circular cylinder. For the triangular ridges this was equivalent to the task of judging whether the apex was greater than or less than 90 degrees. The point of subjective equality (PSE) was obtained for each shape at each size. When comparing across shapes, it was generally found that the disparity-defined depth at the PSE increased in the order: frontoparallel rectangles, triangular ridges, cylinders. In other words, cylinders were perceived as the flattest, then the ridges and the rectangles were perceived as having the greatest depth. Comparing across sizes showed that in most cases the PSE was larger for the bigger objects than the smaller objects, indicating that larger objects are perceived as flatter than smaller objects. Thus both size and shape influence the interpretation of disparity. Our results suggest a number of factors that affect performance in this task: availability of disparity gradients, cue combination with conflicting texture cues, the misperception of half-height with changing height:width ratios and individual differences in subject strategy.

Abstract 310 B3.18

Binocular perception of shape from shading/contour is invariant under ordinal transformations of image intensities

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How light interacts with a matte surface depends on the material structure of the surface, notably its roughness (Nayar & Oren, 1995, Science, 267, 1153). This dependence complicates the recovery of shape from shading since visual image intensities depend on not only object shape and lighting model, but also on the (unknown) surface material. A possible solution is to base shape reconstruction primarily on the (local) ordering of intensities in the visual image. Todd & Reichel (1989, Psychol Rev, 96, 643), among others, have suggested that human visual estimation of shape from shading in achromatic scenes depends primarily on this ordering information (and should, therefore, be insensitive to non-linear transformations of image intensity that preserve intensity order). We test this hypothesis for binocular shape from shading/contour.

Experiment 1: We rendered stereo image pairs of scenes each containing one of ten achromatic matte ellipsoids differing in shape. We transformed the normalized image intensities in both images of each stereo pair by a common power function with coefficient 0.75 or 1.25. Four observers viewed each of the twenty resulting stereo pairs in a Wheatstone stereoscope and estimated the surface orientation at one pre-selected point on each ellipsoid by adjusting a monocular gradient probe. Each setting was repeated 10 times. The order of presentation was randomized. We compared the gradient settings at corresponding points on each ellipsoid when the coefficient was 0.75 and when the coefficient was 1.25. We found no significant effect of transformation on observers' judgments of gradient.
Experiment 2: We repeated Experiment 1 with more extreme power transformations (0.5,1.5). Three observers participated. We again found no discernible effect of these transformations. Our findings are consistent with the claim that human observers use only the order of luminance values in binocular shape from shading and contour.

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Abstract 311 B3.19

Multiple regression reveals 3D internal surface representations
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It is generally believed that surface-based representations bridge the perceptual gap between low-level image features and high-level scene categories. Here we propose a new method to investigate these representations.
First we show that the perception of complex 3D surface configurations can occur in a purely top-down manner, that is in the absence of structured local signals. Observers were asked to indicate the presence or absence of a such a configuration (a large '+' in relief) in random-dot stereograms which, unbeknownst to them, contained only disparity white noise. Both halves of the random-dot stereograms subtended 2.470 x 2.470 deg of visual angle and were composed of a white background filled with 700 black texture elements each spanning 0.048 x 0.048 deg of visual angle (3 x 3 pixels). Each texture element was randomly positioned in the left eye and was shifted in the right eye equiprobably by either -0.963 (one pixel to the left) or 0.963 (one pixel to the right) arcmin. The number of texture elements (average black to white pixel ratio = 0.232) and their perceived depth (approximately 9 mm in front or behind the screen) were chosen such that a noisy cloud of dots was the dominant percept. Even though no signal was ever presented, observers detected, and reported that they could see, the target in an important proportion of the 20 000 stereograms to which they were exposed.
Second, using least-square multiple regression, we revealed the internal 3D surface representations, or more precisely the Wiener kernels, that best accounted for the observers' responses in the least square sense. The templates were shown to be spatially well defined and to be very stable across trials. Multiple regression has therefore allowed us to reveal pure (uncorrupted by low-level signal) 3D internal surface representations.

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Abstract 312 B3.20

Cortical responses to layout change specified by two pictorial cues: An fMRI study
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Humans perceive depth from various types of visual information: binocular cues; motion carried cues; and static monocular or pictorial depth cues. Although the neurological substrates of these processes may differ, it is reasonable to hypothesize that at higher levels of processing the perception of depth converges to common cortical locations. Our study used functional magnetic resonance imaging (fMRI) to investigate the neural correlates of the perception of depth specified by two pictorial depth cues: the T-junction cue (interposition), which provides information for depth order; and linear perspective, which provides information for surface slant. These cues were used to generate two displays that varied in spatial layout: T-junctions specified two sets of cubes that differed in their depth order. Linear perspective specified two different surface slants corresponding to a floor and a ceiling. Within 30s blocks, displays employing the same depth cue alternated with each other every two seconds. Blocks of the T-junction figures and blocks of the linear perspective figures were randomly presented in the same 8 minute scan along with control displays. Control displays were matched to each individual depth cue display. That is, they contained the same number of lines, matched in orientation and length, with the lines repositioned to eliminate depth information. Statistical parameter maps were generated using the general linear model. Cube displays containing T-junctions consistently showed more activation bilaterally in the occipital and parietal regions than their controls, including areas MT+. However, subtracting control condition from displays based on linear perspective showed less robust activation in the occipital and parietal areas.

Binocular

Abstract 313 B3.21

The Binocular Neural Mechanism: Gnostic and Population Coding
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Purpose: Stereo thresholds usually increase rapidly as the pedestal disparity on which thresholds are measured grows. Recently, however, Farell (ARVO, 2001) found a dip in the disparity increment function for narrow bandwidth patterns: Thresholds are lowest off the horopter. Here we investigate possible neural mechanisms underlying this phenomenon.

Method: A full column of 11248 complex cells was used in the simulation (16 frequencies X 19 orientations X 37 disparity phase angles). Cells were modeled after the energy units of Ohzawa & Freeman. Stimuli were gabors; disparity was a shift in carrier phase between the eyes. In the simulation information is integrated hierarchically, first over neurons with the same orientation and frequency but different preferred disparities, then across neurons sharing only frequency tuning, and finally across different frequencies.

Results: We found that, contrary to current thinking, psychophysically measured sensitivity to changes in disparity may reflect the most active neurons (gnostic coding) rather than the neurons whose responses vary the most. Neurons showing the greatest variation can be tuned to any disparity, not just near the horopter. However, the envelope of the most active neurons can account for the psychophysical measurements. The slope of this envelope is shallow at the horopter, reaches a maximum at a phase shift of about ±45 , and then falls again. This gives the dipper.

Conclusion: Using the complex cells found within a full cortical column, we find a basis for the dipper function for disparity increment thresholds. The dipper follows the envelope of neural activity. We also find that each complex cell can be regarded as a gnostic unit (aka grandmother cell). This results from the high correlation between the neurons' phase difference and the gabor phase difference. Population coding is also supported, for psychophysical performance follows the envelope of neural activation.

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Abstract 314 B3.22

The effect of disparity/vertical-scaling conflict in a stereoacuity task

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Purpose. The precision with which the relative depth of two vertical lines is judged, can be as little as 5 arcseconds. However, McKee (Vision Research 23,1983) showed difficulties in detecting relative depth when the vertical lines are perceptually linked in some fashion; for example, when they form part of a real or imaginary square. McKee's stimuli were of a constant physical length, and thus not scaled according to the changes in depth signalled by horizontal disparity. Thus it is possible that the two depth cues conflicted. Methods. Two vertical lines or horizontally connected vertical lines were viewed in a modified Wheatstone stereoscope and stereoacuity was measured using a 2AFC paradigm. Each observation interval was 1 s. Two sizes, either 25` or 3? were used, and three conditions were tested: a) both the horizontal disparity and the vertical scaling associated with real rotation in space were available to the observers, b) vertical scaling consistent with the rotation was removed, c) vertical scaling alone was available. Results. 1) When disparity and vertical scaling provided mutually consistent information about relative depth, stereoacuity for lines was only slightly better than that for the closed configuration. 2) Conflicting vertical scaling information had little effect on stereoacuity for lines, but it overrode disparity information when closed configurations were used. 3) Vertical scaling alone proved an effective depth cue when the lines were connected, but not when they were separate. 4) The impact of vertical-scaling manipulations was bigger for larger stimuli. Conclusions. A disparity\vertical-scaling conflict, introduced when the physical length of the vertical lines is kept constant despite changing horizontal disparity, may provide a possible explanation for the marked deterioration in stereoacuity for closed configurations.

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Abstract 315 B3.23

Binocular contrast detection in the peripheral field in young and older subjects

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Aim: It has been shown that, in the central field, binocular performance for contrast detection tasks decreases in visually normal older subjects compared to young subjects. Although binocular summation in the peripheral field of older subjects has been investigated with respect to a light detection task, no data exist on contrast thresholds to sinusoidal gratings. Methods: Contrast thresholds in young and older visually normal subjects were measured to sine-wave gratings of 1 and 4 c/deg in the fovea and at 10 degrees in the superior field. Monocular and binocular contrast thresholds were obtained with the subjects optimally corrected for both distance and retinal viewing position. Results: Although contrast thresholds were lower in the periphery than in the fovea, binocular summation ratios in the young subjects showed no significant differences ($p>0.05$) in the fovea and at 10 degrees in the superior field, at either spatial frequencies. The older subjects showed higher binocular summation ratios to spatial frequency of 4 c/deg compared to 1 c/deg both in the fovea and in the periphery ($p<0.05$). Conclusions: A decrease in binocular summation is shown with the middle spatial frequency compared to the lower spatial frequency at both the central and peripheral retinal fields in older subjects. Possible reasons for this and the clinical implications are discussed.

Abstract 316 B3.24

Efficiency of stereoscopic transparency

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Purpose: Random dot stereograms containing two disparity populations can be perceived as two surfaces separated in depth (e.g. Akerstrom & Todd, 1988), a far opaque surface being perceived through a near transparent surface. This poses a more complex stereo correspondence problem than a single surface stimulus, as it violates the continuity constraint. We computed the efficiency of depth discrimination for stereoscopically defined transparent surfaces, and compared this to a similar opaque surface task. Methods: We presented random dot stereograms with disparities defining a ‘near’ and a ‘far’ surface (relative to fixation). In the transparent condition the two surfaces were presented simultaneously, in the opaque condition each surface was presented in one of two consecutive

temporal intervals. The observers' task in both conditions was to respond which surface, 'near' or 'far', was farther in depth from the fixation plane. Performance was limited by adding different levels of disparity noise chosen to constrain performance around a d' value of 1. We measured human sensitivities across a range of dot densities and disparity differences. To compute efficiency, the squared ratio of human and ideal sensitivity, we ran simulations of the ideal observer in the same conditions. Results: We found 1) across these ranges human and ideal sensitivities were consistently lower for the transparent conditions; 2) efficiencies were also consistently lower for the transparent conditions; 3) efficiencies depended on both dot density and disparity; 4) efficiencies were consistently low compared to efficiencies reported for other visual tasks. Conclusions: There is a significant processing limitation for depth discrimination of stereoscopic transparent surfaces, greater than that for depth discrimination of opaque surfaces. We suggest that models of stereo correspondence should exhibit similar limitations.
Support: EPSRC

Abstract 317 B3.25

Lateral interactions modify the Pulfrich effect
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Purpose:
When a neutral density filter is placed in front of one eye, a swinging pendulum appears to take on an elliptical orbit (the Pulfrich Effect), due to transmission delays caused by the drop in retinal illuminance. The temporal disparity between the fused moving targets is interpreted as depth with motion. This study investigated whether the Pulfrich Effect is driven locally, or if the delay is affected by light in the surround.

Methods:
Two counter-phased, computer generated pendulum bobs (8.3 arcmin) on a black background were presented to each eye in a haploscope. The bobs presented to one eye had a luminance of 5cd/m2; the fellow eye saw two 50cd/m2 bobs. The bobs in each eye were flanked above and below by 1.7arcmin wide horizontal strips of the same luminance. The bobs "swung" back and forth at 0.95 Hz with an amplitude of 3.26 degrees. By adjusting the interocular phase delay of the two swinging bobs the subject nulled the rotational effect. This difference in phase, quantified in milliseconds, corresponds to the interocular difference in signal timings. To assess the effect of the flanks on the perceived delay we compared a no flank condition to flanks at various gap distances from the bobs (zero deg. - 1 deg.)

Results:
With no surround on a black background, the relative delay was 9ms. The addition of an abutting 1.7arcmin flank increases the interocular delay to 12ms (gap =0), and returns to 9ms with a gap size of 1 degree.

Discussion:
These findings suggest that the transmission delays responsible for the Pulfrich Effect are not strictly dependent on local illuminance. Bright objects within about 1 degrees of a foveal target speed up signal transmission, and the magnitude of the effect is much too large to be due simply to light scatter. When the flanks were abutting and several degrees wide, the relative interocular delay was about 16ms, in agreement with previous findings in the classic Pulfrich paradigm.

Abstract 318 B3.26

Temporal masking of stereo-slant discrimination
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Purpose: To investigate the temporal and spatial properties of simultaneous and sequential stereo slant discrimination.

Methods: Stereo-slant discrimination was tested using random dot patterns (V 1.5 x H 8 deg). Yaw-slant was produced by horizontal magnification of one ocular image. Reference and test target patches were presented either simultaneously (stimulus onset asynchrony, SOA=0) or sequentially (SOA>0) for durations of 83 msec and 167 msec. SOA ranged from 0 to 1333 msec. The reference patch was presented at the fixation spot in the screen center and the test patch was either presented 1.5, 2.5, or 4.5 degrees above the reference. In some trials, the test stimulus was presented on a 5 to 10 arc min disparity pedestal from the vertical horopter.

Results: For adjacent targets, slant discrimination thresholds were lowest when SOA=0 (simultaneous condition) and thresholds were highest for sequential slant discrimination with the shortest SOA (83 msec, temporal masking). Threshold was reduced as SOA increased beyond 83 msec reaching a minimum at 333 msec. With longer SOAs up to 1333 msec thresholds increased from the minimum by 20%. Similar results were obtained with both stimulus durations (83 msec and 167 msec). Temporal masking was eliminated either by presenting the test target on a disparity pedestal or separating adjacent edges of the two targets by more than 0.5 degrees.

Conclusion: SOA rather than stimulus duration determines the threshold elevation for slant discrimination, in accordance with previous masking studies (Breitmeyer, 1984; Butler and Westheimer, 1978). The range of stereo slant masking is limited in time, space and disparity. Normal saccadic gaze shifts would not elevate slant discrimination thresholds with temporal masking because the combined latency and duration of a saccade is larger than the longest SOA that is associated with masking.

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Abstract 319 B3.27

Contrast and orientation dependence on binocular recognition summation in the periphery.
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Binocular and monocular spatial frequency thresholds for recognition were measured at two contrast levels (95% and 7%) and two orientations (vertical and horizontal). Measurements were obtained from 10 visually normal young subjects at the fovea and at 10 degrees superior field. Recognition threshold was defined as the highest spatial frequency at which luminance gratings were perceived veridically. Binocular summation ratios defined as

binocular/monocular spatial frequency were calculated. In the fovea, no significant difference in binocular summation ratios for horizontal and vertical gratings at either contrast level was shown. Binocular summation ratios in the periphery were significantly dependent on the orientation of the gratings as well as the contrast level. Although the high contrast gratings showed no significant difference in binocular summation ratios between the centre and peripheral field, the vertical gratings at the lower contrast showed significantly higher binocular summation compared to the horizontal. Binocular summation for recognition increases at lower contrast and conforms to the radial organisation of the retina (i.e. vertical gratings are seen maximally in the superior field). These results indicate that radial organisation may take place nearer the fovea than previously thought and it may be possible to examine this with more sensitive stimuli.

Abstract 320 B3.28

Contrast adaptation effects under interocualr suppression for normal and strabismic observers.

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Purpose: In the interocular suppression a stimulus presented in one eye is suppressed whereas a different stimulus in the other eye is perceived for a certain time interval. For strabismic observers the suppression continuously occurs between different retinal images made by misalignment of eye positions. It has been in question whether the strabismus suppression is different from the interocular suppression for normal observers. This issue would be important for a developmental aspect of the brain selectivity. In this research we compared contrast adaptation effects under interocular suppression for normal and strabismic observers. Methods: In the suppression condition, the vertical square-wave grating (3-deg diameter, 2.0 cpd, 100 % contrast, 42 cd/m^2 mean luminance) was presented in one eye as a dominant stimulus. The horizontal square-wave grating (3-deg diameter, 1.0~2.5 cpd, contrast: 10 times greater than threshold) was presented in the other eye as an adaptation stimulus. After adaptation, the observer performed contrast matching between the adaptation stimulus and the matching grating of the same frequency. Results: We found that, for both types of observers, effects of contrast adaptation existed in the suppression and no suppression conditions although the contrast adaptation strength was different. Conclusions: These findings suggest that both for normal and strabismic observers the interocular suppression occurred at a site in the visual system after the locus of contrast adaptation.

Abstract 321 B3.29
Withdrawn

Abstract 322 B3.30

Interactions among stereo channels of different scales

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Purpose:
We attempted to find how stereo channels of different spatial scales interact when the observer detected the presence of disparity.
Methods:
We employed a 2afc method to measure disparity thresholds for compound gratings consisting of sinewaves of spatial frequency combinations F+3F, F+5F, and F+3F+5F. The fundamental frequency F was between 0.25c/d and 1c/d for different subjects. Each component was presented at a variety of contrasts to vary its detection threshold. We manipulated the disparities of the components by either yoking them in space (same spatial offset) or in phase (same phase offset) and compared thresholds for the compound gratings with thresholds for the components when tested alone.
Results:
When component disparities were yoked in space, thresholds were generally consistent with independent detection of the components' disparities. Thresholds were determined by the most sensitive channel, with the thresholds for compound gratings equaling the lowest of the component thresholds, in agreement with Heckmann and Schor (1989). However, when disparities were yoked in phase, the results were inconsistent with independent channels. Rather than equaling the lowest component threshold, compound thresholds were similar to or even higher than the highest of the component thresholds.
Conclusion:
To account for interactions among stereo channels in disparity detection, we hypothesize that disparity thresholds for the compound gratings are determined by a single channel among those activated by the stimulus. This channel is non-optimal, biased toward the high-frequency components of the compound, regardless of which components have non-zero disparities.

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Abstract 323 B3.31

Stereo fusional limit and Panum's limiting case revisited using dichoptic color fusion

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We perceive binocular surfaces in depth when viewing random dot stereograms (RDS) only when the horizontal disparity is limited. Several researchers have reported the upper limit of fusion using RDS to be much larger than Panum's fusional area (Julesz and Fender, 1967; Erkelens, 1988; Piantanida, 1986), while others supported the classical limit fusional (Duwaer, 1983). To explore these conflicting conclusions, we developed a RDS requiring dichoptic color fusion. Dichoptic color mixing occurs when the dots are fused to form a surface in depth, and the dots return to their intrinsic colors when they are not fused. The appearance of depth is undisturbed by dichoptic color mixing. We find that the upper limit of fusion for the RDS is comparable to the classical Panum's fusional area, while the limit of depth perception is much greater.
We applied dichoptic color fusion to Panum's limiting case in lines and in RDS. In Panum's limiting case, a single vertical line in one eye corresponds to a pair of vertical lines in the other, and gives rise to the perception of two lines at different depths. Different explanations have been offered for this perception including double-duty matching, a violation of the

uniqueness constraint posited in several stereo algorithms. In our study, the lines in the two eyes had different colors and a distinctly different fused color. We found color fusion for only one of the two lines, the second retaining its monocular color. Different observers had either a consistent nasal or temporal fusional bias. However, this was not the case when we used RDS with extra monocular dots of a different color placed beside binocularly matched dots. In this case observers perceive surfaces at two depths, one of which corresponds to the matched pairs and the other of which has the fused color due to fusing the differently colored dots, in apparent violation of the uniqueness constraint. This may be due to double-duty image matching.

Abstract 324 B3.32

The spatiotemporal frequency property of stereopsis
Seungbae Lee, S. Shioiri and H. Yaguchi Chiba University, Japan

Purpose: To investigate the spatiotemporal frequency property of stereopsis, we measured disparity and contrast threshold for the depth discrimination of moving gratings with variable spatial and temporal frequencies. Methods: Stimulus display consisted with four squares filled with sinusoidal gratings arranged in a 2x2 array with gaps to separate them. The gratings in the upper right and the lower left squares had the same disparity that was opposite of those in the other two squares and the observers responded which pair appeared to be closer in depth. Disparity threshold was measured by a staircase procedure in each combination of six spatial frequencies (0.23~7.50c/deg) and six speeds (0.15~20Hz) at a fixed contrast of 0.1. Contrast threshold was also measured in each condition at a fixed disparity of 10 arc min. Results: The results in both disparity and contrast threshold measurements showed that the spatial frequency property depended on temporal frequency. Disparity threshold was lowest at a spatial frequency of about 2~3 c/deg (i.e., band pass) when temporal frequency was low (<4Hz) on one hand. When temporal frequency was high (>4Hz), on the other hand, disparity threshold increased with spatial frequency at spatial frequencies higher than about 1 c/deg (i.e., low pass). Similarly, contrast threshold was lowest at a spatial frequency of about 1~2 c/deg when temporal frequency was low (<4Hz). When temporal frequency was high (>4Hz), contrast threshold increased with spatial frequency at spatial frequencies higher than about 1 c/deg.
Conclusions: Our measurements suggest that at least two mechanisms with different spatiotemporal-frequency properties contribute to stereopsis.

Abstact 325 B3.33

Visual cues for closed-loop control
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Creating stereo displays typically requires designers to accept a reduction in spatial resolution and/or update rate. Does the depth information provided by binocular disparity justify this loss of quality on other display parameters? We examined this question by pitting stereo against update rate in a spatial display used by operators to perform a closed-loop control task. The participants' goal was to maintain a target object at the same apparent depth as a standard via fore/aft joystick inputs. The target's position was perturbed using pseudo-random (sum-of-sines) disturbances. For half the trials, the participants' inputs mapped to rate control (i.e., the velocity of the target was proportional to the joystick displacement); on the other half, inputs mapped to acceleration control. Update rate (12, 24, or 48 frames-per-second) was crossed with display condition (stereo or biocular).

Our findings suggest that the utility of stereo cues varies as a function of control dynamics (i.e., rate vs. acceleration). Further, we find that the quality of depth cues impacts perceptual processing, while the nature of the control task impacts further "downstream" (i.e., operator's control strategies are affected).

Abstract 326 B3.34

A laminar cortical model of monocular and binocular interactions in depth perception
Piers D.L. Howe, & Stepthen Grossberg Boston University

Monocular information plays a crucial role in depth perception (e.g. da Vinci stereopsis1). Despite some explanatory successes, many popular physiological models of depth perception, such as the disparity energy model2, do not incorporate monocular information and so are limited to describing stereopsis. The present work goes beyond these models by developing a detailed laminar cortical theory of how monocular and binocular information interact in areas V1, V2 and V4 of the macaque visual cortex to form coherent percepts of depth with particular emphasis on surface depth perception. This model builds on previous work that links cortical circuits to psychological and neurophysiological data about grouping, attention and development3. It is consistent with the disparity energy model but makes novel predictions. In particular it provides neural explanations for psychophysical data including: contrast variations of Panum's limiting case and dichoptic masking, depth perception of monocularly viewed objects, da Vinci stereopsis and various lightness illusions, thereby linking known laminar cortical anatomy and physiology to psychophysics and providing new functional insights and predictions about cortical architecture. A psychophysical study has recently found supporting evidence for the model's explanation of the depth perception induced by opposite contrast stereograms by showing that, contrary to several published claims, stereopsis can be achieved only by the binocular fusion of edges whose luminance gradients have the same-sign.

1Nakayama and Shimojo 1990 Vision Research 30:1811-1825. 2Ohzawa et al. 1990 Science 249:1037-1041. 3Grossberg & Raizada 2000 Vision Research 40:1413-1432.
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Abstract 327 B3.35

How are texture and stereo used in slant discrimination?
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When surface slant is specified by disparity and texture gradients, both sources of information are, in principle, useful for estimating slant. Several investigators have argued that combined stereo-texture estimation can be modeled as weighted combination: Sc=WtSt+WsSs (St = texture slant estimate, Ss = stereo estimate, Wt = texture weight, Ws = stereo weight, Ws+Wt=1). Do observers use the combined estimate (Sc) when discriminating surface slants? Three stimuli were presented sequentially in a haploscope. Textures were Voronoi patterns. Two “standard stimuli” had the same texture- and stereo-defined slants (St=Ss=S0) and one “odd stimulus” had different texture and/or stereo slants (St=S0+c*Dt, Ss=S0+c*Ds). Observers indicated the interval containing the odd stimulus. A staircase varied “c” to determine threshold for various directions (Dt,Ds) in the space of possible stimuli (St, Ss). If observers used St or Ss (whichever provided better information) to do the task, stimuli would be discriminable as soon as either St or Ss reached its independent threshold (ignoring probability summation). If observers used only the combined estimate Sc, then stimuli for which Sc=S0 (i.e., Dt = -(Ws/Wt)Ds) should be indiscriminable for any value of c. Furthermore, performance should be better for cue-consistent stimuli (Ds=Dt) than for single-cue-varied stimuli (Ds=0 or Dt=0). We found that in some cue-conflict directions, thresholds were significantly higher than in the cue-consistent direction (although never infinitely higher). This result indicates that the combined slant estimate is used together with the individual cue estimates in slant discrimination. When Dt and Ds have opposite sign, observers' use of Sc resulted in poorer performance than that predicted by use of St and Ss alone. Thus, observers use all three estimates even when more efficient strategies are available.

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Abstract 328 B3.36

Eye dominance changes with eye position and image magnification
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Eye dominance switches depending on whether the observer is looking left or right (Khan & Crawford, 2001). It is not known whether the switch is caused by a change in the eyes’ positions, by a change in relative image magnification, or by both. We investigated the cause of dominance switch by independently manipulating eye position and image magnification. The stimuli were presented in a custom haploscope. A small target was presented in the center of a square. The target had zero disparity and the square had crossed disparity. Eye position was manipulated by rotating the arms of the haploscope so that the observer had to turn the eyes to look at the stimuli. Relative image magnification was manipulated by calculating the magnification associated with a variety of azimuths and applying them to the dichoptic square. On each trial, observers indicated whether the target appeared displaced leftward or rightward from the center of the square. If the left eye was dominant, the target would appear displaced to the left. If the right eye was dominant, it would be displaced rightward. The results showed, in agreement with Khan and Crawford, that the left eye was more dominant when the eyes were turned leftward and the right eye more dominant when they were turned rightward. The results also showed that relative image magnification affected dominance. For example, when the eyes were turned rightward, but the image was larger in the left eye, dominance shifted toward the left eye. We conclude that the shift in eye dominance that occurs with viewing direction is caused by both eye position and relative image magnification.

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Abstract 329 B3.37

A gain-control theory of binocular combination
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When different stimuli are presented to the left and right eyes, only a single, combined "cyclopean" image is perceived. The numerous theories that have been proposed to describe binocular combination rule typically abstract a parameter from each eye's image (e.g., maximum stimulus contrast or the visual direction of a significant point) and use the two eyes' values to predict the parameter value in the cyclopean image. Here we offer a process theory that applies to any image within a spatial frequency band, and predicts, pixel by pixel, the combined cyclopean image. We propose simply that, in every neighborhood, each eye exerts gain control on the other in proportion to the strength of its own input. We tested the theory with superthreshold sinewave stimuli. Sine waves were horizontal to make the cyclopean image independent of vergence. Subjects judged the position of the dark stripe of the cyclopean image relative to an adjacent bar marker. The sine waves in the left and right eyes were of different contrasts and in different phases. The arithmetic addition of two parallel sine waves produces a sine wave of known phase and amplitude. The data consisted of 96 combinations of contrasts of the left- and right-eye stimuli, and of their relative phases. For stimuli to one eye only, and for equal stimuli to both eyes, the position judgments agreed perfectly with the linear summation model. For all other contrasts in the two eyes, the linear summation model failed. From the judged position, we inferred the strength of the contribution of each eye to the cyclopean image. In general, the stimulus with greater contrast had more weight than predicted by simple linear summation. Without estimating any parameters from the data, the gain-control model accounted for 99% of the variance of the data. We conclude that a simple, robust, physiologically plausible model accurately describes binocular combination within a spatial frequency channel.

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Abstract 330 B3.38

Spatial scale interactions in stereopsis for different types of band-limited stimuli

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Stereo depth perception depends on computing the correspondence between image features in the two eyes. This computation is believed to occur in parallel at different spatial scales of the stimulus, and to yield independent estimates of disparity at each scale. In simple terms, the input image is filtered into spatial frequency bands and binocular disparities are computed separately for each band. In order to characterize these spatial-frequency selective computations, various studies have utilized band-limited stimuli such as Difference-of-Gaussian (DOG), Gabor and filtered noise patterns. Results have generally confirmed the importance of spatial scale in stereo depth perception, and have also identified interactions among spatial scales, but have yielded some puzzling inconsistencies. In particular, results have shown that factors other than spatial scale, such as the envelope or outline of the stimulus can play a role in reducing false matches in repetitive and high spatial frequency stimuli. Following this line of reasoning, our research compared how the spatial frequency of different types of band-limited stimuli affected performance in a depth discrimination task, where the pedestal disparity of the reference stimulus was varied. Our immediate goal was to explain why DOG stimuli used by Siderov and Harwerth (1993) revealed a minor effect of spatial frequency, whereas filtered noise used by Smallman and MacLeod (1997) revealed a very large effect. We confirmed that the differences found using DOG and filtered noise patterns were reliable. We also conducted an experiment measuring depth discrimination using filtered noise that was contrast modulated with a Gaussian envelope, thus bridging the effects observed with DOG and filtered noise stimuli. We explained the differences between the different stimuli using a model that was sensitive to the number of false matches in the stimulus.

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Abstract 331 B3.39

Monocular artifacts and the perception of stereomotion speed.

Kevin Brooks & Leland Stone NASA Ames Research Centre

Stereomotion experiments often feature monocularly visible stimuli. When such stimuli move in depth, different monocular motion signals are presented simultaneously to each eye. Though this ‘inter-ocular velocity difference’ cue to stereomotion has been investigated in a number of studies, the observed behaviour could theoretically have been based on properties of an individual monocular image. To isolate such potential artifacts, we performed a 2IFC speed-discrimination task using random dot stereograms moving either directly or obliquely (at an angle of ±0.25 deg, interocular speed ratio 2:1) away from the observer. Stimuli (7.3 x 1.3 deg; 600ms; standard disparity speed, 0.62deg/s) were displayed using ferro-electric shutter glasses on a high-speed fast-phosphor monitor (120Hz per eye). Monocular half-occlusion artifacts were minimised by using horizontally extended stimuli. Multiple interleaved staircases were used to measure speed-discrimination performance for conditions in which the trajectories were direct in both intervals, or in which the trajectory in one interval was direct and in the other oblique. The points of subjective equality in the 'direct' condition were, as expected, unbiased, while those in the 'mixed-trajectory' conditions were biased on average by 9% and 15% (oblique faster) for the 2 observers (one naive) tested. However, discrimination thresholds were similar across all conditions (~25% Weber fraction). Though these data are inconsistent with the monocular strategy of responding on the basis of the image motion experienced in a particular eye, they are consistent with two alternative hypotheses: i) oblique stereomotion appears faster than directly receding motion, or ii) the perceived speed of stereomotion is biased by the monocular image motion from the eye experiencing the faster motion. Supported by NASA RTOPs 711-51-12, 111-10-10, and 131-20-30.

Abstract 332 B3.40

The importance of binocular cues in the on-line control of prehension

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Binocular information is considered paramount in the planning of prehensile movements. Here we investigate its contribution to the online control stage. Subjects reached for objects following an initial monocular view and binocular information was introduced at predetermined intervals during the reach. If, during the reach, the addition of relative disparities between the hand and target is important then reach profiles should approximate those manifest under full binocular conditions. Subjects reached for and picked up objects of three different depths (3, 4.5 and 7 cm) at three different positions (14.5, 25 and 36.7 cm) along the midline. Vision was controlled using a pair of LCD goggles which could alternate between a binocular and monocular view depending on the experimental condition. Six viewing conditions were employed of which the first two were a fully monocular reach and a fully binocular reach. The final four conditions consisted of a monocular initial view followed by the introduction of binocular information 0%, 25%, 50% or 75% into the temporal duration of the reach following movement onset. Movements were recorded using a ProReflex motion analysis system. The expected differences between overall binocular and monocular reaches were present along with normal scaling of the transport and grasp components for object distance and object size respectively. Differences between the reach kinematics of the four 'partial binocular' conditions were found when compared to monocular-only conditions. When binocular information was introduced later in the reach, the benefits were much reduced. Therefore these results suggest that the improvement afforded by binocular cues in on-line control of prehensile movements is only observed when the information is present through at least 75% of the reaches duration.

Biological Motion

Abstract 333 B3.41

Predicting night-time visibility while driving
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Background: In this study we sought to determine whether visual acuity (VA) or Pelli-Robson contrast sensitivity (CS) measured under a range of illumination conditions could better predict night-time driving performance than standard measures of VA. Experimental Design: 24 participants divided into 3 age groups drove around a closed road circuit under day and nighttime conditions. At night, headlight intensity was varied over 1.5 log units using ND filters. Subjects drove twice around the circuit at each light level: once for normal and once for a commentary condition where drivers had to report relevant targets including road signs, road obstacles, and pedestrians who wore retroreflective markings on either the torso or the limb-joints to create "biological motion." Recorded measures included average speed and target recognition. Visual performance measures included VA and Pelli-Robson CS under 4 illumination conditions and dark-adapted pupil size. Results: Recognition performance of all participants was degraded in low light and these changes were more strongly predicted (r=0.18 to 0.63) by Pelli-Robson CS under standard photopic or reduced illumination conditions than by VA (r=0.09 to 0.24). Pedestrian recognition was greatly enhanced by marking limb-joints, a benefit that increased with driver age. Average speeds decreased with age and reduced light, but the latter effect was small. Conclusions: These findings confirm that visibility is seriously degraded during night driving and that, especially with pedestrians, the problem is greater for older drivers. This degradation in night-time visibility was better predicted by Pelli-Robson CS than VA.

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Abstract 334 B3.42

Biological Motion: why some motion impaired stroke patients "can" while others "can't" recognize it? A computational explanation
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Purpose: In its simplest way, Biological motion (BM) is defined by point-lights attached to the major joints and head of a human walker. To investigate the neuroanatomical areas necessary for BM processing we selectively "damage" a biologically inspired computational model of BM recognition to simulate the performance of stroke patients on this task.

Methods: We developed a hierarchically organized biologically driven computational model including both the ventral and dorsal pathway whose neurons exhibit a gradual increase in the complexity of the features processed. Neurons at the recognition level of the hierarchy are laterally connected, giving rise to recurrent network dynamics that can efficiently associate information over time. The model predicts quantitatively differences between the neural activation in different cortical areas. Driven by neuroanatomical and neurophyisiological considerations we used the model to perform simulations of (a) psychophysical results from15 stroke patients impaired on BM and (b) verify our results in fMRI (functional magnetic resonance imaging) studies of patients and normal subjects.

Results In the model, similar to the reports from neurological and fMRI studies, we found that the areas STP (superior polysensory temporal area) and area KO ("kinetic object" area) are necessary for recognition, as are either area MT+ (middle temporal area) in the dorsal pathway or the posterior and anterior IT (inferior temporal area) in the ventral pathway. fMRI results from our group and those of others support the functional-anatomical architecture of the model.

Conclusion: Impaired recognition BM demonstrated by patients with lesions in different cortical areas can be reliably accounted for by selectively "damaging" the network. We suggest that our model provides a biologically plausible functional architecture for biological motion recognition.

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Abstract 335 B3.43

The role of objects and events in the perception of biological motion
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In a point-light walker display we can recognize both event and actor. Recognition is reduced when the display is upside down. This may be due to difficulty recognizing a person in an unfamiliar orientation, or it may reflect difficulty recognizing the event because the dynamic relations are unfamiliar (in such a display objects would fall up). To disentangle these two explanations displays were created with walkers that were upside down without reversing gravity - they walked on their hands.

A signal detection task was employed to evaluate subjects' ability to detect humans in four types of point light displays: Walking on feet right-side up (actor and gravity in a familiar orientation), walking on feet upside down (actor and gravity in an unfamiliar orientation), walking on hands right-side up (actor unfamiliar and gravity familiar), walking on hands upside down (actor familiar and gravity unfamiliar).

To make the displays, an actor walked on feet and then on hands on a walkway with a low ceiling so that when walking on feet they could move their hands along the ceiling, and when walking on hands they could move their feet along the ceiling. The displays were based on the x-y coordinates of all visible joints. Noise was added to displays in the form of masking dots that moved in the same manner as the walker points but displaced in random direction and phase. Target-

absent trials were matched for density by adding additional random-phase elements. Prior to testing, subjects were shown each mode of locomotion without a mask.

Accuracy for walking on feet replicated previous studies: D' for upside down walkers was lower than for right-side up walkers. In the walking-on-hands conditions, turning the walker upside down reduced accuracy. Familiarity of dynamic relations was more important than familiarity of actor orientation. Perception of biological motion may require recognition of events, which in turn may allow recognition of the actor.

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Abstract 336 B3.44

Are we visual animals?

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Numerous studies have shown that human observers are exquisitely sensitive to the visual analysis of human movement. Indeed, the visual analysis of human motion can substantially differ from the visual analysis of moving, inanimate objects such as scissors, cars, clocks, and erasers (Shiffrar, 2001). This difference might be partially due to differences in motor system activity since selective M1 activation is associated with the passive observation of normal human motion but not with observation of inanimate object motion (Stevens et al., 2000). But does human motion perception differ from all other motion processes? The goal of a series of studies was to determine whether the visual analysis of human movement differs from the visual analysis of non-human animal movement. To that end, we selected two "gold standard" characteristics of the visual analysis of human motion, orientation specificity and global spatial processing, and examined whether these characteristics could be found in the visual analyses of animal motion. Following a between subjects design, naive subjects viewed masked point light displays and reported whether they detected one of four possible walking targets: an inverted or upright human or horse. Across experiments, clear evidence for spatially global processing was found in both the horse and human conditions. Surprisingly, orientation specificity strongly depended upon what subjects saw for five seconds before beginning the experimental trials. When an inverted target was shown during instruction, performance in this presence-absence task was superior with inverted targets (whether horse or human) than with upright targets. The reverse pattern was found when an upright target was shown during instruction. Such results constrain theories of the type of information that the motor system may contribute during the visual analysis of human motion. Simply put, the visual system may classify humans as just another animal.

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Abstract 337 B3.45

Change mindfulness: Attention to human movement

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The deployment of attention within a complex scene has received much attention in the last decade (e.g., O'Regan, Rensink, & Clark, 1999; Rensink, 2000; Simons & Levin, 1998). Much of this work demonstrates a startling "blindness" to changes in objects, arrangements, even people. Some work suggests that tacit social goals may guide the deployment of attention (Simons & Levin, 1998). We examined such a possibility. We hypothesized that the movements of people would garner attentional resources since such movements might have social significance to an observer.

To test this proposal, we compared the detection of changes in a person's movement to the detection changes in a moving person. We constructed two short videos. In each video, we created five abrupt, unusual changes, two to the appearance of an actor and three to the behavior of one or more actors. A change of appearance, for example, was accomplished by changing an actor's clothing from dark to light as she passed behind a pillar. A comparable change in behavior involved an actor walking behind a tree and then reappearing with a limp. In every target change, the actor moved throughout the scene.

We presented 50 undergraduates one of two videos and then asked them to recall any surprising changes in the video. Two assistants independently coded observers' responses. Responses were regarded as reflecting detection of the target change if the observer identified either the person involved, the place where it occurred, or the change itself. As expected, the frequency of detection varied with the type of change, $F(4, 98) = 4.34$, $p < .01$. Pairwise comparisons suggest that observers were more likely to report changes in actors' behavior than in their appearance. Subsequent probes demonstrated that observers were capable of detecting and remembering all of the target changes. These findings suggest that the movement of entities in a complex scene may be more salient than the appearance of moving entities.

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Abstract 338 B3.46

Shaping Biological Motion: Adding realistic form cues to biological motion displays.

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Recognition of human action from point-light displays has occupied a unique position in the study of visual perception and cognition. The attraction of these stimuli is their facility to omit irrelevant aspects of the human form that might make recognition or detection trivial. In some situations, however, point-light stimuli are too abstract to reliably depict person characteristics and there is an increasing trend towards using animated models that incorporate additional form information. We performed two experiments to compare the perception of point-light (PL) displays to solid body model (SBM) displays that depict the same captured human movements. Solid body models are well-developed animation tools that provide precise control over the presentation of form as a volumetric solid. In

comparing PLs to SBMs we expect that performance in judgements about PLs would differ from those about SBMs, in cases where shape informs the required judgement. In Experiment 1 observers were asked to categorise the affect of actors performing knocking movements with 10 emotions. Results showed little difference in proportion correct responses or in a psychological space of affect, based on multi-dimensional scaling of the confusion matrix of responses. This indicated that body shape does not inform perception of emotion. SBMs had, however, been presented with neutral facial expressions and we might expect that varying facial expression would strongly effect the interpretation of motion cues to emotion. In experiment 2 observers were asked to make judgements about the weight of an invisible, pushed object. Results showed that a greater range of weights was used to describe objects pushed by SBMs than the same objects pushed in PL displays. This suggests form information, when combined with motion information, modulates the perception of perceived weight to a greater extent than motion alone.

Abstract 339 B3.47

Motion induction by biological motion.
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We found a new visual illusion caused by biological motion, in which a background pattern appears to move oppositely to a human locomotion indicated by gait. To exemplify this phenomenon, we conducted two experiments presenting an ambiguous motion as a background of a point-lights walker stepping on a tread-mill. In experiment 1, observers judged motion direction of a counterphase grating with a 2-alternative forced choice method (left or right). In experiment 2, random dot kinematograms (RDK) with varying signal-noise ratios were used to evaluate sensitivity for coherent motion. Results indicated that the counterphase grating appeared to move in the direction opposite to that of walking in 75% of trials, significantly higher than chance level. As for RDK backgrounds, the psychometric function for coherent motion sensitivity was biased toward the direction opposite to walking. In addition, such tendencies disappeared when configurations of point-lights were scrambled, although total composition of 1st-order motions was unchanged. Since the earlier visual system is not likely to detect biological motion, these results indicate involvements of the higher visual system in the induction. The results also indicate that the output of such high level processes as those involved in biological motion effectively interact with low level motion output.
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Abstract 340 B3.48

Frequency, context, and human motion perception
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Does the visual perception of human movement benefit from our social interactions with other people? To investigate this question, we created point-light displays of human gaits that varied in unusualness. Under normal conditions, walkers automatically adopt the most energy efficient combination of stride frequency and amplitude for any given speed. Occasionally, humans might adopt an unusual stride frequency-amplitude combination (such as taking quick, short steps on hot sand). Hence, some gaits are frequently experienced while others are not. Is visual sensitivity to common gaits greater than visual sensitivity to unusual gaits? To answer this question, point-light walkers exhibiting both common and unusual gaits were created by videotaping one of two walkers on a treadmill. Stride frequency and amplitude were systematically manipulated across ten different speeds. Using a two-interval forced choice procedure, pairs of movies depicting the same walker at two different speeds were sequentially presented to naive observers. Walker speed differed by 0.5 or 1.0 km/hr. Subjects were asked to report which walker was walking faster. Speed discrimination did not significantly differ across variations in gait frequency, suggesting that human motion perception is not a function of experience with any particular movement. An identity discrimination task was then employed to determine whether frequency might influence a more socially relevant task such as our ability to identify individuals from their motion. Colleagues of the two models used in Experiment 1, and the models themselves, viewed the movies described above and judged the identity of each walker. Overall, models performed equally well with common and unusual gaits. With colleagues, performance was a function of the type and extent of social relationship with the model. Thus, experiential differences can influence biological motion perception under socially relevant contexts.

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Abstract 341 B3.49

Detecting point light walkers within masks: Influence of orientation, translation, and location
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Purpose: People easily and accurately identify the movement of points of light that correspond to the joints of a walking person. Although it is known that motion of additional moving points of light can mask the motion of a point light walker, little is known about what aspects of the point light walker influence its detectability within a mask. Method: Twenty-nine naive participants viewed artificially created point light walker sequences with masks for approximately one second. Three properties of point light walkers within masks were examined: 1) translation (translation versus no translation), 2) location (static versus random point light walker location across trials), and 3) orientation (upright versus inverted). Each participant was randomly assigned to a given combination of the translation and location variables. For the particular translation-location combination assigned, each participant completed 100 trials at each orientation. Results: Statistical analyses showed that all variables influenced the detectability of point light walkers (as measured by d'). Participants were better at detecting the point light walker when it was not translating (that is, walking in place), its location was static, and it was upright. There were also statistically significant interactions (all two-way and the three-way) between translation, location, and orientation. Conclusions: The detectability of point light walkers within a mask depends on their orientation, translation, and location. Although a person walking through our field of

view is a common occurrence, it is apparently easier to mask that motion (a point light walker with translation) than the presumably less common occurrence of someone walking in place (a point light walker without translation).

Abstract 342 B3.50

Perception and categorization of computer animated walking figures

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Computer graphics has long benefited from an understanding of human vision. Basic perceptual phenomena such as trichromacy, opponent colors, and color JNDs have enabled the design of graphics hardware and software. More complex stimuli such as human movements are also important for graphics but are not so well understood.

We present an investigation of the mapping between the parameters used by a computer to generate animated movements (different gaits of a walking figure), subjects' descriptions of movements, and their judgements of the similarity of the movements.

Experiment One: examined the classification of gaits within the structure of pairs of opposite movement description terms. We found that the focus of attention varied among subjects, but that similar stimulus characteristics were salient in determining the classification of gaits, and that classification was somewhat consistent across most of our subjects and could be reduced to three to four principal components.

Experiment Two: explored the metric properties of motion similarity judgements by asking subjects to make comparisons between a limited range of movements that were unlikely to span boundaries between multiple linguistic descriptors, but which were perceptually distinct. We conclude that similarity judgements do not have all of the metric properties but that their evaluation was similar across subjects.

Observed intersubject differences suggest that animation systems should be customizable not only for the user's preferences, but for their perceptual abilities and movement categories as well. If our findings are correct, we can predict that this customization might be achieved by altering parameter values associated with the relative weights given to common perceptual cues without the need to add new cues or substantially modify the nature of the cues themselves.

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Abstract 343 B3.51

An investigation of neural activity associated with viewing point-light animal, face and hand movements

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Purpose. A region on the human posterior superior temporal sulcus (posterior STS) has been implicated in the perception of human activity, including biological motion as portrayed by Johansson's point-light animations. This area is more active when observers view biological motion than when they view the same motion vectors scrambled such that the perceptual coherence is destroyed (Grossman et al, 2000, Grossman & Blake, 2001). To test whether the neural response in this area is specific to human body movement, we measured the BOLD signal changes when observers viewed point-light animals, human hand and face movements versus the scrambled counterparts. Methods. Point-light human body motion animations were created by digitizing video of an actor with reflective tape on the joints performing various activities. Point-light animals were created by encoding the joint positions of various animals from the published Muybridge collection, and displaying the frames in rapid sequence to give the appearance of natural movement. Point-light hand animations were created by digitally recording hand movements in a dark room with glow paint applied to the joints. Because faces have fewer joint positions, point-light facial expressions were created by placing glow paint in scattered positions on the entire face. Scrambled versions of all types of animations were created by randomizing the starting positions of the dots. Results. Posterior STS was strongly modulated by the human whole body animations, but less so by any of the other animations. Still, viewing animal movements and facial expressions resulted in more neural activity in posterior STS than scrambled motion. The results indicate a strong selectivity for human movement over these other types of natural, biological motion patterns.

Abstract 344 B3.52

The role of experience in the perception of biological motion

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Can the daily work experience of adults translate into differences in the organization of perceptual events? Human observers are especially sensitive to human motion, as opposed to the motion of objects or animals (Shiffrar, 2001). Tests of this sensitivity frequently make use of point-light displays where an image is reduced to a set of points corresponding to key joints such as the shoulders, wrists, hips, knees and ankles (Johansson, 1973). To what degree might experience influence our ability to detect these events?

We investigated the potential effect of work experience on the perception of biological motion. Two experiments contrasted the performance of naïve observers, seal trainers and dog trainers. In the first experiment observers were shown canonical and inverted displays based on the motion of seals, dogs and people and asked to report what they saw. Patterns of recognition were compared for each of the experimental groups. A second experiment assessed sensitivity by means of a two-alternative forced choice task. Expert and

novice observers were shown canonical and inverted target displays similar to those used in the first experiment and asked to determine the presence or absence of figures embedded in noise. Conditions were blocked by stimulus type and orientation.

In Experiment 1 all groups had a tendency to report seeing human motion when viewing canonical displays. In Experiment 2 no differences in sensitivity were found between trainer groups. Familiarity with the actual animals and situations from which point-light displays were abstracted did not directly translate into improved recognition or detection. The relationship between experience and recognition appears to be complex: motor experience may impact visual recognition differently than visual experience. Results are discussed within the context of Gibsonian and perception/action theories that have been advanced to account for our sensitivity to human displays.

Classification Images

Abstract 345 B3.53

Estimation of human-observer templates in temporal-varying noise
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Estimation of human-observer templates in temporal-varying noise

The spatial templates that human-observers use for signal detection and discrimination can be estimated by constructing stimulus classification images (Ahumada and Beard, ARVO 1999). The purpose of this study was to elucidate whether the spatial-temporal templates could be estimated with the classification method. We performed signal detection experiments using a two interval forced choice (2IFC) method. The stimulus was a Gabor signal within additive white noise. Both the signal amplitude and the noise pattern varied during the 500ms display period. The 2 cycle/degree Gabor signal was presented in the middle of the noise image. The amplitude of the signal was varied according to a temporal function. Independent white noises were presented sequentially at a given rate during the display. The task was to determine whether the Gabor signal was presented or not. Each block included 100 trials. Within a block each noise sequence was repeated twice. Each of the two observers performed 40-60 blocks for every tested condition. We computed the linear classification images by averaging noises separately for each stimulus-response trial type. Results showed that at the high noise-changing rate (60Hz) the classification images contained no spatial templates or temporal templates. At low noise-changing rates (6Hz and 12Hz), the images had the templates similar to the shape of the Gabor signal. Moreover, the amplitudes of the cross-correlation between the classification images and the Gabor signal had temporal distributions similar to the temporal function of the signal, suggesting that the observers used temporal templates for signal detection. We further estimated the level of internal noise using the probabilities of agreed responses to the same noise sequence. At the high noise-changing rate, the internal noise overwhelmed the external noise. Thus the observers could not make a decision based on the contribution of each external noise pixel.

Abstract 346 B3.54

Classification images for a cueing paradigm with 100% valid simultaneous cues: Evidence for attentional leaking
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Human cue validity effects in many cueing tasks can be explained with a weighted linear (Kinchla, et al., P & P, 1995) or Bayesian (Shimozaki, et al., 2001, ARVO; Eckstein, et al., JOV, 2001) integration model that preferentially weights the cued location, without proposing either an improved quality of processing at the cued location, or limited attentional resources. Precue effects with a 100% valid simultaneous cue (Dosher & Lu, VR, 2000), however, are not predicted by a Bayesian (ideal) observer, which ignores the precue and considers only the test location indicated by the simultaneous cue. One explanation of these precueing effects is that attention improves the tuning of the perceptual template (or excludes irrelevant external noise) at the test location when the precue and simultaneous cue agree. Another hypothesis is that observers (unlike an ideal observer) are unable to ignore information from the precued location when the precue is invalid (i.e., attentional leaking). Classification images were used to estimate human perceptual templates at the precued (invalid trials) and test locations (valid and invalid). Two observers (LL and JT) participated in a cued contrast discrimination of a 50 ms Gaussian signal in image noise at four possible locations, with a 150 ms precue (62.5% valid) and a simultaneous cue (100% valid). LL had large precue effects (d'0.5), and her invalid precued classification image was not significantly different from the test location classification image. JT had no precue effects, and his invalid precued classification image did not differ from zero. Also, for both observers, no difference was found for the test location classification images in the valid and invalid precued trials. For this task, we conclude that precueing validity effects (for LL) were due to the inability to ignore information at the invalid precue location (attentional leaking), and not the improved tuning of perceptual templates at the test location.
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Event Perception

Abstract 347 B3.55

Detection of Collision Objects Travelling on Curved Paths
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Previous work on detection of collision objects (Andersen & Kim, 2001) examined objects travelling on linear paths at constant speeds. Under these conditions a collision event is

specified by objects that are expanding and that have a constant bearing (the location of the object remains fixed in the flow field). In the present study, we examined the detectability of collisions with objects travelling on circular paths. Collision objects travelling on curved paths do not maintain constant bearing as they approach the observer, but their bearing goes to zero as a collision becomes eminent. The displays simulated observer motion along a straight path, while a spherical object approached along a circular path from the horizon. We varied path curvature and display duration, maintaining time-to-contact, speed, and initial image position of the collision objects. Observers were asked to report whether or not the object was on a path that would result in a collision with the observer. Results show that collision detection accuracy decreases with increasing path curvature. Collision detection accuracy decreases with decreased display duration, especially for highly curved paths. These results indicate that observers can detect collision objects that are on circular paths, with the sensitivity to detect such collisions decreasing as a function of the curvature of the path.

Andersen, G.J. & Kim, R.D. (2001). Perceptual information and attentional constraints in visual search of collision events. Journal of Experimental Psychology: Human Perception and Performance, 27, 1039-1056.

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Abstract 348 B3.56

Recognition of objects and actions

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Human observers can readily recognize point-light defined versions of locomoting people and animals. Is this ability restricted to the analysis of simple animal motions? To answer this question, we created point light displays of complex mechanical and biological actions. The stimuli included point-light defined vehicles, toys, animals, random motion foils, and humans. The human stimuli ranged from simple actions such as picking up an object to extremely challenging yoga moves. Two second clips of each movement were presented in randomized order to naive subjects. The first experiment involved a free report procedure in which subjects wrote a description of what they had seen after each clip. The second experiment involved a multiple choice task in which observers were asked to identify the term that best described what they had seen. Subjects selected one term from a list of five possibilities: animal, human, mechanical, plant-like, and other. Data from the free report procedure were categorized according to whether the observers reported local or global levels of analysis. The results indicated that the human and animal motions appeared to have been more globally analyzed than the mechanical motions. Moreover, physically challenging yoga poses as well as complex object motions were described with terms that reflected more localized levels of perceptual analysis than the terms used to describe relatively simplistic human actions. The results of the second experiment suggest that observers were most accurate in their classification of simple human motions but still performed at above chance with all types of stimuli. Interestingly, challenging yoga moves were much less likely to be categorized as "human" than were simple human actions. Thus, with some interesting twists, recognition of point light displays extends to a wide variety of complex, embedded motions.

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Abstract 349 B3.57

Use of Speed Information in Detecting Collision Events

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We used a speeded response paradigm to determine whether observers use tau to detect collision events when multiple moving objects are present. Tau is an optical variable specified by the inverse rate of expansion of an approaching object that indicates the time to contact (TTC) and is independent of the speed of the observer and/or object. In the present study we examined whether observers' simulated speed affects their response time to detect a collision event when multiple moving objects are present. Observers were shown displays simulating a roadway extended in depth. Within the scene objects were present that translated independently of the observer's motion. The size of the objects was randomly varied within a range. On each trial observers were presented with a variable number of objects in the scene and were asked to indicate whether or not an object was on a collision path with the observer and that they should respond as quickly but as accurately as possible. To determine whether other factors such as observer speed are important we systematically varied the speed of the object and observer motion such that the TTC was constant across a range of object motion and observer motion conditions. If observers use TTC then variations in observer/object speed should not influence their response time to detect a collision event. The results indicated significant variations in response time to detect a collision event as a function of different combinations of object and observer motion across three different values of TTC. Response time increased with an increase in the number of objects in the scene. The results illustrate that subjects use speed information of the surrounding scene to detect collision events and that tau is not the only source of information for the detection of collision events.

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Abstract 350 B3.58

Judgments of time to contact when an approaching object is partially concealed by a static or moving occluder

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PURPOSE. Studies of time-to-contact (TTC) typically focussed on judgments of unoccluded approaching objects. DeLucia, et al. (ARVO '00) reported that a stationary occluder can affect the object's optical size, and local tau margin derived from the unoccluded portion of the object; they also reported differences in TTC judgments of occluded and unoccluded objects. Effects of moving occluders on TTC judgments were measured here. METHOD. A computer-generated object approached the S while partially concealed by an occluder that was stationary, or

moved leftward or rightward. The latter motions resulted in an increase and decrease, respectively, in the local tau margin. In one condition, the occluder nullified the object's optical expansion. Global tau was not affected by occlusion. Sixteen Os pressed a button when they thought the object would reach them; TTC estimates were measured. RESULTS. There were significant effects of the occluder's motion and interactions between motion and other variables such as the object's TTC and shape, $p < .05$. Generally, compared with stationary occluders, rightward-moving occluders resulted in smaller TTC estimates; occluders that nullified expansion resulted in greater estimates. Although such directional changes in TTC estimates are consistent with the local tau margin, the latter predicted a greater change in TTC estimates than was observed. CONCLUSIONS. Moving occluders can affect TTC judgments of approaching objects. Results are difficult to reconcile with explanations based on local or global tau. Effects of occlusion on TTC judgments must be considered in models of perceived collision. CR: None. SUPPORT: Texas Advanced Research Program.

Abstract 351 B3.59

Perceptual learning and point-light human actions

Karyn Danatzko, Jeannine Pinto, & Maggie Shiffrar Rutgers University-Newark, Lafayette College, Rutgers University-Newark

Adults are exquisitely sensitive to human movement, even when its appearance is reduced to a dozen discrete "point-lights." However, this sensitivity seems to be orientation specific. Why do we readily recognize upright human motion but fail to perceive the same figure when it is inverted? One possibility is that our extensive experience with upright human movement tutors perception. If sensitivity is a function of perceptual learning, it should be possible to improve the recognition of inverted human figures with increased experience.

To provide such experience, we required observers to make judgements about human motion. We created brief video displays of 4 fully-visible actors engaging in each of 4 activities: running, walking, skipping, and marching. We recorded reaction time (RT) and accuracy as participants repeatedly categorized these actions. One-half of the observers were presented inverted displays. For both orientations, RT improved with practice. Sessions continued until RT reached an asymptote ($M = 8.0$ sessions).

To examine whether visual experience of fully-rendered human movement supports the perception of point-light figures, we created point-light displays of the 4 target activities. Over sessions ($M = 8.2$), observers repeatedly categorized the actions. If perception of upright point-light displays arises solely from the extraction of motion patterns available in our ordinary visual experience, then we should find that exposure to the fully-visible inverted figures improves observers' perception of inverted point-light actions. When presented point-light displays, observers' initial RTs were again slow. However, all 3 of the observers judging upright displays showed evidence of "savings," the transfer of perceptual skill from fully-visible to point-light displays. In contrast, only 1 of the 3 observers judging inverted displays showed savings. This failure to improve during the inverted trials suggests other constraints on visual processing. Supported by NEI grant R01 EY12300

Abstract 352 B3.60

The importance of temporal coherence in the perception of natural communication behaviours.

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The attribution of meaning in biological motion displays is highly dependent on the correct spatio-temporal information. Here we assess the importance of the temporal coherence, between and within actors, for the interpretation of non-verbal cues conveyed in video sequences depicting two actors engaged in interlocution. The actors read 6 excerpts from plays for 15 seconds (depicting the communication of fear, aggression, happiness, love and neutral emotions) which were videoed and converted to point-light biological-motion displays with one point on the head, two on the shoulders, elbows, wrists, hips, knees and feet. In exp.1 subjects were required to discriminate a pair of actors who were videoed together from 3 dyads who were videoed with a different partner. In exp.2 intra-subject temporal coherence was manipulated by disrupting the spatio-temporal order of the video sequence. In exp.3 inter-subject temporal coherence was disrupted by offsetting the two actors by n frames until the discrimination of the correct natural dyad fell to chance. In exp. 4 we investigated whether subjects could classify the emotions depicted by the actors. Performance in exp.1 was close to perfect for all subjects which suggests that the correct inter-personal emotions, displayed by the non-verbal behaviours, were easily discriminable from spatio-temporal information contained in point-light displays. This ability was invariant to intra-personal manipulations where performance remained at above chance levels with disruptions up to 320 msecs. The disruption of inter-personal coherence had an effect on performance, which fell to chance with perturbations of only 3 frames (120 msecs). Exp. 4 showed that subjects could decode and categorise the emotions displayed. These results suggest that the temporal coherence of inter-personal behaviour, which controls turn taking and the communication of emotion, can readily be discerned in the spatio-temporal pattern of point-light displays.

Abstract 353 B3.61

Timing and the interpretation of motion in human and animal displays

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Does the visual analysis of human movement differ from the visual analysis of non-human animal movement? Since temporal aspects of motion perception are typically investigated using apparent motion displays (Shiffrar & Freyd, 1990, 1993), we presented pictures of locomoting mammals, birds, and humans in a two-frame apparent motion display. In the first condition we presented paired snapshots taken from video footage of locomoting animals. In the second, snapshots were based on video sequences of humans imitating equivalent

motions. In a between-subjects design, naïve observers saw either animal or human picture pairs and were asked to make qualitative assessments of the smoothness of the apparent motion they experienced at each of ten different SOAs. Stimulus duration was fixed at 100ms and the interstimulus interval varied between 0 and 600ms. Qualitative assessments were rendered with a 7-point scale in which 0 represented no apparent motion and 7 indicated perfectly smooth motion. The results suggest an impressive degree of similarity in the qualitative nature of animal and human movement perception across large variations in SOA. That is, the temporal window within which apparent motion can be perceived is very similar for animal and human displays. The results for penguin motion and its human imitation were strikingly different, however, from all other animal/human pairs. One possible explanation may be effects related to the unique dynamics of semi-aquatic animal motion: penguin motion may have been especially difficult for humans to imitate, organize and analyze visually. These results are discussed in the context of recent neurophysiological findings suggesting that common mechanisms may underlie the visual analysis of human and animal motion.

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Illusory Contours

Abstract 354 B3.62

fMRI responses to perceptually completed regions in the human Lateral Occipital Complex: bounding illusory contours are not a necessary condition.

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It was previously reported that regions in the human Lateral Occipital Complex (LOC) show BOLD fMRI responses to illusory Kanizsa diamonds (Mendola et al. 1999), but it was not known whether the bounding illusory contours (ICs) were necessary to elicit the response. To test this, we generated new stimuli by rounding the corners of the Kanizsa 'pacmen' inducers and misaligning them slightly. Although ICs were no longer perceived, the configuration of the inducers nevertheless created an impression of an enclosed, *Salient Region (SR).* Baseline stimuli (no SR) were generated by flipping the inducers outwards. Observers viewed alternating blocks of SR and baseline stimuli (16 sec blocks, 256 sec runs). In separate runs, observers viewed Kanizsa (IC) diamonds alternating with facing-out inducers. IC/SR size was either 6.5 or 13 deg. EPI images were taken on a Siemens Allegra head-only 3T scanner (16 near-coronal slices, 3x3x3 mm voxels, TR=2s, TE=30ms). Regions of interest (ROIs) were pre-defined as the voxels in LO cortex (inferior and middle occipital gyri, lateral and inferior occipital sulci, and the lunate sulcus when present) which produced a greater BOLD response to pictures of objects than scrambled objects. Eight observers were tested (5 males; 6 naive). The across-observer average time-course in the ROIs was computed. The results showed a significant elevation of activity for both the IC and SR stimuli, compared to their baseline stimuli. There was no significant difference between the two conditions: the amplitude of fMRI response was just as strong for the SR stimuli. We conclude that the previously reported LOC responses to Kanizsa-type stimuli did not require the presence of bounding illusory contours. LOC response to Salient Regions may be the result of fast but crude region-based segmentation processes. Further research is needed to test if the more refined contour-based processes involve early cortex, as suggested by electrophysiological studies.

Abstract 355 B3.63

Cognitive theory fails to explain illusory form and brightness enhancement

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Purpose: To study the role of "cognitive hypotheses" in the formation of illusory figures, such as the Ehrenstein illusion (1954). Top-down approaches (Gregory, 1972; Rock, 1972) focus on the incompleteness of the inducers and the need for a perceptual postulate occluding an unlikely stimulus. Consistent with this assumption, illusory form and inducing stimuli appear to be separated in depth. We show that brightness enhancement and illusory contours emerge also when the inducers are perceptually complete and are coplanar with the inducing stimuli. Method: Nine Ehrenstein patterns were made from alphabetical letters instead of radial lines. Capital letters with terminators (e.g., L, I) and without (O, D) were used and letters were oriented either towards or away from the central area (gap). Magnitude estimation was used to quantify the strength of (i) the illusory contour, (ii) brightness enhancement, and (iii) depth segregation. Three groups of fourteen subjects participated in the experiments. Results: Strong illusory figures and brightness enhancement were perceived without the need for apparent occlusion, amodal completion, or depth segregation between the illusory surface and the inducers. Conclusion: This result logically weaken cognitive explanations of illusory figures and instead favors a low-level, bottom-up explanation in terms of a neurophysiological mechanism in the cortex (Dresp and Bonnet, 1991). How such a mechanism would operate to produce illusory contours and brightness enhancement from physical contours is unclear.

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Abstract 356 B3.64

Kanizsa square without pacmen created by selective edge adaptation

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A low-contrast disk can be made invisible, and filled in by the surround brightness/color, after adaptation to a high-contrast edge that spatially overlaps with the contour of the disk (Shimojo & Kamitani, VSS 2001). We report here that this edge adaptation technique can be applied to "part of" the edges in the Kanizsa configuration, leading to emergent percept of illusory filled-in surfaces. Low-contrast "packman" stimuli (5% brighter/darker than the gray background) that constituted the conventional Kanizsa square were presented, after adaptation to four high-contrast disks that alternated between white and black at 1 Hz for 15 s. The pacmen and the disks shared their

edges except for the wedge portions. Thus the edges corresponding to the corners of the "square" were left unadapted. Subjects fixated to a dot placed in the middle of the four disks/pacmen throughout the adaptation and test periods. All subjects (9) reported that at the beginning of the test period (for 2.7-4.3 s), only a square was perceived on a homogeneous background, and that the square region was filled with a distinct brightness, which was darker (brighter) than the background when the luminance of the pacmen was higher (lower) than the background. A similar illusory square was perceived using different shapes of stimuli that were designed to leave the same edges (the corners of the "square") unadapted, even if the test stimulus (cross- or pie-shaped figures) did not produce a vivid illusory square/surface by itself. The results indicate that the edges (local luminance contrast) at the corners were preserved, and sufficient to create the illusory square, while the other edges were masked by adaptation, and filling-in occurred across them. It suggests that visual surface representations can be formed based on local edges and filling-in process between them, rather than global luminance profiles, or spatial context of visual shapes.
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Abstract 357 B3.65

Do spatial factors influence the microgenesis of illusory contours?
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Spatial factors such as contour curvature and support ratio influence the perceived strength of illusory contours. However, it is unknown whether these determinants of interpolative strength affect how quickly interpolated contours emerge during visual processing (microgenesis). We approached this issue using a dot localization method. Observers briefly viewed Kanizsa-type illusory shapes with varying support ratios and relative inducer orientations, as well as stimuli containing comparable spatial cues that did not give rise to illusory contours (non-IC stimuli). During the last 40 ms prior to masking, a small dot appeared somewhere between two inducers. Observers judged whether the dot appeared inside or outside of the illusory shape's perceived boundary. Dot position varied based on observer responses; two interleaved staircases produced the 83% threshold points for seeing the dot inside versus outside of the boundary. This objective paradigm revealed both the accuracy of the interpolation and the strength or precision with which the contour is perceived. Stimulus duration varied from 40 ms to 480 ms, allowing investigation of the microgenesis of contour formation. Our results indicated that observers localized a dot more accurately and precisely relative to illusory contours than relative to comparable non-IC stimuli; this difference diminished at longer durations, suggesting that the time course of illusory contour formation differs from the time course by which more cognitive strategies become useful. Second, consistent with previous data, our results suggest that all illusory contours emerge rapidly; precision reached asymptote within the first 120 ms following stimulus onset. Finally, preliminary data suggest that spatial factors affecting the subjective strength of illusory contours (curvature and support ratio) also influence the time course over which interpolation proceeds. These results will be discussed in the context of contour interpolation models.

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Abstract 358 B3.66

Three-dimensional contour interpolation: Testing the 90-degree constraint
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We have investigated 3-D contour interpolation using a paradigm in which two illusory tabs, slanted in depth about an axis horizontal to the observer, were judged to be in either parallel or converging planes. Speed and accuracy were better when the spatial relations of the tabs supported interpolation of contours and surfaces between them. Control conditions (e.g. tabs with tangent discontinuities removed) indicated that the observed facilitation was the result of contour and/or surface completion. Overall results were consistent with a 3-D elaboration of the 2-D notion of contour relatability. Here we address an important unresolved issue. 2-D relatability includes a 90-degree constraint, such that interpolated contours can not bend through more than 90 deg. Is there a 90-degree constraint that governs 3-D interpolation as well? Initial studies of 3-D interpolation suggested there may not be; a performance advantage was evident even for virtual objects in which the interpolated edges bent in depth through as much as 128 deg. However, stereoscopic slant in our displays was specified entirely through shear. We suspected that slant was greatly underperceived in these displays, due to conflicting perspective cues. To test perception of slant in these displays, we used two methods: 1) an adjustment method (Gillam, 1968) in which the observer matched perceived slant using a Meccano wheel viewed in full-cue conditions, and 2) an adjustment method in which the subjects adjusted the stereoscopic displays to an apparent 90 deg angle. Results from both methods indicated that slant was substantially underperceived (45% on average). This underperception and other factors make a reliable test of the 90 degree principle impractical using the parallel/converging method. We will present results testing the 90 degree constraint using a categorization paradigm whose difficulty is independent of slant, and stereoscopic stimuli whose slant is more accurately perceived.

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Abstract 359 B3.67

Threshold recognition of phantom contour objects requires constant contrast velocity.
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The process of object recognition of phantom objects – with contours defined by rapid phase contrast flicker, was investigated under conditions of abrupt and ramped onset and offset. Nine subjects with normal or corrected-to-normal vision participated. Thresholds were determined for the discrimination of a phantom letter "E" of four orientations (the letters defined

by imaginary edges between a texture of lighter random dots inside the E compared with a texure of darker dots outside the E). Contrast revedsal at 58.5Hz was performed. For abrupt onset/offset, threshold was almost independent of the duration of presentation time over a 10-fold range from 34 – 340 msec (Mean 1.98% ±0.16%). However, when the onset and offset were shaped by a triangular envelope, over the same range of stimulus durations, threshold contrast varied strictly linearly with stimulus duration in all subjects (Mean correlation coefficient r2 = 0.96 ± 0.01). For the longest stimulus durations, thresholds exceeding 60% static contrast obtained. The results suggest that the transient edge of neural responses to novel stimuli is highly critical for recognition and that a quantity “contrast velocity” (rate of change of threshold contrast with duration time, Mean = 2.21 ± 0.19 /sec) be defined as a threshold measure for object recognition under gradual presentation conditions.

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Abstract 360 B3.68

The oblique effect on Kanizsa squares versus diamonds with misaligned edges

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Given that vernier acuity is lower for the oblique than the cardinal axes due to the oblique effect, illusory contour figures without adjacent line ends should be less subject to distortion when orthogonal squares are rotated 45 degrees. Experiment 1 tested this prediction using 4 types of inducers (pacmen, irregular shapes, lines, and corner-ends) with 8 different edge alignments: 0, 2, 4, 6, 8, 10, 12, and 14 degrees. Using a scale of "goodness-of-square" magnitude estimates, observers rated the stimuli that were presented randomly on a high-resolution computer screen. The results showed that the perception of "squareness" or "diamondness" was more stable in illusory contour figures for greater degrees of misalignment than in real line figures. While these findings indicate that the former benefits from the oblique effect, experiment 2 compared these results to vernier judgements of the same stimuli using only 1/2 of the figures. The results revealed that the "figure–superiority" effect found in experiment 1 appears to be due to vernier acuity but not global figural factors.

Abstract 361 B3.69

Can illusory contours and grouping produce spatial masking?

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Purpose: Recently, we demonstrated that, contrary to predictions by classical hierarchical vision models, global context affects spatial masking (Barghout and Tyler ARVO 2000). Here we ask whether these effects can be altered by synchrony grouping with a spatially remote stimulus. Methods: We measured threshold elevation as a function of pedestal contrast (TvC) of a vertical 8 c/d micro-Gabor target in five stimulus configurations. The three control configurations controlled for known masking effects: the target alone, the target within a horizontal 2 c/d grating, and the target with the same grating surrounded by a ring whose contrast modulated in synchrony with both 2AFC intervals. The two experimental conditions manipulated global context and perceptual grouping: the target within a grating whose left field was shifted by .5<pi> (producing a line-end induced contour) and the same grating surrounded by a synchronous ring. Results: As predicted by classical masking theories, our control conditions produced no masking or facilitation. Contrary to classical theories, the line-end induced contour produced both low-contrast facilitation and high-contrast masking (Barghout and Tyler ARVO 2000). These changes in threshold due to the induced contour were attentuated when the target was grouped with the surrounding ring by synchrony. Thus, global spatiotemporal context introduced by both induced contours and synchrony grouping can alter local masking effects.

Imagery & Brain Systems

Abstract 362 B3.70

Painting by mind's eye: investigating the patterns of functional integration between cortical regions in artists

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Although appreciation and spontaneous creation of visual art are intrinsic elements common across cultures and races, little is known about the functioning of the human brain while mentally composing an artwork. In this study, this issue was addresses by analyzing multivariate EEG signals obtained from two broad groups - artists (professionally trained in fine art) and non-artists - while they were mentally drawing paintings of their own choices. EEGs at rest were also considered. Our analysis was motivated by the hypothesis that mentally composing an art, like other complex cognitive act (Bhattacharya et al. (2001) J. Neurosci. 21: 6329-6337), requires not only co-activation of distributed cortical regions but also functional interdependences between them. To assess the hidden coupling or synchrony between multiple cortical regions, three measures, inspired by nonlinear dynamical system theory, were applied as follows: (i) index based on generalized synchrony (dynamic correlations including asynchronous coupling), (ii) mean phase coherence (circular variance of the angular phase difference), and (iii) phase synchrony index based on entropy (based on the generalization of noisy and chaotic coupled system in a common framework); results consistent across all three measures were emphasized. Comparing task (mental drawing) to rest, artists showed extensive delta and theta band synchrony over multiple cortical regions bilaterally and higher beta and gamma band synchrony in temporal cortex, whereas non-artists showed enhancement, to a lesser extent, primarily in frontal regions over multiple frequency bands. Comparing two groups during the task, significantly higher delta band synchrony was found in artists as compared with non-artists, yet desynchronization was found

in the alpha band in artists; higher synchrony in low frequency band (primarily delta) is likely due to an involvement of a more advanced long-term visual art memory in artists. The results indicated that the patterns of functional integration during spontaneous mental creation of paintings are significantly different in artists from that in non-artists.

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Lightness

Abstract 363 B3.71

Objects in one field of illumination benefit from articulation in another

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When a row of five adjacent rectangles is suspended in midair and illuminated with a spotlight, a dramatic compression in the range of perceived grays results. This compression can be reduced by increasing articulation, or the number of surfaces in the spotlight (Gilchrist et al, 1999), which according to Katz (1935) improves lightness constancy. Based on our prior findings that spatially separate fields of illumination can group together, we asked whether adding articulation to one field can reduce compression in another. A 25-patch Mondrian was added to the scene. The Mondrian and the five rectangles were equally illuminated and coplanar, but separated laterally by 45 cm. Two groups (Mondrian present vs. absent) made Munsell matches for the five rectangles. Presence of the Mondrian produced significantly less compression, but there was a loss of efficiency. The reduction of compression was only one third what would have been obtained had the two displays been merged into a single display. Four additional experiments showed that efficiency of grouping (measured as a decrease in compression) increases with: a) decrease of the illumination difference between the five rectangle display and the Mondrian; b) increase of the difference between display illumination and room illumination; c) decrease in lateral separation (20, 45, or 65 cm); d) decrease in depth separation (from 0 to 74 cm). We conclude that the visual system functionally combines articulation from separate fields of illumination, but with a loss of efficiency as the fields are separated either geometrically or photometrically.

Abstract 364 B3.72

Perceived transparency across dissimilar backgrounds

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Robilotto, Khang, & Zaidi (2001) showed that for physically different filters on identical backgrounds, perceived transparency is predicted by both perceived contrast of the overlaid region and filter transmittance (proportion of incident light passing through the back surface). We now extend this study to filters on dissimilar backgrounds. Two Achromatic backgrounds differing either in contrast or mean luminance were generated on a CRT as random overlapping ellipses. Two neutral density filters were simulated as moving in circular motions, one on each background. The filters were generated based on two independent physical properties, reflectivity (proportion of light reflected at a change in media), and inner transmittance (proportion of light passing from front to back surface within the filter). The Standard filter had both physical properties fixed. The Matching filter had one property fixed while observers adjusted the other. In Exp. 1, observers adjusted the variable parameter to make the two filters appear equally transparent. In Exp. 2, the overlaid regions were rotated to abolish transparency cues, and observers adjusted the variable parameter to make the two overlaid regions appear equal in contrast. In all background conditions, observers were able to equate the perceived transparency of physically different filters through a linear tradeoff between reflectivity and inner transmittance. Equated transmittance was the physical determinant of equated perceived transparency and equated perceived contrast of the overlaid region was the sensory determinant. In conditions where Standard filters were presented over backgrounds of lower contrast or lower mean luminance, observers made settings so that the transmittance of the Matching filter was lower than for identical backgrounds. When identical filters were placed on dissimilar backgrounds, perceived transparency was lower on backgrounds of lower contrast or luminance, as was perceived contrast.

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Abstract 365 B3.73

Selective luminance induction on bright and dark regions in textures

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It is thought that the “ON” and “OFF” channels, used for detecting luminance increments and decrements, are perceptually inseparable when we process complex textures (e.g. Solomon, Sperling and Chubb, 1993). Here we show that this is not the case. Methods: a 256 grey-levels texture patch (0.5 x 0.5 deg.), with the characteristic second order statistics of natural images, was surrounded by a uniform luminance region of various sizes (up to 4.0 x 4.0 deg.). We have modulated the luminance of the surrounding region sinusoidally in time (at 0.6Hz) either above or below the mean luminance of the central texture. We found that this modulation induced changes in the perceived contrast of the central patch. Subjects were asked to null this induction by adjusting the depth of modulation of either the bright or the dark regions of the central texture. Results: when uniform surround luminance was modulated above the mean luminance of the central patch, subjects chose to null the perceived induction by primarily altering the modulation of the bright regions of the texture. Conversely, when uniform surround luminance was less than the mean of the central patch, subjects chose to null the induction by primarily altering the modulation of the dark regions of the texture. This implies that, in contradiction to previous reports, our perception of bright and dark regions in complex textures is mediated by perceptually segregated ON- and OFF-channels.

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Abstract 366 B3.74

Perceived higher luminance in the glare effect does not give rise to a stronger afterimage

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Purpose: The glare effect refers to the phenomenon that when a surface is surrounded by regions of outwardly decreasing luminance, it will be perceived as self-luminous (Zavagno, 1999). It is also perceived to be of higher luminance. We investigated whether such a stimulus also gives rise to a longer lasting afterimage, as a stimulus of higher luminance would.

Method: Two glare-effect stimuli and two controls were used. The first glare-effect stimulus was a cross figure – a white square surrounded by four squares, the luminance of each of the four decreases outwardly. The second stimulus was a white disk surrounded by an annulus of decreasing luminance in the radial direction. For the control stimuli, the direction of the luminance gradient was reversed. In each trial, a stimulus was presented against a gray background for either 8, 12, or 16 seconds. It was then replaced by an outline figure, which was either a square or a circle slightly smaller than the white square or disk of the stimulus just presented. When the dark afterimage disappeared within this outline figure, the subject pressed a button to record the lifetime.

Result: As expected, the longer the stimulus presentation, the longer its afterimage lasted ($F(2,6)=11.22$, $p<0.01$). However, the glare-effect stimuli did not give rise to longer lasting afterimages. In fact, the lifetime was slightly shorter ($F(1,3)=10.91$,$p<0.05$).

Conclusion: The glare effect, although perceived to be of higher luminance, does not register a longer lasting afterimage. This indicates that the percept involves higher mechanisms than those responsible for afterimages.

Abstract 367 B3.75

The effect of scattered light on brightness for different contrast conditions in the mesopic range

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We have shown that, in the mesopic range, glare reduces the perceived brightness of a foveal test patch in a non-linear fashion (Colombo, Barraza, Issolio, LR&T, 32(2), 2000). Here we report the effects of glare measured under a variety of different contrast conditions obtained by modifying the background luminance.
The experiment was carried out using a reference test patch of 4 deg in diameter and a uniform luminance of 0.5 cd/m2, and a similar comparison patch with a luminance value in an interval of six possibilities. Both patchs was presented on a background of 14x18.5 deg whose luminance was varied in order to obtain contrasts between 1 and -3 with the reference luminance (Lr-Lb/Lr). The reference test patch was presented under conditions of transient glare produced by shining a bright light located 10 deg away from the line of sight, resulting an illuminace of 60 lx between the two eyes .
Subjects had to compare brightness of the two patchs displayed sequentially. The observer reported which field was brighter. A forced choice paradigm using the method of constant stimuli was adopted to determine the luminance that produced equal perceived brightness.
Results show an asymmetry in behaviour for the two polarities of contrast. Over most of the range there is a darkness induction, as in previous results. However, for the smallest negative contrasts there is a brightness induction.
This variation is produced by a trade-off between two effects: first, intraocular scattered light raises the retinal illuminance of the test patch causing brightness induction. Second, the background retinal illuminance reduces the apparent brightness of the test patch. The final sign of the perceptual effect (brightness or darkness induction) depends on the relative weights of these two effects.

Abstract 368 B3.76

A probabilistic explanation of simultaneous brightness contrast

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A growing body of evidence suggests that visual perception is generated according to the probabilistic relationship between the components of retinal images and their possible physical sources. We have further explored this idea by asking whether simultaneous brightness contrast effects can be explained by the statistical relationship between the physical sources of the light reaching the retina and the corresponding luminance values in the retinal image. To this end we first created a database of spectral returns (radiances) based on the interaction of average daylight (CIE D65) at 500 different levels of light intensity with 200 achromatic reflectances (interpolated from 6 standard achromatic reflectances of Macbeth ColorChecker). A database of luminances was then created by converting each of the 100,000 spectral returns obtained in this way into an RGB value using the standard CIE conversion. We then used the luminance database to create standard and 'articulated' brightness contrast stimuli. An analysis of the probability distributions of the possible illumination and reflectance values that could have generated the stimuli showed that: 1) the illumination of a gray patch with a dark surround is likely to be less intense than the illumination of the same patch in a lighter surround; 2) the illumination difference of gray patches in uniform surrounds is likely to be less than the illumination difference of the same patches in articulated surrounds. Thus on solely empirical grounds, these probability distributions predict that a gray patch with a darker surround will look brighter than the same patch on a lighter surround, and that the articulated version will generate a stronger perceptual effect. The significance of this work is to demonstrate that the effects of standard brightness contrast stimuli can be rationalized on the basis of the probability distributions of the sources derived from a contrived but nevertheless plausible database of visual 'scenes'.

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Abstract 369 B3.77

Lightness constancy and apparent slant in interpolated surfaces elicited by motion parallax and by binocular disparity

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Sparsely distributed dots in depth often elicit a percept of a 3D surface which spans the blank regions. We examined this surface interpolation phenomenon for point depths defined either by motion parallax or binocular disparity. In Experiment 1 a novel 'brightness illusion' technique was used to evaluate surface interpolation. The stimulus consisted of two vertically separated groups of dots (each in a frontal plane). The upper plane was closer to the observer in depth than the lower. The background was light grey, with a dark grey horizontal, depth-ambiguous strip located between the groups of dots. Interpolation between the groups of dots caused the horizontal strip to appear slanted and brighter than when perceived as frontal, consistent with the operation of lightness constancy. We manipulated the vertical distance, y, between the dots and the strip in both cue conditions. Observers set the brightness of a remote probe to match the horizontal strip. The apparent depth of the points was matched across cue conditions, permitting a useful comparison of interpolation. Results showed clear consistency across cue conditions, however, there were large individual differences in illusion magnitude, and variation with y. To determine if the inter-subject differences were attributable to variation in perceived slant, we measured perceived slant as a function of y in Experiment 2. The results again showed consistency across cue conditions, and the variation in slant judgements accounted for the individual differences in Experiment 1. Taken together, these experiments provide convincing evidence that: 1, Surface interpolation is not depth cue specific, rather it depends on the apparent depth of points in a scene. 2, Its operation varies between individuals. 3, Lightness constancy is applied to interpolated regions and is not depth cue specific.

Abstract 370 B3.78

Lightness constancy in 4-month-old infants: The effect of background reflectance

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Purpose. Chien at al. (ARVO 2001) reported that, tested with grey stimuli against a homogeneous white background field, 4-month-old infants exhibit adult-like simultaneous lightness contrast. By manipulating the background reflectance, our present goal is to test whether infants exhibit lightness constancy when either the anchoring cue or the local luminance ratio cue provided by the white background is absent.
Methods. The forced-choice familiarization method (Chien et al, ARVO 2001) is being used to measure infants' novelty responses. The apparatus is a 24"*30"*24" (L*H*D) testing chamber with a front 12"*12" open window for infants to view the stimuli. The stimuli are real paper surfaces of different reflectance (64% (light grey) and 23.5% (dark grey)) and are patterned as square smiley faces. The background reflectance is either 90% (white) in the full cue experiment, or 5% (black) in the dark-background experiment. Two incandescent illumination levels differing by about a factor of 3 are being used. In the familiarization phase of each trial, infants are exposed to two identical smiley faces under one illumination. In the test phase, the illumination is either increased or decreased by about a factor of 3. The infant is presented one smiley face that has the same reflectance but with a novel luminance and another smiley face with a novel reflectance but the same luminance. If infants have lightness constancy, they are expected to prefer the face with a novel reflectance regardless of changes in illumination.
Results. In the full cue experiment, infants (n=10) showed significant novelty responses to the face with a novel reflectance, regardless of changes in illumination. This behavior indicates that the reflectance-matched face is seen as familiar across changes in illumination, indicating the presence of lightness constancy when both an anchoring cue and a luminance ratio cue are present. Data collection on the reduced-cue experiment is in progress.

Abstract 371 B3.79

Dichoptic lightness contrast effects

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Simultaneous lightness contrast (SLC) effects are frequently thought of as perceptual byproducts of low-level retinal interactions, even though high-level processes involved in the perception of depth, 2-D, and 3-D spatial organization have been shown to play an important role in mediating SLC effects. The current study uses a simple dichoptic technique in which a classic SLC display is partitioned so that gray targets are presented to one eye while black and white inducing backgrounds are presented to the other (Cataliotti & Bonato, ARVO 1998). Strong contrast effects were found in some conditions and are consistent with the findings of Anstis and Ho (1998). Under other conditions binocular rivalry interfered with the seamless fusion of the gray targets and their contra-image areas, causing an ambiguous surface color experience (fluttering or luster) of the gray targets. Clear unambiguous fusion and contrast effects were obtained only when the sign of the edge produced by the target-to-surround luminance relationship in the one eye was equal to the sign of the edge produced by the contra-image-to-surround luminance relationship (partial edge correspondence) in the other eye. In these cases we obtained lightness contrast effects that were significantly stronger than those experienced under normal viewing. We also find that as the target's perceived background luminance is systematically manipulated, the slope of the contrast effect is similar under both normal and dichoptic viewing conditions. Overall, these findings suggest that the same or a similarly designed high-level process may be responsible for dichoptic and normal SLC effects.

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Abstract 372 B3.80
Withdrawn

Motion

Abstract 373 B3.81

Effects of luminance and isoluminant masking noise on second-order chromatic smooth motion
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Purpose: It has been reported that second-order chromatic apparent motion is influenced by first-order isoluminant chromatic noise but not by first-order luminance noise. The aim of this study is to investigate whether these effects emerge for apparent motion alone or whether these effects are generally observed for second-order chromatic smooth motion.
Methods: We measured simple detection and direction discrimination thresholds for luminance and chromatic drifting gratings in the presence of luminance or isoluminant chromatic noise. A 0.25 cycle/deg envelope motion was produced by contrast modulation of a 1 cycle/deg carrier component composed by anti-phase modulation of red and green sinusoidal gratings. The contrast of 1D-spatial luminance or isoluminant noise, superimposed on the stimuli, was varied. The speed of the envelope motion was 1 deg/sec. All stimuli were presented on RGB monitor at 150 Hz.
Results: 1. Detection and direction discrimination thresholds for isoluminant stimuli were not affected by the luminance noise, whereas both detection and direction discrimination thresholds for luminance stimuli increased as contrast of the luminance noise was increased. 2. The isoluminant chromatic noise influences motion discrimination of the isoluminant stimuli but not the luminance stimuli.
Conclusions: There is a strong influence of isoluminant masking on second-order chromatic smooth motion identification but less or little effect of luminance masking. This is consistent with the previous study for second-order chromatic apparent motion. These results indicate that second-order chromatic motion is mediated by a genuine chromatic mechanism.
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Abstract 374 B3.82

Relative Motion in Conflict with Binocular Disparity and Size Change
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Purpose: Veridical perception of the environment requires the integration of multiple depth cues. Previous work has shown that relative motion (RM) and binocular disparity (BD) combine in shape perception, and that BD and size change (SC) interact in time to contact estimation. How do these multiple cues combine in signalling motion through space? We used the radial speed illusion (in which an expansion pattern appears faster than a rotation pattern of the same local dot speed) as a measure of the contribution of BD and SC to the perception of motion-in-depth.
Design and Methods: Points of subjective equality (PSE) were obtained from 3 naive observers between an expanding random dot pattern, signalling approaching motion-in-depth, and a rotating pattern. Each dot was a narrow-band Difference of Gaussian. The disparity of the RDK's was manipulated in three experiments: in Experiment 1 BD was fixed at one of 7 levels during each trial, signalling a fixed depth plane; in Experiment 2 BD was varied throughout the trial, signalling receding motion-in-depth. In Experiment 3 disparity and shrinking dot size signalled receding motion-in-depth.
Results: Experiment 1: For all observers defining the expanding pattern at a fixed depth plane made no significant difference to the magnitude of the speed illusion.
Experiment 2: For all observers conflicting dynamic disparity signalling receding motion made no impact on the speed illusion.
Experiment 3: Both receding dynamic disparity and diminishing size cues combined did not reduce the speed illusion.
Conclusions: The relative motion information contained in an expanding radial motion pattern is such a strong cue to motion-in-depth that incongruent size change and disparity cues, whether fixed or dynamic, have no impact on the magnitude of the radial speed illusion. In terms of cue combination theory this represents a strong example of cue veto that should be reflected in cue combination models.

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Abstract 375 B3.83

Evidence for multiple motion aftereffects for radial flowfield stimuli
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Purpose. The motion aftereffect (MAE) and interocular transfer (IOT) can be used to probe the human visual system for characteristics and location of motion mechanisms. In the present study, we used these techniques to examine several radial flowfield stimuli, which differed in motion coherence and dot lifetime (LT), by measuring direct and transfer MAEs with static and dynamic test stimuli. Methods. Adaptation stimuli were random dot expanding radial flowfields with acceleration, viewed by one eye. We compared a 100% coherent, infinite LT stimulus to a 100% coherent minimal LT stimulus and an infinite LT stimulus matched to the latter in terms of motion salience (35% coherence). The duration of direct MAEs was measured in the same eye, and that of transfer MAEs in the opposite eye. Results. Direct and transfer static MAEs were shortest for the incoherent stimulus, longer for the minimal LT stimulus and longest for the infinite LT stimulus, with transfer being partial (about 25%) for all. Direct dynamic MAEs were longer than static MAEs, with the coherent stimuli giving longer MAEs than the incoherent stimulus. IOT was around 50% for the coherent stimuli, irrespective of LT, and almost 90% for the incoherent stimulus. Conclusions. The results with the static test reveal mainly monocular mechanisms dependent on the coherence and LT parameters (low level). In

addition, the dynamic test provides evidence for the strong involvement of binocular mechanisms that integrate over time. In the case of the incoherent stimulus, the mechanism is almost totally binocular, indicating that spatial integration can be achieved only at high binocular levels.

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Abstract 376 B3.84

Two temporal channels underlie the dynamic motion aftereffect

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Purpose: To characterise the temporal tuning of the motion aftereffect (MAE) using temporally filtered dynamic random noise (DRN).
Methods: Adaptation to orthogonal bivectorial motion was used to produce the MAEs, whose direction was measured. Adapting speeds were either: 1.5 & 6, 1.5 & 24, or 6 & 24 deg/s. Each speed pair was tested with DRN filtered into one of 5 octave-width passbands with centre frequencies: 1.1, 2.1, 4.3, 8.5 & 17 Hz. MAE directions were then re-measured using DRN interleaved with a static noise pattern. Finally, MAEs were measured on a static-only noise pattern.
Results: Dynamic only: MAE direction for the 4-octave speed difference (1.5/24 deg/s) changed smoothly from opposite the slower vector to opposite the faster vector as test temporal frequency increased. The 2-octave speed pairs also varied smoothly with test frequency but over smaller directional ranges. Static only: MAE direction for static test patterns was directly opposite the slower vector for the 1.5/24 & 6/24 deg/s pairs, and opposite the vector sum for the 1.5/6 deg/s pair. Dynamic+static: Interleaving a static component with the temporally filtered DRN had little or no effect on MAE direction.
Conclusions The asymmetries in the dynamic-only conditions fit a two-channel model of temporal processing, comprising a low-pass and a high, bandpass channel. Dynamic MAEs seem to reflect the combined adaptation in both channels. The static MAE behaves quite differently and does not appear to interact with the dynamic MAE, being possibly mediated by mechanisms in the form pathway.

Abstract 377 B3.85

Is induced motion due to position illusions?

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A stationary stimulus flanked by moving stimuli can appear to move in the opposite direction. Most explanations involve motion sensitive receptive fields with positive and negative lobes corresponding to opposite directions of motion. For grating stimuli, motion induction exists only for velocities below 2.5 deg/sec. For uniform and shear motion, motion is detected by position tracking at these slow velocities and by motion-energy units at higher velocities (Tsujimura and Zaidi, 2001). We test, therefore, whether motion induction is due to apparent changes of position of the stationary stimulus caused by position changes of the surrounding stimulus, or due to receptive field properties of motion-energy units. A stationary grating (Contrast=.33) was flanked by two moving gratings at the same spatial frequency (SF: 0.5, 1, 2 cyc/deg). We used four kinds of motion for the flankers: 1) A unidirectional moving grating (Contrast=.33; TF: 0.25, 1.0, 4.0 Hz); 2) The moving grating added to a stationary grating (Contrast=.66) of the same spatial frequency. The compound grating's amplitude and spatial-phase oscillate with time, but the motion energy is contributed solely by the moving grating and is unidirectional; 3) A unidirectional grating whose amplitude was modulated like the compound grating; and 4) A grating (Contrast=.66) whose spatial phase was modulated like the compound grating. Observers had to choose whether motion in the central grating was "unidirection", "oscillation" or "no-motion". For the compound grating inducers, observers will respond oscillation or unidirection depending on whether motion is induced by position changes or by motion-energy. Observers reported oscillatory induced motion for velocities below 2 deg/sec. At faster velocities no induced motion was reported for any condition. This suggests that induced motion is due to illusory position changes of the central test in the opposite direction to the position changes of the compound grating.
Grants: Novartis Ophthalmics to S.Tsujimura, and NEI EY07556 & EY13312 to Q. Zaidi.

Abstract 378 B3.86

Representational Momentum using complex, continuous motion

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Representational momentum (RM) refers to a memory distortion in which the final position or configuration of a moving object is misremembered as being too far forward along its actual or implied trajectory. RM has been well established when motion or change is implied, however, some debate still exists as to whether it can be observed with smooth, continuous motion. Typically, smooth motion studies have involved simple translation or rotation in the picture plane. Under these conditions, when eye movements are controlled, little if any forward shift is obtained. This suggests that overtracking may account for the errors observed with smooth motion. However, it is also possible that the addition of a salient central reference point (fixation cross) also influences localization accuracy given such simple displays. The purpose of the current work was to measure RM with continuous displays where eye movement artifacts would be unlikely to occur. In one series of studies, video sequences of human crowd scenes were used as stimuli. In another, complex, non-rigidly deforming novel shapes were expanded and contracted around a central fixation point. In all studies we found memory distortions consistent with the errors observed in previous RM studies. These findings suggest that Freyd's (1987) "dynamic mental representations" may underlie our perception of continuous as well as implied motion sequences.

Abstract 379 B3.87

Perceived global velocity is strongly influenced by motion inside the moving elements

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We investigate whether the presence of local movement inside an object influences its perceived global motion. To test this, we did the following psychophysical experiment: Two Gabor patches moved downwards along straight paths on a computer monitor. In addition to moving vertically, they could also move horizontally, either towards or away from each other. The sinusoidal patterns of the Gabor patches could also move relative to their boundaries, either inwards or outwards. Subjects were instructed to detect whether the two Gabor patches were globally moving towards or away from each other.
When the sinusoidal pattern of the Gabor patch was stationary relative to its boundary, subjects showed no bias for the perceived direction of horizontal global motion. However, when the sinusoidal pattern of the Gabor patch was moving relative to its boundary, subjects showed large biases. These biases depend solely on the direction and speed of the motion within the Gabor patch; they do not depend on the speed of the Gabor patch as a whole. When the motion within the Gabor patches relative to the boundaries is inwards, the global motion of the Gabor patches needs to be outwards in order to appear vertical, and vice versa.
Although they were specifically instructed to look at the motion of the Gabor patches as a whole, subjects appear to track the absolute movement of simple features within the Gabor patch.

Abstract 380 B3.88

Motion Sharpening in Moving Natural Images

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Moving objects often appear normal or even sharper than they actually are. This effect, called motion sharpening, has been demonstrated empirically. Video-taped images are actually somewhat blurred, but they look sharp when the video is played. Most studies regarding the motion sharpening have used simple stimuli, such as moving gratings. We have examined this sharpening process by varying the amount of blur in moving natural images.

We prepared movies from natural images (running animals, flying birds, aerial landscapes, river flow, moving CG images, and so on), each of which comprised 100 frames. X of the 100 frames were blurred by low-pass filtering and combined with the non-blurred frame to make a movie of 30 fps. Subjects judged the perceived sharpness of the movies by comparing the movie to a blurred still image.

When the amount of blur was small (1/20 of the compression rate in the JPEG algorithm), motion sharpening was perceived even when all 100 frames were blurred. This was shown earlier. However, no sharpening was perceived if all 100 frames were blurred to a level at which the details of the images were disappeared (1/200 of the compression rate, in which the spots on the body of a cheetah disappeared, for example). However, we found dramatic motion sharpening even when 70 frames were greatly blurred (so that the movie contained only 30 sharp image frames). Even with 90 frames greatly blurred, the appearance of the movie was still acceptable, though some flicker between blurred and non-blurred images was perceived.

Since the amount of blur is very large in the above case, our results suggest that motion sharpening is stronger than previously recognized. This kind of strong motion sharpening depends on the spatial structure (layout) of the images. The sharpening is stronger when the background pattern is moving (in the situation when a moving object is tracked by a camera, for example), which suggests contrast gain control in a motion detecting mechanism.

Abstract 381 B3.89

Converging vs. diverging local motions in motion integration

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Purpose: The previous study has shown that two moving lines shown in vertically arranged apertures in combination with a positively-oriented line in the upper aperture and a negatively-oriented line in the lower aperture ("<" shape) tend to be integrated more than those in the reverse combination (">" shape) when they move rightward (ARVO2000). The present study tries to examine the determinant of this result. Methods: Lines oriented 15 and -15 deg, 30 and -30 deg, 45 and -45 deg, 60 and -60 deg, or 75 and -75 deg, were presented in pairs, in a combination of either "<" shape or ">" shape, and two 90 deg lines were used as a control condition. Eccentricity, that is, the distance between the fixation point in the center of the display and the center of the two apertures, was varied either horizontally or vertically. The lines moved horizontally rightward or leftward. Subjects reported whether the two motions cohered or not. Results: (1) Perceived coherence depended on the spatial configuration of line orientation. Performance declined from 100% for 90 deg lines to 0% for 15 and -15 deg lines, and considerably degraded at 30 and -30 deg lines. (2) The lines presented in peripheral vision were integrated more than those presented in fovea. (3) Not the shape of the two lines, but the combination of local directions affected coherence. (4) Perceived coherence was higher when the lines in "<" shape moved rightward rather than leftward, and when the lines in ">" shape moved leftward rather than rightward. These results show that converging motions cohere more than diverging motions. Conclusions: The direction combination effect turned out to be the determinant in the line combination effect, and whether local motions are converging or diverging plays an important role in motion integration.

Abstract 382 B3.90

Contextual modulation of perceived motion direction: evidence for non-terminator based mechanisms

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A horizontally moving grating can be made to appear to move obliquely either upwards or downwards by introduction of appropriate depth-ordering cues (Duncan et al., J. Neurosci, 2000). A widely held explanation of such depth-motion

interactions is that depth cues allow identification and suppression of motion signals arising from 'extrinsic' line-terminators. We show that depth-cues alter the perceived direction of unoriented moving features, a result not accounted for by terminator-based explanations.

Stochastically moving random dots were viewed through a diamond-shaped aperture. The four panels defining the aperture had one of two depth configurations: 1) Upper-left and lower-right panels in front of the moving stimulus (NEAR), lower-left and upper-right behind (FAR), or 2) vice-versa. Motion was oscillatory with some dots moving along the NEAR-to-NEAR axis and the rest moving along the FAR-to-FAR axis. The NEAR vs. FAR percentage ratio was varied from 86:14 to 14:86. Five naïve observers reported the perceived motion axis in a 2AFC direction discrimination task. A no-depth condition provided comparison.

For all observers, psychometric curves for the depth-ordered stimuli were shifted relative to the no-depth condition. For the completely ambiguous condition (50:50 NEAR to FAR ratio), motion was reported along the NEAR axis on 75% of the trials. The effect of depth cues on perceived motion direction is thus not limited to overcoming the motion ambiguity of oriented features (i.e. the aperture problem). Consequences for models of depth-motion interaction will be discussed.

Abstract 383 B3.91

Age-related deficits in motion coherence thresholds

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Several studies have suggested that various aspects of motion perception decline with age. Amongst those highlighted are motion coherence thresholds. In this study we extend previous findings by (1) measuring coherence thresholds across a wide range of speeds and (2) relate the findings to changes in earlier visual processing as indexed by contrast sensitivity to grating patterns over a wide range of spatial and temporal frequencies. Standard two-option forced-choice techniques were used to measure motion coherence thresholds for random dot patterns at four speeds covering a sixteen-fold range, and contrast sensitivity to gratings at three spatial frequencies and three temporal frequencies. In agreement with previous findings we find that coherence thresholds decline with age for slow movements, however contrary to previous findings we find no loss of performance for a range of medium to fast motions. Such results are inconsistent with theories of selective loss of M-cell function in old age.

Abstract 384 B3.92

Neuroimaging of direction-selective mechanisms for first-order and second-order motion stimuli

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Psychophysical findings have indicated functional segregation of processing pathways for first-order motion (movement of luminance modulation, LM) and second-order motion (e.g., movement of contrast modulation, CM). However, neural correlates of those pathways are still controversial. To investigate whether there is corresponding anatomical segregation, we conducted a novel fMRI study with deliberate control of attention, to localize direction-selective cortical mechanisms for first- and second-order motion stimuli by measuring direction-contingent response changes induced by motion adaptation.

We used Siemens 3T scanner along with a flattened occipital format. The stimulus was a rotating windmill defined by a 10% LM superimposed on a static random-dot noise, or by a 100% CM of a static noise. Every 32s, the rotating stimulus (LM or CM) gradually disappeared and reappeared with or without direction reversal between the 32-s periods (a reversal occurred every 64s). We asked subjects to maintain fixation at a central spot and to detect speed changes of the stimulus rotation, which occurred at unpredictable timings (independent of the direction reversals) and were as tiny as the detection threshold, in order to keep the subject's attention to the motion stimulus.

We obtained time courses of MR signals from V1, V2, V3, VP, V3A, V4v and MT+, defined by other retinotopic stimuli. We compared cortical activations between the first 32s period (after direction reversal) and the second period (without reversal) to isolate the effects of direction-selective adaptation from those of motion onset. The results obtained so far suggest that the CM stimulus generated direction-selective adaptation in V3A and MT+, but not in V1 and V2. However, the LM stimuli produced clear direction-selective adaptation in V3A, MT+, and (if the LM depth was increased) also in V1 and V2. Therefore, the functional difference between the first- and second-order motions may originate in V1 and V2.

Abstract 385 B3.93

Global motion processing: the Red-Green mechanism

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The interaction of colour and motion cues for global motion integration across space has only recently been studied. To establish the tolerance limits of global motion we first determined global motion detection thresholds (81%) as a function of the chromatic contrast in the isoluminant cone-opponent colour-space (S-(M-L) space). We used random dot kinematograms with 300 coloured gaussian blobs (0.22 , 1 /s, 5.1 x 4 , 200cm viewing distance). Observers had to distinguish between an interval with random motion and an interval with 40% of the blobs moving either left or right (2IFC). Experiment 1: all blobs had the same colour and were presented on a grey background (luminance= 50cd/m2). Eight out of ten observers were not able to perform the task for S-cone isolating colours. In all other colour directions we found that the thresholds were determined by the stimulation of the red-green (R/G) mechanism. Experiment 2: we further tested this by adding chromatic noise (with a constant projection onto the R/G mechanism) to the red and green stimuli. We found that the width of the chromatic noise distribution did not affect the results and the thresholds were predicted by the projection onto the R/G mechanism. Experiment 3: To evaluate possible

luminance artefacts we established observers' individual isoluminance by heterochromatic flicker and rerun Experiment 1. We obtained the same results. Experiment 4: To determine whether this is a single R/G mechanism, half the dots in the display were green and the other half red. We found that threshold coherence levels were not greater than 40%, indicating the presence of a single R/G mechanism. Conclusion: the S cone input in our global motion task is negligible for the majority of observers. Global motion extraction in the observer's isoluminant plane appears to be mediated exclusively by a single R/G mechanism andthe observed sensitivity to global motion is predicted by the projection onto this mechanism.

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Abstract 386 B3.94

Apparent motion depending on luminance and hue variations

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Purpose: To study apparent motion produced by luminance and hue variations. By alternately increasing and decreasing the luminance of a short radial line running parallel to another whose luminance is kept constant, the two lines appear to change their spatial position back and forth. For example, when pairs of lines are arranged such as to create two spoke wheels of different diameter, changing the luminance in counterphase will make the inner and outer wheels appear to rotate in opposite directions. The change in spatial position is also present when the hue of one of the radial lines is varied. Method: Two frames of the same spoke wheel pattern were presented with a change of luminance (or color) in one of the two parallel lines. The amplitude of the luminance change as well as line width and distance between the two parallel lines was varied. Twelve naive subjects participated in each experiment. Results: Very small variations in luminance are sufficient to create the impression of apparent motion, while increasing the luminance difference between the lines increased the strength of the effect. In comparison, increasing the spacing between the paired radial lines reduced the strength of apparent motion. By combining a luminance change with a change in width of one the lines perceived rotation could be enhanced, cancelled or reversed. When one line becomes brighter while the other becomes darker, illusory rotation could be obtained in one direction only. Hue variations affected the amplitude and direction of the apparent motion differently. Conclusion: Oscillating rotary apparent motion has been demonstrated by luminance variation of paired parallel lines arranged in the form of a spoke wheel. This apparent motion effect is different from stroboscopic motion as no change in stimulus position is involved.
Supported by Freiburg-Padua Program and Alexander von Humboldt Foundation

Abstract 387 B3.95

A model for the contribution of local and global gains to the motion aftereffect

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Snowden & Milne (1997, Curr. Biol., 7, 717-722) reported evidence for the existence of higher level - complex motion - detectors. They used a radial stimulus divided in quadrants where only two quadrants (e.g. quadrant 1 and 3) contained moving dots. Apart from the classic motion aftereffect (MAE) in the quadrants that actually contained moving dots, they showed that motion adaptation could be measured for (locally) non-adapted locations also. This phenomenon is known as a phantom MAE. It is likely that this indicates a global gain. Interestingly, the threshold elevation for the non-adapted locations was smaller than for the locally adapted regions. The starting point of this study was to gain more insight in the mechanisms underlying this difference. We tested a linear model where we assumed that the coherence threshold for the directly adapted regions is a product of the setting of the gains of the local motion sensors plus the gain of the global system. This opens up a way to quantify the contribution of the local gains: in the areas that were not directly stimulated, the threshold elevation is due to the setting of the global gain only, whereas the threshold in the stimulated part is due to both the local as well as the global gain. As a result the value of the local gain is the coherence threshold for the adapted region minus the threshold value in the phantom area.
This model opens up possibilities to quantify the contribution of even higher order mechanisms like attention. For example, by paying attention to only one of the quadrants (either containing motion or not).

Abstract 388 B3.96

Does depth from motion pop-out?

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To examine whether targets defined by depth from motion information pop-out or not, we conducted visual search experiments in which the target was defined by motion parallax, that is, motion disparities yoked to observers' voluntary head movements. In the experiments, stimulus displays were presented to observers for 200 msec (exps. 1 and 2) or 500 msec (exps. 3-6). The observers responded whether the target was present or absent. Display sizes were 4, 9, 16, or 25, and one half of the trials contained the target item. In head-moving (HM) conditions, observers performed tasks with head movements to which item motions were yoked. We expected that depth information was available in target searching in these conditions. In head-fixed (HF) conditions, observers performed tasks with their head fixed. The item motions were not yoked but simply controlled by a PC, and the motion information alone was available in target searching in these conditions. In the first two experiments, the target was defined by motion (exp. 1) and speed (exp. 2). These manipulation yielded depth between the target and distracters from motion parallax (the HM condition). In the following experiments, using motion parallax, the target was defined by slant (exp. 3), magnitude of slant (exp. 4), direction of slant (exp. 5), or shape of the depth surface (exp. 6). As results, search efficiencies in the HM condition were equal to or below those in the HF condition for all cases. Moreover, almost all observers reported that they hardly see depth in the stimulus displays even when

the item motion was yoked to their head movements (the HM condition). These results indicate that depth from motion information does not provide pop-out. The observers might use the motion information itself in target searching, regardless of the depth from motion. This suggests that the depth processing from motion has lower frequency properties in temporal and/or spatial domains than the motion processing. Supported by HFSP grant.

Abstract 389 B3.97

Direction-selective mechanism mediates identification of spatial patterns moving behind narrow slits
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It is often assumed that direction selectivity is the machinery for extracting motion information, and that non-direction-selective mechanisms analyse spatial pattern information. This view however is challenged by the anomalous perception of moving spatial patterns presented through static apertures (e.g., Parks, 1965; Shipley & Kellman, 1997). A striking example is an advertisement display (PoleVision, AVIX inc) that shows horizontally moving characters in an array of vertical LED lines. In spite of only a fraction (one per ten lines) of the image being actually presented at any instant of time, the running catchword can be effortlessly read. Spatiotemporal interpolation phenomena, including this example, can be interpreted as implying the brain's integration of spatial pattern information over motion trajectory, which supposedly requires direction-selective spatial pattern mechanism (Burr et al., 1986). This hypothesis was tested by masking and adaptation experiments. I briefly (320 ms) presented two sets of letters (identical alphabet in each set) separately through arrays of static vertical slits located above and below the fixation point. The sets moved in opposed directions to eliminate the effects of eye tracking. For a range of inter-slit intervals, pattern movement significantly improved letter identification performance in comparison with static control conditions. In masking experiments, I filled the inter-slit areas with a random noise mask that coherently moved independently of the letter movement. It was found that the masking effect peaked when the masking noise moved in the same direction, and at around the same speed, as the letter movement. I also measured the effect of motion adaptation, and found that letter recognition was worse for the letters moving in the adapted direction than for those moving in the opposite direction. These results clearly indicate the involvement of direction selective mechanisms in spatial pattern recognition.

Abstract 390 B3.98

A dynamical account of motion and non-motion perception for radial counterphase sine gratings
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The perception of motion and non-motion were studied for radial counterphase sine gratings. The perception of stationary "spoke" patterns predominated at low contrasts, motion and non-motion percepts were bistable at intermediate contrasts, and motion predominated at higher contrasts. Motion could be perceived at temporal frequencies too high for attentional tracking and for presentations too brief for saccadic eye movements to imbalance competing clockwise (CW) and counter-clockwise (CCW) motion directions. The imbalancing of opposing motion detectors, which is the basis for perceiving only CW or only CCW motion, is attributable instead to: 1) random fluctuations in activation, and 2) inhibitory competition between the detectors suppressing the motion direction not favored by the random fluctuations (by pushing its activation below the threshold level required for perception). In an additional experiment, prior adaptation to a low contrast drifting grating (CW or CCW) resulted in increased motion perception for the counterphase grating and decreased detection of the grating. The increase in motion detection by adaptation was attributed to the reduction of inhibitory competition. Motion detection increased more at high contrasts than low contrasts, indicating mutual inhibition increases with activation. The activation-dependence of inhibition is inconsistent with accounts attributing the absence of motion perception to the cancellation of equal and opposite motion directions. It is argued instead that when motion is not perceived, it is either because the contrast of the grating is too low, or because of competition between motion- and pattern-detectors reducing motion detector activation below threshold (as indicated by the decrease in grating detection when motion perception was increased by prior adaptation).

Abstract 391 B3.99

Detecting motion along spatio-temporally coherent vs. incoherent trajectories
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Purpose: Watamaniuk, McKee & Grzywacz (1995) have reported that observers are surprisingly efficient at detecting a single coherently moving dot within an array of short-lifetime noise dots. A possible explanation is that visual system pools over outputs of local motion detectors along spatio-temporally coherent trajectories (i.e. trajectories consistent with a velocity of the local motion). This strategy would improve signal strength for motion along an extended trajectory. We tested whether observers exhibit sub-threshold summation of motion energy distributed over spatio-temporally coherent trajectories. Method: Subject's task was to detect motion embedded in noise. Dynamic white noise was convolved with a local spatio-temporally oriented filter, resulting in a drifting surface with limited temporal correlations (pixel correlations fell to zero within 70ms, or 0.63 of movement). The drifting surface was blended with background noise using a small gaussian spatial window (s=0.5), which moved at the same speed as the drifting surface (9.4 /s) along a trajectory extending 6.3 . The gaussian window moved either in the same direction as the surface motion (coherent condition), in the opposite direction (opposite condition), or in an orthogonal direction (orthogonal condition). In the coherent condition, the local motion energy propagates along a global 'trajectory' that is consistent with the motion signal, while in the other conditions it does not. On each trial, observers indicated whether the trajectory was located to the left, to the right, below, or above the fixation point (4AFC). The signal-to-noise ratio was varied to determine thresholds. Results: Detection thresholds were the same across the three

conditions. Motion propagating along a consistent trajectory did not improve the detection of the motion. Conclusions: We found no evidence that spatio-temporal coherence facilitates detection of sub-threshold motion energy.

Abstract 392 B3.100

Fine Motion Discriminations at Isoluminance
Nestor Matthews Denison University, USA

Purpose: To determine the extent to which fine direction and speed discrimination depend on luminance contrast when these two tasks are performed under identical stimulus conditions.

Method: 20 naïve undergraduates participated in a within-subjects experimental design. Two random-dot cinematograms (RDCs), that always differed from each other in speed and direction of motion, were presented successively on each trial. The dots were differently colored than the surround, and either matched the surround's luminance (isoluminant condition = 0% contrast) or differed from the surround's luminance (luminance-contrast condition = 40% contrast). The task was randomly varied, requiring either speed judgments or direction judgments. Across these two tasks, the stimulus conditions were held constant. Discrimination thresholds, defined as one half the stimulus increment needed to alter the response rate from 0.25 to 0.75, were measured for each subject, task, and luminance condition.

Results: Within-subjects ANOVAs indicated that neither speed thresholds ($F(1,19) = 0.07$, $p=0.78$, n.s.) nor direction thresholds ($F(1,19)=0.05$, $p=0.82$, n.s.) were affected when the luminance difference between the surround and the dots was eliminated. A control experiment with the same statistical power and subjects suggested that performance on the speed task was based upon motion cues and not upon time cues that were also available: Speed thresholds were significantly lower than time thresholds in both the isoluminant ($F(1,19)=27.29$, $p<0.0001$) and the luminance-contrast ($F(1,19)=22.8$, $p=0.0001$) conditions.

Conclusions: The findings are consistent with the notion that, for RDCs, fine direction and speed discrimination are limited by neural noise that does not require luminance contrast. The present data could be modeled either by a shared noise source for the two tasks, or by task-specific noise sources that obey similar rules regarding luminance contrast.

Abstract 393 B3.101

Separated processing of local motion signal depending on its polarity in MDM detection
Maruya, K. & Sato, T U. of Tokyo, Japan

Purpose: We have already reported that reversed-phi was perceived with Motion Defined Motion (MDM) stimulus (ARVO2001). This suggests that polarity-dependent detector function for MDM (Maruya & Sato, 2000; 2001: cf. Zanker, 1993). In this study, we further investigated the role of polarities by comparing perception characteristics for the stimuli with the same modulation waveform but containing only a single motion direction (uni-directional) and those with two opposite directions (bi-directional). The uni-directional motion was created by raising the modulation waveform for bi-directional motion by half of its amplitude. Methods: The stimulus was 10 (V) x 4 (H) deg horizontal motion-defined patterns consisted of dynamic random dots. Dot density was uniform over the whole field, and dots were moving horizontally (right or left). The dot speed was modulated along V-axis either by sinusoidal (Exp. 1) or missing fundamental (Exp. 2) function (spatial frequency: 0.2 c/d). In bi-directional condition, the speed was modulated either -100 to 100 or -200 to 200 min/sec (both to the right and left around 0). In uni-directional condition, the speed of the dots was modulated between 0 and 200 min/sec, i.e. by plus/minus 100 min/sec function raised by 100 min/sec DC level. A 5-frame apparent motion was presented with a 1/4-cycle shift between frames. SOA was fixed at 320 ms. Subject was asked to report the perceived direction by 2AFC. Results: We found the motion was perceived stronger under the uni-directional condition than under the bi-directional condition. This suggests, in the MDM detection, signals after local motion detection-level are processed separately depending on its polarity. If this is the case, in the bi-directional stimuli, the signals were processed by separate detectors depending on their polarities, so the waveform of local motion flow-field was rectified and the detection supposedly is less efficient than in coincident condition.
Supported by JSPS, HFSP

Abstract 394 B3.102

Motion-induced masking
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Introduction: The location of moving objects can be misperceived in the direction of motion. This mis-localisation is believed to derive from mechanisms that compensate for the processing time of motion signals (Ramachandran and Anstis, 1990). We investigate whether a moving object masks a stationary target that is presented next to it.

Methods: Two random dot kinematograms (RDKs) were presented at 3 deg above and below a fixation cross. One RDK moved to the left while the other moved to the right. Both RDKs were modulated by a Gaussian envelope in space and time. Even though the Gaussian envelope was stationary, each RDK was perceived as displaced in its direction of motion (De Valois and De Valois, 1991). On each trial, a small target was placed either to the left or right of one of the two RDKs. The contrast of the target was varied. Observers had to report the location (4AFC) of this briefly presented target.

Results: We measured detection thresholds for the target. Despite the fact that the targets were presented at a fixed distance away from the centre of the RDKs, targets were usually easier to perceive when they were behind rather than in front of the RDK.

Discussion: Our results show that moving objects interfere with the perception of other, stationary objects in a scene. One possible explanation for these results is that the moving and stationary objects are competing for a common position in

perceptual space – the static target is perceived near its true location, while the moving object is mis-localised, causing masking or crowding.

We acknowledge the support of HFSP grant RG0109/1999-B.

Abstract 395 B3.103

Do Chinese and Americans see opposite apparent motion? Replicated and revised.

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Tse and Cavanagh (2000, Cognition 74 B27-B32) showed that Chinese and Americans see opposite illusory line motion in the last horizontal stroke of " " in a stroke-by-stroke presentation. They supposed that the direction of motion perceived by Americans was due to transformational apparent motion; this, in turn, makes the fact that Chinese perceive the opposite direction hard to explain. In this study, prediction of the attention gradient model (Hikosaka, Myauchi, & Shimojo, 1993, Vision Research 33 1219-1240) was tested by varying stimulus onset asynchrony (SOA) between the two critical strokes, so that the predicted direction should be opposite in short (90 ms) and long (900 ms) SOAs, even for Chinese. In addition, two possible top-down factors, script (chirographic, square) and stroke sequence (writing, random), were manipulated. Data from thirty-two Chinese subjects tested individually and 163 tested in groups were collected. The results showed that in the 8 conditions (SOA x font x sequence), only when chirographic characters were presented in writing sequence under the 900 ms SOA condition (exactly that used in Tse & Cavanagh, 2000) did Chinese see the opposite direction of movement from what Americans saw. They see the same direction of movement as Americans in the other 7 conditions. Our data support that attention should be involved in this motion perception, and the top-down factors that make Chinese see the opposite direction were the script and stroke sequence derived from over-learned writing experience.

Abstract 396 B3.104

Non-classical receptive field structure for motion mechanisms revealed by lateral masking

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Purpose: The main objective was to examine non-classical receptive field structure for motion mechanisms using lateral masking paradigm. Length-width ratio for classical motion-dependent receptive fields has been estimated close to one by using masking and spatial summation techniques, while the ratio for motion-independent mechanisms are known to be elongated with ratios approximately 1.8 or 2. As for non-classical receptive fields, Polat and his collaborators found elongated receptive fields by using lateral masking paradigm.
Methods: Stimuli consisted of three Gabor patches arranged vertically or horizontally. The central patch was the target signal, and peripheral patches were the mask signals. The target signal drifted at the same temporal frequency as the mask signals in a direction either the same as or opposite to the mask. Consequently, there were four experimental conditions. The separation between target and masks were 3 cycles of wavelength. With these stimuli, we measured the contrast threshold for target motion as a function of mask contrast.
Results: For the same direction conditions, the threshold first decreased to its minimum and then increased. However, for the opposite direction conditions, threshold did not change regardless of mask contrast. Results were quite similar to vertical and horizontal arrangements. In addition, we estimated the relative magnitudes of contrast for vertical and horizontal conditions using the results. Although Polat and his collaborators have reported a higher enhancement for vertical than for horizontal arrangement, we obtained similar enhancements for the two conditions.
Conclusions: The present results together indicate that the non-classical motion-dependent receptive fields have characteristics fundamentally different from those of motion-independent non-classical as well as classical receptive fields.
Supported by JPSP and HFSP.

Abstract 397 B3.105

Perceived local velocity within a moving element is strongly influenced by its global motion

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We investigate whether the global motion of an object influences the perceived local motion of structures inside the object. To test this, we did the following psychophysical experiment: Two Gabor patches moved downwards along straight paths on a computer monitor. In addition to moving vertically, they could also move horizontally, either towards or away from each other. The sinusoidal patterns of the Gabor patches could also move relative to their boundaries, either inwards or outwards. Subjects were instructed to detect whether the sinusoidal patterns of the Gabor patches within their boundaries were moving inwards or outwards.
When the global velocity of the Gabor patches was exactly vertical, subjects showed no bias for the perceived direction of the motion within the Gabor patch. However, when the global motion of the Gabor patch contained a horizontal component, subjects showed large biases. These biases depend solely on the horizontal component of the global motion; they do not depend on the vertical motion component. When the Gabor patches are moving inwards globally, the motion within the Gabor patches relative to the boundaries needs to be outwards in order to appear stationary, and vice versa.
Although they were specifically instructed to look at the motion within the Gabor patches relative to their boundaries, subjects appear to track the absolute global movement of simple features of the Gabor patch.

Abstract 398 B3.106

A common motion mechanism for first- and second-order stimuli

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The independence of first-order, luminance-defined motion, and second-order, texture-defined motion was tested in three apparent motion experiments. In Experiment 1, a uniform square was presented against a uniform luminance background, and to its left, a checkerboard square was presented against a checkerboard background with the same average luminance. Motion can be perceived between the two squares when the luminance of the uniform square and the contrast of the checkerboard square are simultaneously changed in opposite directions. Evidence was provided for the inter-changeability of luminance and contrast changes: As the size of luminance and contrast changes were varied, the likelihood of motion being perceived between the uniform and checkerboard square was similar to the likelihood of it being perceived between two uniform squares with the same luminance changes and between two checkerboard squares with the same contrast changes. In Experiment 2, the perception of motion between two checkerboard squares due to changes in their contrast could be eliminated by counteracting the change in contrast for one of the checkerboards with a change in average luminance in the opposite direction (and vice versa). Experiment 3 provided evidence against changes in the location with the most salient element as a factor in the perception of luminance-to-texture motion: Motion was perceived between a uniform square and a checkerboard square even though the most salient square always remained at the same location. All of the above were observed at temporal frequencies for which attentional tracking was not possible. Conclusion: There is a common mechanism for the perception of apparent motion for first- and second-order stimuli that responds to counter-changing activation at nearby spatial locations, regardless of whether the activation changes are the result of changes in luminance or changes in texture contrast.

Abstract 399 B3.107

Integration and segmentation of opposite contrast polarities in the perception of motion

Paul B. Hibbard U. of St Andrews, UK

Purpose While the early stages of motion detection are selective for contrast polarity, this selectivity does not appear to be maintained at higher levels of processing (Edwards & Badcock, 1994; Vis Res 34, 2849-58.). This may reflect the fact that opposite polarities will often need to be integrated in the interpretation of optic flow. Indeed, the distributions of velocities carried by opposite polarities are broadly overlapping in global motion stimuli such as those used in the above study, suggesting that they relate to the same underlying motion. The current study investigated whether segmentation by contrast polarity might improve motion perception in other situations, using transparent motion stimuli in which the distributions of velocities carried by opposite polarities clearly differed. Method On each trial, two random dot kinematograms (RDKs) were presented sequentially. In one, the directions of motion of the dots were drawn from a single Gaussian distribution, while in the other the directions were drawn from two distributions with different means. The observer's task was to decide which interval contained two distributions of directions. The minimum difference between the means of the two distributions for which this could be accomplished was measured in two conditions: (i) all dots had the same polarity and (ii) the dots in the two distributions were presented in opposite polarities. Results Transparency thresholds were lower when the two distributions were presented in opposite polarities, suggesting that the independent processing of opposite polarities is maintained when the two signals carry distinct motion information. Conclusions The integration of opposite contrast polarities in the perception of global motion is not obligatory. Rather, both integration and segmentation of opposite
polarities may both occur, according to task demands.

Abstract 400 B3.108

Comparing real world and computer generated motion in depth

Julie M. Harris & Val L. Tuck U. of Newcastle upon Tyne, UK, U. of Newcastle upon Tyne, UK,

The perception of binocular motion in depth has been studied under a wide range of conditions. Under some conditions, but not others, thresholds for motion in depth detection can be poorer than for equivalent lateral motion. However, studies all agree that the visual system responds symmetrically to disparities in front of and behind the fixation point. Here we were interested in how useful these precise computer-controlled studies are for predicting how we respond to motion in depth in the real world. We addressed this issue by measuring motion in depth direction thresholds for the real world motion of a small bright target, moving along a linear track, powered by a stepper motor. Observers viewed a stationary fixation point at 1.3m, while motion in depth thresholds were measured for motions centred around a range of positions from 15cm in front of, to 15cm behind fixation. We collected data for both monocular and binocular viewing. Data were compared with those from experiments in which motion in depth was generated and presented on a computer monitor, with motion parameters as close as possible to those for the real world motion. For real-world motion, we found a binocular advantage for motions centred in front of and around fixation. Performance was not symmetrical around fixation: binocular performance was worse than monocular for motions centred behind fixation. For computer generated motion in depth we found a symmetrical pattern of performance with binocular performance deteriorating as motions were centred further away from fixation. In summary, there are small, but distinct, differences in performance between real-world and computer-generated motion in depth perception. We will consider the implications of this data for our understanding of binocular depth perception and the use of binocular disparity in virtual displays.

Funded by EPSRC, UK.

Abstract 401 B3.109

Individual Differences in Low-Level Visual Motion Processing:
Jeremy Wilmer, Harvard U

Background and Goals: A number of studies have found a specific deficit in visual motion processing among dyslexic persons. Most previous studies have used one of several variations on a random dot detection paradigm, and one study has used a velocity discrimination paradigm with sinusoidal gratings. One goal of the present study was to replicate both of these previous results, while examining the relative strengths of these two paradigms for isolating such individual differences: a) their relative power for discriminating these groups, b) their relative association with various measures of dyslexic traits, c) some of their basic psychometric properties. The second goal was to probe for associations between the two tasks to probe whether they may be sensitive to related variation in visual-motion-processing capacities.
Results and Conclusions: In replication of previous results, both motion paradigms - and not their associated control tasks – differentiate dyslexic participants from controls. There was no clear 'winner' in terms of discriminatory power between these groups, and both paradigms were associated to a roughly equal degree with measures of dyslexic traits. The random dot paradigm exhibited more robust psychometric qualities. There was no association between performance on these two tasks across subjects.
Conclusions: This study bolsters evidence for the specific (to motion-oriented tasks) existence of a generalized (across motion paradigms) visual motion processing deficit in dyslexia. This deficit appears generalized enough so as to be found across motion paradigms that do not show an association with each other across participants. No evidence was found for these two paradigms being sensitive to individual differences in related visual-motion-processing capacities.

Sunday PM Talks (North Hall)
Cue Integration

Moderators: Shinsuke Shimojo & David Knill

Abst #	Time	Authors
402	1:30	Gepshtein, Banks, Levitan
403	1:45	Knill, Saunders
404	2:00	Qiu, Macuda, von der Heydt
405	2:15	Ernst, Banks
406	2:30	Alais, Burr
407	2:45	Backus, Matza-Brown, Zabulis
408	3:00	Shams, Thompson, Shimojo, Allman

Abstract 402 1:30 PM

How sight and touch are combined depends on viewing geometry
Sergei Gepshtein, Martin S. Banks & Carmel A. Levitan
University of California at Berkeley

We studied how the brain combines information from sight and touch in size perception. Contrary to earlier views that sight always dominates touch, recent evidence shows that the more visual information is corrupted by external noise, the more perceived size depends on touch. We asked whether touch information affects size perception when size is hard to measure visually. In a 2-IFC procedure, each interval contained two planes. Observers indicated the interval containing the more widely separated planes. Visual stimuli were depicted with stereograms, and touch (haptic) stimuli with force-feedback devices (PHANToMs). The planes were presented in three orientations: (1) perpendicular to the line of sight so the separation had to be judged from disparity-specified depth alone, (2) parallel to the line of sight so the separation could be judged from 2-D separation, and (3) 45 deg relative to the line of sight. Observers made size discriminations for these orientations with vision alone (V task), touch alone (T task), and with vision and touch together (VT task). In the VT task, the visual and haptic sizes were the same in one interval and differed in the other. We found that the just-discriminable separation in the V task depended on the planes orientation: it was significantly higher when they were perpendicular as opposed to parallel to the line of sight. Performance in the T task did not depend on orientation. Because the visual estimates varied with orientation and the touch estimates did not, optimal use of the two sources of information predicts visual dominance in the parallel orientation and more touch influence in the perpendicular orientation. Results in the VT task were very consistent with this prediction. Thus, the brain combines information from sight and touch in a way that depends on stimulus orientation. This is evidence that the weights given to sight and touch vary according to the relative reliabilities of the two information sources.

Abstract 403 1:45 PM

Humans optimally weight stereo and texture cues to estimate surface slant
David C. Knill & Jeff Saunders Center for Visual Science, University of Rochester

Purpose: The optimal, linear way to combine information from multiple cues is to weight cues according to their reliability. Previous work has shown that subjects adapt their cue weighting in response to global parameters that affect cue reliability (e.g. viewing distance for stereo). Cue reliability, however, can also vary with the value of the parameter(s) being estimated. Texture is a highly reliable cue for surface slant at high slants, but is much less reliable at low slants. We tested whether subjects' weighting of texture and stereo cues varies as a function of surface slant in an optimal manner. We further tested whether inter-subject differences in cue weights are predicted by the relative reliability with which subjects individually discriminate slant from the two cues in isolation.
Method: In a first experiment, we used a 2-AFC task to measure thresholds for discriminating slant from texture alone (monocular views of random tiled textures), stereo alone (binocular views of random dot patterns) and texture and stereo combined (binocular views of random tiled textures). In the second part, we used a similar psychophysical procedure to measure points of subjective equality between stimuli with

small cue conflicts and those without, as a way of measuring the weights given by subjects to stereo and texture cues. Results: Discrimination thresholds for slant from texture decreased relative to thresholds for slant from stereo as surface slant increased. As predicted by theory, subjects' texture weights correspondingly increased with increasing slant. Moreover, after subtracting the main effect of slant on texture and stereo weights, individual subjects' relative stereo / texture thresholds accounted for 60% of the remaining variability in cue weights.
Conclusions: Subjects weight stereo and texture cues for slant in a manner consistent with the uncertainty of their own estimates of slant from the cues, as predicted by an optimal model.

This research was supported by grant NEI-EY09383 from NIH.

Abstract 404 2:00 PM

Combination of stereoscopic and monocular form cues in cells of monkey area V2
Fangtu T. Qiu, Todd J. Macuda, & Rüdiger von der Heydt Johns Hopkins University, USA, Johns Hopkins University, USA, Johns Hopkins University, USA

Stereopsis is a powerful mechanism for 3D object perception. However, in the absence of sufficient surface texture the stereoscopic information is often ambiguous. For instance, the disparity of a vertical contrast border provides depth information, but does not indicate whether the border corresponds to an edge formed by two surfaces, as in a roof, or an occluding edge, and whether the occluding edge belongs to the surface on the left or the surface on the right. We used single cell recording from awake fixating monkeys to explore how the visual cortex combines monocular form cues with stereo information.

(1) Many cells signal border ownership for figures in uniform surface displays, which requires processing of monocular form cues (Zhou et al., 2000). We found that about 1/3 of these cells combine monocular border ownership cues with selectivity for edges in random-dot stereograms and differentiate step edge polarity. They were usually tuned to some disparity D1 for one side of the edge, and responded if and only if the disparity on the other side is "farther" than D1. We found that the "near" side generally agreed with the preferred side of ownership. (2) Many cells differentiated between convex and concave roof edges in uniform surface displays. Thus, a contrast border was represented as a 3D feature on the basis of the disparities of distant contours. (3) Some cells showed interaction between roof shape and edge contrast polarity. In 10 out of 11 the interaction was in the same direction as in human vision which implies illumination from above. These signals contribute shape from shading. (4) Cells that were convex-concave selective with random-dot stereograms were generally not selective with uniform surface displays, and vice versa.

These results suggest that stereoscopic and contextual monocular form cues are combined in cells of monkey area V2. There seem to be several stages in this process.

Supported by NIH NS38034 and NIH EY02966

Abstract 405 2:15 PM

Discriminating the odd: Boundaries of visual-haptic integration
Marc O. Ernst & Martin S. Banks Max-Planck-Institute for Biological Cybernetics, Tuebingen, Germany; UC Berkeley, Vision Science Program & School of Optometry, USA

We investigated the degree to which visual-haptic fusion occurs. If the nervous system uses a statistically optimal integration rule, the combined visual-haptic percept is a weighted average of the visual and haptic estimates and its variance is lower than that of either estimate alone. We used an oddity task to investigate whether the combined estimate is used in discrimination or whether independent visual and haptic estimates are used. Three horizontal bars were presented sequentially. Two of them were identical and had equal visual and haptic heights (standard stimulus). The third had a visual and/or haptic height differing from the standard (odd stimulus). Subjects indicated which of the three intervals contained the odd stimulus. If subjects used visual or haptic information independently without combining them, then discrimination would occur whenever the visual or haptic height in the odd stimulus differed from the height in the standard by more than the vision-alone or haptic-alone threshold. In contrast, if subjects relied on the combined visual-haptic estimate, discrimination should be most difficult when the visual and haptic heights differed in opposite directions from the standard's height (such that weighted averages of odd and standard stimuli are equal) and easiest when they differed in the same direction from the standard (weighted averages different). We found that discrimination was indeed most difficult when the weighted averages were the same and easiest when they differed. Thus, the fused visual-haptic percept is used for discrimination. However, if the conflict between the visual and haptic stimuli is too large, this difference in discrimination performance is not observed. In other words, visual-haptic fusion breaks with large conflicts. In some conditions, metameric behavior is observed: discrimination would be better if subjects shut the eyes or removed the hand from the bar.

Abstract 406 2:30 PM

An audio-visual flash-lag effect
David Alais & David Burr Istituto di Neurofisiologia del CNR, Italy.

PURPOSE: The flash-lag effect (FLE) has recently generated much activity in vision research. Here we broaden the scope of enquiry by examining a cross-modal, audio-visual FLE. METHODS: Motion stimuli were either translating gaussian blobs (t=0.64s; s=0.45deg; speed=35deg/s) or low-pass (<2kHz) auditory noise sources which were moved smoothly over the same trajectory by varying the sign and magnitude of interaural time differences. Flashed (20ms) gaussian blobs or auditory noise bursts served as 'flash' stimuli, which occurred approximately in the middle of the motion trajectory (randomly jittered). Adaptive staircases varied flash location and homed in on subjective alignment of the 'flash' with the instantaneous motion position. In 4 conditions, the flash (f) or motion (m)

could be visual (V) or auditory (A): Vf/Vm, Vf/Am, Af/Vm, Af/Am. RESULTS: In all conditions, the 'flash' was perceived behind the moving stimulus, requiring a large advance to be perceptually aligned (i.e., the FLE). Effect size was speed dependent. In the Af/Am version, misalignment over 4 speeds increased linearly with a time constant of ~170ms. In the Vf/Vm version, the time constant was ~20ms. The cross-modal conditions, (Vf/Am, Af/Vm) had intermediate values of ~70ms and ~120ms respectively. CONCLUSIONS: Whether motion was auditory or visual, differential delays were ~100ms longer for auditory flashes. Whether the flashes were auditory or visual, differential delays were longer by ~50ms for auditory motion. These effects suggest general sensory processing principles underlie the FLE. The symmetry of effects suggests linear combination of delays within and between sensory modalities.

Abstract 407 2:45 PM

A reexamination of the Enright (1970) illusion: Distance from motion and stereo?

Benjamin T. Backus, Daniel Matza-Brown & Xenophon Zabulis University of Pennsylvania

An observer looking out the side window of a rapidly moving automobile, with a neutral density filter over one eye, sees the world as dwarfed and moving by slowly (Enright, 1970). Enright argued that increased disparity from the Pulfrich effect causes near objects to appear nearer still, so that size constancy requires they be small, and speed constancy that they be moving slowly. However, it is possible the effect results from solving for absolute distance using mutual constraints provided by structure from motion and shape from relative binocular disparity (Richards, 1985; Kellman & Kaiser, 1995). In this case, the three-dimensional scene would retain its original apparent shape, and, critically, the entire scene (not just the near objects) would appear smaller and closer. Previous studies used small displays of isolated objects and failed to find such an effect (Brenner & Landy, 1999).

We reproduced the illusion under laboratory conditions. 180 digital images of a tabletop scene were taken at 0.35 cm intervals. Stereoscopic moving images were created by selecting pairs of images from this sequence; movies had varied camera speeds and interocular baselines. The resulting movies were displayed in a repeating 1-sec loop using a haploscope. Images subtended 30 x 20 deg. Vergence eye posture was held constant at approx. 0 or 6 deg by instructing observers to fixate a distant object in the scene.

As the baseline was increased from 7 mm to 12 cm, near objects in the scene appeared nearer and smaller, and apparent speed went down, as in the original illusion. Far objects decreased in apparent size, as predicted, but also increased in apparent distance. This violation of size-distance scaling suggests that separate computations exist for size and distance, with perceived distance and retinal image size not wholly determining perceived object size. Direct calculation of distance from motion and relative disparity does not account for Enright's illusion in any simple way.

Funded by the University of Pennsylvania.

Abstract 408 3:00 PM

Sound-induced illusory visual motion

Ladan Shams, Sam Thompson, Shinsuke Shimojo, & John Allman California Institute of Technology, USA

Vision is considered the dominant modality particularly in the domain of spatial perception. Thus, judgments on the spatial aspects of a visual stimulus are expected not to be significantly affected by characteristics of accompanying sounds etc. We provide evidence to the contrary. Methods: A red uniform disk was briefly flashed either in the fovea or in periphery. The flash was accompanied with a brief binaural tone which simulated a sound a) stationary in space, b) moving horizontally to the left, or c) to the right. Participants were asked to judge in each trial whether the disk was stationary, or moving horizontally. Eye movements were monitored throughout the experiment. Although the visual stimulus was stationary in all trials, observers perceived the disk (only when in periphery) as moving in the majority of trials when it was accompanied by auditory motion. We refer to this phenomenon as sound-induced illusory visual motion. In a second experiment, we added conditions in which the disk was physically moving to the left or right. As before, observers reported perceiving motion when the stationary disk was accompanied by moving sound. In addition, we found a reverse effect: some of the moving flashes which were accompanied by stationary sound were perceived as stationary. This effect was significantly smaller than the illusory motion effect, however. In a third experiment, in which the continuously moving sound was replaced by discrete sounds, we found that illusory visual motion can also be induced by apparent auditory motion. Conclusion: Various control conditions indicated that the illusory motion is a perceptual illusion and is not due to a cognitive bias derived from knowledge of the sound. The results altogether demonstrate that a moving sound (real or apparent) can induce perception of motion for a temporally coincident visual stimulus in the periphery. These findings counter the general belief that vision is unconditionally the dominant modality in spatial perception. Support: NIH grant HD08506.

Sunday PM Talks (North Hall)
Object Recognition

Moderators: Mary Peterson & Michael Tarr

Abst #	Time	Authors
409	3:30	Cheng, Tarr
410	3:45	Schyns, Gosselin
411	4:00	Peterson
412	4:15	Thoresz, Lipson, Sinha
413	4:30	Bar, Aminoff

Abstract 409 3:30 PM

SINNOR: Evaluating a simple image-based neural network for object (and face) recognition

Yi D. Cheng & Michael J. Tarr Brown University

Computational models of human visual object recognition have been incomplete and limited in their ability to account for human behavioral phenomena. The goal of the present work was to evaluate the performance of a Simple Image-based Neural Network for Object (and face) Recognition (SINNOR) and by doing so use it as a tool for investigating the same visual processes in humans. The model is a 3-layer feed-forward RBF network that uses an image-based representation as input. To date we have evaluated the model along three different dimensions. First, simulations demonstrate that the model can perform visual object recognition at multiple levels of categorization. To assess the relationship of the model's performance relative to human visual categorization, we had subjects provide similarity ratings for the same images used in the simulations. We correlated their ratings with the model's confusion matrix across individual objects. Critically, we found that the correlation between the model's performance relative to all human subjects was comparable to the correlation for any given subject relative to all other subjects. Second, "lesioning" the model at different points in processing provides proof that a single visual recognition system can produce many different patterns of sparing and loss in visual categorization. These simulated "patients" show recognition behaviors that are consistent with the patterns of neuropsychological deficits found in visual agnosia: object agnosia, prosopagnosia, and category-specific deficits. Third, simulations involving recognition over viewpoint changes, illumination changes, other-race effects, and other generalization problems were compared to human performance to further assess the validity of the model. Given the simplicity of the current version of our model, we view the degree of correspondence to human behavior as quite promising and one step towards formulating a comprehensive model and theory of human visual object recognition.

Supported by NSF IGERT and PEN – awarded by the James S. McDonnell Foundation.

Abstract 410 3:45 PM

A natural bias for basic-level object categorizations

Philippe G. Schyns & Frédéric Gosselin Glasgow U., UK, U. of Montréal, Canada

People can categorize the same object at different levels of abstraction (i.e., superordinate, basic, and subordinate). Of these, there is a bias to the basic level. However, the origin of the bias to the basic level remains unsettled. For categorization researchers, the bias is due to the organization of categories in memory producing faster access to the basic level (Murphy, 1991). For recognition researchers the bias arises because the visual system primarily extracts parts, and these parts are utilized to represent categories at the basic level in memory (Biederman, 1987). Here, we test a third alternative: A basic-level bias could naturally arise from a bias on the distribution of perceptually available visual cues. Namely, basic-level categorizations could be invariant to scale, whereas subordinate categorizations could depend on scale.

In Experiment 1, 20 observers learned 2 exemplars of 8 species of 3D rendered, shaded animals varying in size (6 sizes spanning 12, 6, 3, 1.5, .75, .38 deg of visual angle on the screen). In a verification task, an animal name (either subordinate or basic) was followed by a low-contrast version of the animals with a level of Gaussian additive white noise adjusted to maintain performance at 75% correct. Computations of d' for each size revealed basic and subordinate slope differences: d' slopes for the basic-level rose quickly to reach ceiling levels, indicating a relative independence to scale, whereas subordinate-level slopes rose slowly, never reaching ceiling, indicating a dependence on scale. To assign this difference in performance to specific scale cues, we adapted Bubbles (Gosselin and Schyns, 2001) to randomly destroy the phase information of a 2D Fourier Transform of the animal stimuli whilst keep the contrast energy constant. The resulting profile of the use of scale information reveals the expected bias for fine scale cues at the subordinate level in contrast to the basic level which is scale invariant.

Abstract 411 4:00 PM

Memory for novel shapes of grounds? An alternative hypothesis.

Mary A. Peterson* U. of Arizona, USA
*became first author/presenter after first author dropped out unexpectedly

Adjacent regions compete for ownership of a common edge. The figure owns the edge; the ground does not. Treisman & DeSchepper (T & D; 1996) used a discrimination task to test for memory of novel ground shapes in paired prime-probe trials. Primes were black and white regions sharing an edge, shown above a black shape; the black region was figure, the white region was ground. Probes were separated black and white shapes above a white shape. Observers reported whether the shape below matched the same-color shape above. For probes the top black shape was a distractor. White top shapes were repeated across experimental prime and probe trials, but not control trials. T & D found negative priming (NP) on experimental trials and concluded that before figure assignment, equivalent memories are established for shapes lying on both sides of an edge, with an "ignore" tag attached to the shape of the ground. We propose an alternative: NP reflects a delay in probe figure assignment caused by competition from memory for the prime figure. We eliminated the white region on prime trials to reduce similarity between white prime and probe shapes and positioned the distractor farther from the

white probe shape on half the trials to reduce any partial closure it provided. NP was reduced in the far condition relative to the near condition, but some response competition was observed in the near condition. Did the response competition arise from the distractor or from the potential to see the prime figure on the ground side of the probe, amplified by partial closure? We replaced the near black distractor with a vertical bar and eliminated the far distractor. The bar provided partial closure, as had the distractor, but not response competition. Both NP and response competition were observed. Here, response competition arose from the potentially present prime figure. We suggest that an understanding of the competitive nature of figure assignment is necessary to interpret the obtained NP.

Support: NSF BCS 9906063 to MAP

Abstract 412 4:15 PM

Common representations for scenes and objects
Keith Thoresz, Pamela Lipson, & Pawan Sinha MIT Department of Brain and Cognitive Sciences, USA, Imagen Incorporated, USA, MIT Department of Brain and Cognitive Sciences, USA

A major question in high-level vision is how to represent image structure for the task of recognition. Although there is unlikely to be a unitary answer for all tasks, it is important to look for strategies that may be reasonably general and not too domain dependent. To this end, we have been developing a simple qualitative representation scheme. Motivated by the rapidly saturating contrast response functions for many early visual neurons, the scheme relies exclusively on the use of local ordinal relationships between attributes of neighboring image regions. For instance, if the attribute of interest is luminance, an image is encoded as a collection of luminance inequalities, without having to maintain absolute luminance levels or even the magnitude of contrast. Last year at VSS, we described the use of this scheme for encoding faces. Tests with a computer implementation yielded encouraging face detection performance in novel images. However, it was not clear whether the scheme was applicable only to the task of encoding faces or whether it could be used more generally. In order to address this issue, we have examined the effectiveness of the qualitative representation scheme in a very different domain – natural and urban scenes. Each scene is represented as a collection of inequalities defined over luminance and hue of neighboring regions. The set of regions is initially arbitrary, but can be reduced in cardinality by learning across multiple inputs. We find that this representation yields good results for the tasks of scene indexing (retrieving scenes similar to a given image from a database) and scene categorization. Overall, we find it encouraging that the qualitative representation strategy appears to be applicable across two seemingly very different high-level tasks of object detection and scene categorization. We shall describe the strengths and limitations of this scheme and the prospects for it to serve as a versatile image representation strategy.

Abstract 413 4:30 PM

Contextual processing of visual objects in the brain
Moshe Bar, & Elissa Aminoff NMR Center at MGH, Harvard Medical School, Charlestown, MA, USA

Objects that share the same context tend to appear together in our environment. Is this frequent co-occurrence manifested in the organization of their representation in the brain? Given how little is known about the neuronal analysis of context, the first step in addressing this question is to define the cortical network involved. To elicit maximal contextual activation, we first identified for each of the 40 contexts in the experiment a "key object" that is most commonly associated with that specific context (e.g., a flower for a garden, a hardhat for a construction site). In addition, we identified another set of objects that are not associated with any specific context (e.g., a rope). Average reaction time for recognizing the objects in both sets was equal. We then used fMRI to scan six subjects while they were engaged in recognizing those individual objects (3T magnet; TR=2sec; 33 slices, 3mm each). The cortical activation elicited by highly contextual objects ("key objects") was compared with the cortical activation elicited by "non-contextual" objects. The resulting differential activation concentrated in the temporal cortex, primarily in the collateral sulcus and extended into the parahippocampal gyrus. This focus, which was exceptional in its extent, significance, and consistency across subjects, is suggested to play a central role in the representation and processing of context. What is the specific function associated with this focused activity? One possible explanation is that it reflects the co-activation of multiple objects that share the same context, triggered by the recognition of a "key object." Such contextual representations may include information about typical members of each context as well as the typical spatial relations between those objects (schema or "context frames"). Alternatively, this activation may be a manifestation of semantic and abstract information associated with the specific contexts. We will contrast these accounts.

Supported by the McDonnell-Pew Program in Neuroscience (# 99-6 CNS-QUA.05) and NFFBI.

Sunday PM Talks (South Hall)
Motion – Neuro

Moderators: Tania Pasternak & Tony Movshon

Abst #	Time	Authors
414	1:30	Tadin, Lappin
415	1:45	Pack, Born
416	2:00	Rust, Simoncelli, Movshon
417	2:15	Ditterich, Mazurek, Shadlen
418	2:30	Majaj, Smith, Kohn, Bair, Movshon
419	2:45	Pasternak, Zaksas
420	3:00	Zaksas, Pasternak

Abstract 414 1:30 PM

Impairment of motion discrimination for large stimuli at high contrasts: Psychophysical analog of antagonistic center-surround mechanisms in MT

Duje Tadin & Joseph S. Lappin Vanderbilt Vision Research Center, USA, Vanderbilt Vision Research Center, USA

Intuition suggests that increasing either the size or contrast of a moving stimulus should improve the detection and discrimination of motion. Here we report a result contrary to this intuition. Observers required longer exposure durations to discriminate motion direction of a large high contrast Gabor (~60ms), as compared that of a small Gabor patch (~15ms).

We measured the threshold exposure duration required for human observers to discriminate motion direction of a foveally presented Gabor patch (sigma = 20-150arcmin, contrast = 3-92%, SF = 1c/deg, TF = 2Hz, vertically oriented). For small Gabors, as expected, the duration thresholds first decreased as contrast increased and then remained constant for contrasts higher then 10%. For large Gabors, however, duration thresholds INCREASED about five-fold as the contrast increased from 3 to 92%. Furthermore, at high contrast, increasing the size of the Gabor patch also resulted in substantial increases in duration thresholds. This pattern of results was replicated with Gabors moving at 8Hz, and with Gabors whose spatial frequency was scaled with size (i.e. fixed spatial bandwidth).

These results resemble the known properties of antagonistic center-surround receptive fields (RF) in area MT. This counterintuitive result occurs only for Gabors that are sufficiently large to stimulate both the centers and the antagonistic surrounds of foveal RFs in MT. The large Gabor patches will activate the antagonistic motion surrounds, and the resulting inhibition may be responsible for the observed decrease in motion sensitivity. The threshold increase with increasing size is less pronounced at low contrast, in agreement with the lower contrast sensitivity of the antagonistic surrounds. Additional experiments also indicate that "the critical size" required for this effect increases with eccentricity, paralleling the corresponding increase in RF size.

Abstract 415 1:45 PM

Integration of motion signals over regions of uniform luminance by MT neurons in the alert macaque

Christopher C. Pack & Richard T. Born Harvard Medical School, USA, Harvard Medical School, USA

Object velocity can be measured by tracking changes in local contrast, but many objects contain relatively large regions of uniform luminance. We investigated the representation of motion in such regions by recording MT cell responses to three types of moving stimuli: discs of uniform luminance, annuli, and dot fields. All stimuli varied in diameter from 5 to 35 deg, and were centered on the receptive fields of individual MT neurons, while the monkeys maintained fixation. By slowly drifting the stimuli in the preferred and null directions for each cell, we measured the strength of direction selectivity for each stimulus. As expected all cells responded in a direction-selective manner to both the discs and the annuli when the stimuli were confined to their classical receptive fields. Neuronal responses typically decreased with increasing stimulus diameter. Surprisingly, however, when the stimulus edges were far outside the classical receptive fields many cells still exhibited direction selectivity for the discs, but not for the annuli, even though the local motion signals were similar for both stimuli. The preferential responses to uniform-luminance discs were most prevalent in the cells with inhibitory surrounds (as measured with the dot fields), and were seen primarily in the later phases of the temporal response profiles. These differences may be related to the different local luminance profiles that define the disc and annulus edge. However, varying the width of the luminance step defining the annulus edge did not influence the responses in any obvious way. In a smaller sample of V1 cells, we observed similar responses to stimuli that extended as much as 6 deg beyond the classical receptive fields. These results suggest that a population of neurons in macaque visual cortex can represent the motion of objects, even in regions lacking luminance contrast. Such a representation could help to define figure and ground for large moving objects.

Supported by a McDonnell-Pew Fellowship, NIH EY11379 and The Whitehall Foundation.

Abstract 416 2:00 PM

Inhibitory interactions in MT receptive fields

Nicole C. Rust, Eero P. Simoncelli, and J. Anthony Movshon Center for Neural Science and HHMI, New York University, New York, NY

Most neurons in macaque area MT (V5) respond vigorously to stimuli moving in a preferred direction, and are suppressed by motion in the opposite direction. The excitatory inputs come from specific groups of directionally selective neurons in lower-order areas, but the inhibitory signals are not so well understood. Some models (e.g. Simoncelli and Heeger, 1998, Vision Res) assume that these signals are pooled across the receptive field, but Qian et al. (1994, J Neurosci) suggested instead that inhibitory inputs interact with excitatory ones only within local regions of space.

To explore the location and direction specificity of interactions between MT receptive field subregions, we stimulated small areas of the receptive field with Gabor patches drifting in the preferred direction. We presented these alone and in combination with stimuli drifting in non-preferred directions so that we could study inhibitory signals against background firing elevated by preferred stimuli. Non-preferred gratings suppressed responses strongly when they were presented in the same retinal location as the preferred grating. When the two gratings were separated, suppression was much reduced and was no larger than the suppression of spontaneous firing produced by a non-preferred stimulus presented alone.

Our results show that non-preferred stimuli can only inhibit responses generated by excitatory stimuli from nearby regions of space; this suggests that direction-specific inhibition acts within spatially localized subregions of the receptive field. The results can be described by a model in which local excitation and inhibition are combined and rectified before a final stage of spatial pooling.

Supported by NEI and HHMI

Abstract 417 2:15 PM

Microstimulation of area MT affects response times in a direction discrimination task

Jochen Ditterich, Mark E. Mazurek, & Michael N. Shadlen U. of Washington, USA, U. of Washington, USA, U. of Washington, USA

Using cortical microstimulation (µStim), Newsome et al. showed that direction-selective neurons in area MT represent the evidence upon which monkeys base their decision about direction in a stochastic random-dot motion task. Near threshold, µStim caused monkeys to favor the direction preferred by the stimulated neurons. Our goal is to understand the mechanism underlying the transformation of such sensory evidence to a decision. Insight into this process can be gained by measuring the amount of time it takes to reach a decision. We trained monkeys on a version of the random-dot motion task that allowed us to measure both sensitivity and reaction time (RT). In contrast with previous experiments, the monkey controlled viewing duration by making an eye movement to one of two choice targets when it was prepared to indicate its decision. The percentage of coherently moving dots was varied over a range that spanned psychophysical threshold and µStim was applied on half of the trials. Consistent with previous reports, µStim caused the monkey to bias its decisions in favor of the preferred direction of neurons near the stimulating electrode. Microstimulation also affected RT in a manner that depended on the direction of motion. When motion was in the neurons' preferred direction, µStim reduced RT for correct choices. When the motion was in the opposite (null) direction, µStim prolonged RT. These findings suggest that the monkey forms its decision by integrating motion information coded in area MT until the accumulated weight of evidenced is sufficient to commit to a behavioral response. The prolonged RT on null direction trials suggests that MT information is not only used as evidence in favor of the preferred direction, but also as evidence against the opposite direction. The effect of µStim on both the speed and accuracy of decisions lends new insight into the neural mechanisms responsible for reading the visual cortex.

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Abstract 418 2:30 PM

A role for terminators in motion processing by macaque MT neurons?

Najib Majaj, Matthew A. Smith, Adam Kohn, Wyeth Bair, & J. Anthony Movshon NYU, NYU, HHMI & NYU, NYU, HHMI & NYU

At low speeds and contrasts, bar textures moving obliquely to their orientation change their apparent direction. Initially they seem to move at right angles to the bar orientation, then over ~200 ms they change and appear to lock to the true direction of motion defined by the bars' ends ("terminator motion"). Responses in macaque MT neurons behave analogously - initially they are dominated by motion orthogonal to the bars; over time they come to respond to the direction of terminator motion. These changes in perception and neuronal selectivity are thought to be due to a transition between two motion signals, a rapid one related to orientation and a slower one related to terminators.

The Fourier spectra of bar textures have an interesting distribution of component contrasts for different orientations. Components parallel to the bars have the highest contrast, while those at other orientations have lower contrasts. We wondered if the changes in direction selectivity were due to a well-known effect of contrast on visual processing: lower contrast targets are processed more slowly than high contrast ones.

We filtered bar textures down to their four fundamental component gratings, maintaining the contrast ratios among the components. The resulting patterns have no obvious terminators but their spectral structure retains the essential structure of bar texture spectra. We used these stimuli to examine the time evolution of directional selectivity in MT neurons recorded in anesthetized, paralyzed macaques. Despite the absence of terminators, MT cells changed their direction selectivity over time for the reduced stimuli in precisely the same way they did for unfiltered bar textures. We conclude that the motion of terminators is not responsible for the change, and propose that the late transition to terminator motion sensitivity is due simply to the delayed processing of the low contrast components that carry information about the true direction of motion.

Abstract 419 2:45 PM

Memory for visual votion: what is remembered and how is it used?
Tatiana Pasternak & Daniel Zaksas University of Rochester, USA

When asked to compare two moving stimuli separated by a temporal delay, observers must identify and remember stimulus direction. We examined the properties of these processes in two macaque monkeys by sequentially presenting two random-dot stimuli, sample and test, in opposite hemifields and introducing a random-motion mask during the delay. By manipulating the spatial location of the mask, its size, temporal parameters, and the time of its presentation during the delay we examined the nature of the remembered stimulus.
We found that the mask was effective only when introduced at the location of the test, about 100-200ms after the start of a 1500ms delay, and when its size was similar to that of the remembered sample. The spatial specificity of the mask effect suggests that the information about the remembered direction presented in one hemifield is transferred to the site of the upcoming test in the opposite hemifield. The effectiveness of the mask early in the delay indicates that this transfer is likely to occur shortly after the offset of the sample. The finding that the properties of the remembered stimulus faithfully reflect signals used to encode it suggests the involvement of motion-processing cortical areas in its storage, even when information has to be transferred to the opposite hemifield. This is consistent with the recent finding that the spatial scale of the mechanism underlying storage of visual motion matches that of MT neurons (Zaksas et al, JNP 2001).

Abstract 420 3:00 PM

Activity of MT neurons is affected by remote visual stimuli used in a memory for motion task
Daniel Zaksas & Tatiana Pasternak U. of Rochester

Neurons in area MT have localized receptive fields representing the contralateral hemifield and play an important role in processing of visual motion. We recorded the activity of these neurons during a working memory task in which the remembered (sample) and the comparison (test) random-dot stimuli, separated by a temporal delay, were presented in opposite hemifields. This allowed us to determine whether the activity of MT neurons during the performance of this task is generated locally within MT or reflects top-down influences of cortical areas with access to the information from the entire visual field.
In nearly half of the recorded neurons (n = 45), activity during every epoch of the trial was altered by the presentation of stimuli at a remote contralateral location. Following a sample placed in the receptive field, many neurons showed transient activation early in the delay. A remote sample often induced inhibition, and was almost never followed by the early delay activity. Excitation and inhibition were equally likely responses during a remote test. These effects were present even when both sample and test were presented at a location remote from the receptive field.
Since area MT is strongly retinotopic, neural activity associated with remote stimuli is unlikely to be generated by local connections. Rather, such effects may be indicative of top-down influences of cortical areas with access to information from the entire visual field. These areas, along with area MT, may form the circuitry underlying the ability to remember visual motion.

Supported by EY11749, T32 NS07489, P30 EY01319.

Sunday PM Talks (South Hall)
Navigation

Moderators: Heinrich Buelthoff & Frances Wang

Abst #	Time	Authors
421	3:30	Fajen, Beem, Warren
422	3:45	Foo, Warren, Tarr
423	4:00	Wang, Brockmole, Abdul-Salaam
424	4:15	Riecke, von der Heyde, Bülthoff
425	4:30	Ellard, Thompson

Abstract 421 3:30 PM

Route selection emerges from the dynamics of steering and obstacle avoidance
Brett R. Fajen, Nicholas O. Beem, & William H. Warren Rensselaer Polytechnic Institute, USA, Brown University, USA, Brown University, USA

Previous experiments on elementary steering and obstacle avoidance behavior in humans were used to develop a dynamical model of on-line route selection in simple and complex scenes (Warren, Fajen, & Belcher, VSS 01). The model describes how turning is influenced by the current distance and heading angle of goals and obstacles. In the present experiments, we tested several model predictions about route selection by having participants walk to a goal through specific configurations of obstacles in a 12 x 12 m virtual environment. They wore a head mounted display (60 x 40 deg, 50 ms latency) and head position and orientation were recorded by a sonic/inertial motion tracking system. In Experiment 1, a pair of obstacles was presented, one on either side of the initial heading to the goal and at different distances. When the initial angle between the far obstacle and the goal was small, participants favored an outside route around the far obstacle. As this angle was increased, participants switched to an outside route around the near obstacle, and then to a route between the two obstacles. The same sequence of bifurcations was predicted by the model. In Experiment 2, we created a “local minimum” by presenting a cul-de-sac, an array of obstacles arranged in an arc. Participants were instructed to walk to the goal by either passing through the array or detouring around it. The arc length and the width of the gap between obstacles were varied independently. Participants were more likely to walk directly through the cul-de-sac as arc length increased (creating a larger barrier) and as gap width increased. These data were consistent with the model, which similarly avoided local minima. The results demonstrate that human route selection in

complex scenes can be understood in terms of the competition between on-line steering and obstacle avoidance strategies.

NIH R01 EY10923, NIH KO2 MH01353, NSF DGE 9870676

Abstract 422 3:45 PM

Dependence on path integration and landmarks when learning a new environment

P. Foo, W. Warren, & M. Tarr Brown University, USA, Brown University, USA, Brown University, USA

Like honeybees (Dyer, 1991), humans do not seem to build a metric "cognitive map" from path integration, but rely on visual landmarks to take novel short-cuts in a known environment (Foo et al., 2001). In the present experiment we investigate dependence on path integration and local landmarks when learning the layout of a new environment. Do people, like ants (Collett, et al., 1999), first depend on path integration to learn the locations of landmarks, and then shift to rely on landmarks? Or do they rely on landmarks from the beginning? Participants walked in a 40 x 40 ft virtual environment while head position and orientation were measured with a sonic/inertial tracker. Training: participants learned two legs of a triangle with feedback: the paths from Home to A and Home to B. A configuration of colored posts surrounded the A location, with another cluster placed on the path between H and B. Test: participants walked the learned legs or the novel short-cut between A and B without feedback. On catch trials, one cluster of posts were translated by 2m, so as to probe reliance on landmarks denoting a place (H-A), a known route (H-B), a route home (B-H), or a short-cut (B-A). Catch trials were initiated immediately after the onset of learning to track changes in the reliance on landmarks vs. path integration. Preliminary results suggest that participants' early use of path integration decreases during learning so they come to rely on landmarks that are associated with targets and routes. Thus, like ants, active navigation becomes dependent on local landmarks with increased familiarity with the environment.

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Abstract 423 4:00 PM

Spatial updating across environments

Ranxiao Frances Wang, James R. Brockmole, & Rashad A. Abdul-Salaam University of Illinois at Urbana-Champaign

Spatial updating refers to the process that computes the egocentric directions and distances of targets as one moves. Self-movements cause a change in the spatial relationship between oneself and the whole world and, thus, everything needs to be updated to maintain proper orientation. However, Wang (1999) suggested that the spatial updating system may have a limited capacity and not all targets in the environment are updated at the same time. Two experiments tested this hypothesis by investigating the updating process with respect to two environments (room & campus). Participants learned 5 targets inside a lab room and were blindfolded. Then they re-learned 5 familiar campus buildings with respect to their current position. Afterwards, they were instructed to turn with respect to one environment ("updating") and then tested on their knowledge of the target directions in the other, "non-updated", environment. One group turned to face the 5 room targets in a random order, and then pointed to the room targets followed by the campus targets. The other group turned to face the campus targets and then pointed to the campus targets followed by the room targets. For the room targets, participants were equally fast and accurate whether they were "updated" (after turning in room) or "non-updated" (after turning in campus). However, for the campus targets, participants were slower and less accurate after they turned in the room comparing to after they turned in campus, suggesting the campus targets were only updated when participants were explicitly instructed to do so (turn with respect to campus). Control experiment suggested this asymmetry was not a result of switching between two environments alone. These results suggest that only the immediate surroundings were automatically updated, while more remote environments were not updated unless under demand.

Abstract 424 4:15 PM

Spatial updating in virtual environments: What are vestibular cues good for?

Bernhard E. Riecke, Markus von der Heyde, & Heinrich H. Bülthoff Max Planck Institute for Biological Cybernetics, Tübingen, Germany

When we turn ourselves, our sensory inputs somehow turn the "world inside our head" accordingly so as to stay in alignment with the outside world. This "spatial updating" occurs automatically, without conscious effort, and is normally "obligatory" (i.e., cognitively impenetrable and hard to suppress). We pursued two main questions here: 1) Which cues are sufficient to initiate obligatory spatial updating? 2) Under what circumstances do vestibular cues become important?

STIMULI: A photo-realistic virtual replica of the Tübingen market place was presented via a curved projection screen (84x63 FOV). For vestibular stimulation, subjects were seated on a Stewart motion platform. TASK: Subjects were rotated consecutively to random orientations and asked to point "as accurately and quickly as possible" to 4 out of 22 previously-learned targets. Targets were announced consecutively via headphones and chosen to be outside of the current FOV.

Photo-realistic visual stimuli from a well-known environment including an abundance of salient landmarks allowed accurate spatial updating (mean absolute pointing error, pointing variability, and response time were 16.5 , 17.0 , and 1.19s, respectively). Moreover, those stimuli triggered spatial updating even when participants were asked to ignore turn cues and "point as if not having turned", (32.9 , 27.5 , 1.67s, respectively). Removing vestibular turn cues did not alter performance significantly. This result conflicts with the prevailing opinion that vestibular cues are required for proper updating of ego-turns. We did find that spatial updating benefitted from vestibular cues when visual turn information was degraded to a mere optic flow pattern. Under all optic flow conditions, however, spatial updating was impaired and no longer obligatory. We conclude that "good" visual landmarks can initiate obligatory spatial updating and overcome the visuo-vestibular cue conflict.

SUPPORT: Max Planck Society and Deutsche Forschungsgemeinschaft (SFB 550)

Abstract 425 4:30 PM

Plasticity in the sensorimotor associations used in a blind walking task
Colin G. Ellard & Lori S. Thompson U. of Waterloo, CANADA

Many experiments in human navigation have relied on measures of blind walking, where participants view targets and then walk to them without vision. Even without practice participants can carry out such tasks with high precision. This suggests that participants must possess an accurate calibration between the viewed distance of a target and the kinesthetic, proprioceptive and/orvestibular stimulation associated with walking to the target. We set out to explore the nature of this calibration using deception. Partipants were shown targets at a range of distances from 6 to 16 metres on an outdoor walkway. They were informed that they were to practice blind walking to visual targets and that they would receive an auditory signal when they had reached the target location. The participants were trained to walk to locations that were equal to, or 10% or 20% closer or further away than the viewed target location. In debriefing, very few (7.4%) subjects reported that they had noticed the mismatch between walked and viewed distances. Each subject received 21 training trials, following which they were presented with visual targets at 8, 12 and 16 m, in random order and they were asked to walk to the targets without vision. Our findings showed that even a brief period of training with a misleading calibration between visual and locomotor targets produced systematic and robust biases in blind walking in the predicted directions. These findings suggest a remarkable plasticity in the calibration between visual and locomotor space in the blind walking task and they underline the importance of practice effects in this commonly used task.

Research supported by a grant to CGE from the Natural Sciences and Engineering Research Council of Canada

Monday

Monday AM Talks (North Hall)
Striate/Extrastriate

Moderators: Edmund Rolls & Deborah Giaschi

Abst #	Time	Authors
426	9:00	Lyon, Kaas
427	9:15	Hudson, Kalik, Victor, Schiff, Purpura
428	9:30	Aggelopoulos, Rolls, Franco
429	9:45	Martinez-Conde, Troncoso, Macknik
430	10:00	Ress, Heeger
431	10:15	Giaschi, Bjornson, Jan, Tata, Au Young, Lyons, Good, Wong

Abstract 426 9:00 AM

Evidence for a complete V3 in a wide range of primate species
David C. Lyon, & Jon H. Kaas Vanderbilt University, USA

The third visual area, V3, was initially described using degeneration studies indicating that the region was a mirror image of the retinotopic organization of V2. Though subsequent studies confirmed these retinotopic patterns through tracer connections and microelectrode maps, a major issue remained. Evidence for connections between dorsal V1, representing the upper visual quadrant, and dorsal V3 (V3d) were clearly demonstrated, whereas connections between ventral V1, representing the upper visual quadrant, and ventral V3 (V3v) were either not found, or were considered to be with ventral V2 instead. This apparent connectional asymmetry resulted in several different theories of cortex organization, including those without a ventral V3 (replaced by the ventroposterior area, VP) or a dorsal V3 (replaced by the dorsomedial area, DM). We addressed this issue by using more sensitive tracers to re-examine V1-V3v connections. Ventral and dorsal V1 injections in Old World macaques, 4 species of New World monkeys, and prosimian galagos unequivocally demonstrated connections with V3v and V3d. In addition, the connection patterns confirmed that V3d/v was a mirror image of V2 retinotopy. This V3 is much narrower than initial proposals, about half the width of V2, rather than of equal size. Furthermore, as assessed through extrastriate feedback to V1 (via anterograde tracer injections into V1), the V1-V3d/v connections were second to only V1-V2 connections. An additional finding was that cytochrome architecture revealed dark and light staining bands in V3d/V3v, indicative of modular organization. As V3 was found in all species examined, it likely is a feature common to all primates, including humans. This work was supported by National Eye Institute Grant EY02686.

Abstract 427 9:15 AM

Dynamic receptive field substructure in extrastriate cortex of the awake macaque
Andrew E. Hudson, Steven F. Kalik, Jonathan D. Victor, Nicholas D. Schiff, & Keith P. Purpura Weill Medical College and Graduate School of Medical Sciences of Cornell University, New York

Characterizing receptive fields of visual cortical neurons in the alert primate presents a significant challenge due to the limited duration of fixation bouts. Short fixation bouts also limit the quantitative analysis of behavioral modulation of receptive fields. We adapted the multi-input m-sequence technique to study substructure within receptive field maps by knitting together neural activity obtained across multiple fixation bouts. Reverse-correlation of the spike rate with the stimulus generates a detailed spatiotemporal map of a receptive field. By generating these maps from data selected from specific temporal intervals relative to the start or end of a fixation bout, we determined how the receptive field substructure evolved during an interval controlled, in part, by the monkey. Significant first-order kernels were computed from single-and

multi-unit extracellular recordings obtained from cortical areas V2, V3 and TE. Many of the extrastriate single-unit receptive fields had demonstrable substructure. Examination of the receptive fields in 500 ms subintervals of the fixation bouts (lasting at least 1650 ms) revealed significant differences in gain, polarity, spatial extent, and dynamics between the subintervals. These observations suggest that the spatiotemporal structure of extrastriate receptive fields is modulated during the course of prolonged bouts of fixation. The source of this modulation is the subject of further study.

Supported by NIH grants GM07739 (AH), EY07138 (SK), EY9314 (JV), NS02172 (NS) NS36699 (KP).

Abstract 428 9:30 AM

Information encoding in the inferior temporal visual cortex: contributions of the firing rates and the correlations between the firing of neurons

Nikolaos C. Aggelopoulos, Edmund T. Rolls & Leonardo Franco University of Oxford

An important issue in visual neuroscience is the extent to which the neural code utilizes the numbers of spikes each neuron emits, or the relative time of firing of different neurons, which might reflect stimulus-dependent synchronization and thus could encode information. We analyzed the extent to which populations of primate inferior temporal visual cortex (IT) neurons utilize these different types of encoding by using a quantitative information-theoretic approach that compares the information encoded in these different ways (Panzeri et al, 1999). The formula quantifies the corrections to the instantaneous information rate which result from correlations in spike emission between pairs of neurons. The responses of small sets of neurons were simultaneously recorded with multiple single neuron microelectrodes while a rhesus macaque performed a visual fixation task and was shown 20 images effective for different IT neurons such as objects and faces. It was shown that almost all the information was present in the number of spikes emitted by each neuron, with stimulus-dependent synchronization effects adding for most sets of simultaneously recorded neurons almost no additional information. It was also found that the redundancy between the small sets of simultaneously recorded neurons was low, in the region of 4-10%. In addition, it was shown with a decoding procedure for measuring the information, that for the whole population of 20 neurons analysed, the information increased linearly with the number of neurons in the sample. The overall conclusion is that IT neurons convey information that is almost independent, with little redundancy; and that stimulus-dependent synchronization contributes very little to the code. The encoding is thus in an appropriate form for readout by receiving areas in which the neurons compute a dot product between the numbers of spikes received from different neurons and their synaptic weight vectors (see Rolls ET and Deco G, 2002, Computational Neuroscience of Vision, Oxford University Press; Panzeri S, Schultz SR, Treves A and Rolls,E.T., 1999, Correlations and the encoding of information in the nervous system. Proceedings of the Royal Society B 266: 1001-1012).

Research supported by the Wellcome Trust, by the MRC IRC for Cognitive Neuroscience, and by the Human Frontier Science Program.

Abstract 429 9:45 AM

The neural correlates of Vasarely's artworks, or how shape perception can be built up in our brain

Susana Martinez-Conde, Xoana Troncoso, & Stephen L. Macknik Institute of Ophthalmology, University College London, UK

In order to determine how shape perception is constructed in our brain, we need first to establish what the most fundamental building blocks are. Edges are often considered the most basic features in the visual world, and neurons in the early visual system are often referred to as "edge detectors". However, some works of art by Victor Vasarely show that junctions can be more salient, perceptually, than edges, even when the physical luminance change is equivalent. To examine the underlying physiology, we presented Vasarely's illusions (and some novel effects based on them) to awake monkeys while recording eye movements and neural activity from single neurons in the LGN and area V1. Our results show that junctions do in fact generate stronger visual responses than edges in the early visual system. These data furthermore represent the first physiological correlates of Vasarely's effect, and may have broad implications for the processing of shape perception at its earliest stages.

Abstract 430 10:00 AM

Cortical Activity Corresponding to Threshold Visual Pattern Perception

David Ress & David J. Heeger Stanford University, USA, Stanford University, USA

Purpose: To quantitatively relate fMRI activity in early visual areas to psychophysical responses during a yes-no threshold pattern-discrimination task. Methods: Subjects performed a rapid sequence of 2-s-duration trials each consisting of a 1-s-duration stimulus followed by a response period. A background mask pattern was presented on every trial. On 1/6th of the trials, a low-contrast target grating was added to the mask. Subjects responded by pressing one of two buttons to indicate the presence or absence of the target.Target contrast was set to each subject's threshold (d' ~ 1). Thus, the majority (~70%) of the trials corresponded to correct rejections. Subjects were trained to adjust their criterion so that the remaining trials were approximately evenly divided between hits, false alarms, and misses. In separate experiments, we used two different masks, a 20%-contrast plaid or a high-contrast white-noise pattern. Functional images were
recorded at a 1-s frame rate while each subject performed the task. fMRI time series were spatially averaged over voxels in several areas of early visual cortex (V1, V2, V3). Correct-rejection trials were used as a baseline. Results: In all subjects and visual areas, cortical activity was greater for hits than for the baseline correct rejects. More interesting, cortical activity was greater for false alarms than misses, contrary to the magnitude of the physical contrast in the stimulus. The

amplitude of these effects was about a factor of two larger for the noise-mask stimulus than for the plaid-mask. Conclusions: Neural correlates of threshold visual perception are evident in human visual cortex. The observed activity could correspond to intrinsically noisy sensory signals, or to feedback signals from higher-level areas corresponding to the subjects' behavioral choices.
Supported by grants from the NEI and HFSF.

Abstract 431 10:15 AM

Conscious visual abilities in a patient with early bilateral occipital damage
Deborah Giaschi, Bruce Bjornson, James Jan, Matthew Tata, Simon Au Young, Christopher J. Lyons, William V. Good, & Peter K.H. Wong U. of British Columbia, Canada, U. of British Columbia, Canada, . of British Columbia, Canada, U. of British Columbia, Canada, U. of British Columbia, Canada, U. of British Columbia, Candada, Smith Kettlewell, USA, U. of British Columbia, Canada

MM is a young adult who experienced bilateral strokes at birth that resulted in loss of left Brodmann areas 17, 18, 19 and right area 17, with extensive damage to right area 18. In spite of the total absence of primary visual cortex, he plays video games and can ride a bicycle in traffic (Jan et al., 1986, Ped Neurol). This is a preliminary report on his preserved vision. Horizontal OKN could be elicited from either eye. Smooth pursuit showed saccadic intrusions. The color of red, green and blue targets could be named, but Farnsworth color discrimination performance was at chance. Binocular grating acuity using Teller acuity cards was 10 cpd, providing MM was allowed to move his head and eyes. This is within normal limits for a 3 year-old child. The direction of motion in 100% coherent random dot kinematograms could be identified with perfect accuracy at speeds above 2 deg/s. MM reported he could "see" the moving dots and was not guessing. At speeds below 2 deg/s, he could not perceive motion and showed no evidence of better than chance guessing. These abilities are different from those termed "blindsight" in patients with homonymous hemianopia because MM appears to be aware of the stimuli he can discriminate. His vision may be similar to the residual vision reported in patient GY (eg. Morland et al., 1999, Brain). MM's motion perception was further studied using functional MRI. Fast motion activated several cortical regions: anterior and posterior left superior temporal gyrus (BA 22, 38), right premotor cortex (BA 6), right precuneus (BA 31) and right posterior cingulate (BA 23). Although the right area V5/MT+ appeared to be present based on anatomic landmarks, no activation was observed in this region. No activation occurred with slow motion, stationary dots or full-field flashes of light. This case demonstrates remarkable plasticity in the human visual system and may have implications for understanding the functional organization of the motion pathways.

Monday AM Talks (South Hall)
Locomotion

Moderators: John Wann & Michael McBeath

Abst #	Time	Authors
432	9:00	Durgin, Kearns
433	9:15	Fink, Warren
434	9:30	Kearns, Durgin, Warren
435	9:45	Wann, Wilkie
436	10:00	Brouwer, Brenner, Smeets
437	10:15	McBeath, Sugar, Morgan, Oberle, Mundhra, Suluh

Abstract 432 9:00 AM

The calibration of optic flow produced by walking: The environment matters
Frank H. Durgin, Melissa J. Kearns Swarthmore College, USA, Brown University, USA

The question of how perceptions differ between VR and the real world has far reaching implications for the interpretation of perceptual studies conducted in VR. Here we investigated how accurately optic flow and walking speed could be matched in VR. Banton, et al. (2000) reported that optic flow had to be increased by about 50% in a VR HMD to seem normal to subjects walking on a treadmill. The present study sought to test whether this apparently poor calibration was really due to VR itself, to oddities of treadmill locomotion, or to the specific visual environment (VE) used.
On each trial, subjects (22 Swarthmore students without prior VR experience) walked 5-7 m through one of two VEs, and made a FC decision about the speed of the VE relative to their walking speed. Both VEs were richly-textured corridors, but one of them also had randomly positioned textured pillars (providing inter-object parallax and salient cues about time-to-passage). Half the subjects walked on solid ground (head position monitored by an optical wide-area tracker); the other half walked on a treadmill at a normal speed. The gain of optic flow was altered only along the axis of the corridors (to preserve frontal motion-parallax information). Multiple interleaved staircases were used to measure subjects' estimate of normal gain in each of the two environments.
With pillars in the corridor, matched gains in the both the treadmill and solid-ground conditions did not differ reliably from 1. Even in the absence of pillars, matched gains in the two conditions rose only about 10%.
Evidently, there can be good calibration in VR when the visual environment is sufficiently rich. Moreover, performance is comparable when matching either enforced (treadmill) speeds or voluntarily produced (solid ground) motions. Given these results, we are now in a position to use VR to examine what visual information is used for detecting a discrepancy between locomotor activity and the resulting visual experience.

Swarthmore College Faculty Research Grant, NSF LIS IRI-9720327

Abstract 433 9:15 AM

Velocity dependence of optic flow strategy for steering and obstacle avoidance
Philip W. Fink & William Warren Brown University, USA, Brown University, USA

Recent research has suggested that both egocentric direction and optic flow are used to guide locomotion to a goal (Warren et al., 2001; Wood, et al., 2001; Harris & Carre, 2001). However, the contribution of the optic flow strategy should depend on the velocity of the flow field. In a pair of experiments, we examined the relative contributions of egocentric direction and optic flow while varying the effective flow field velocity. Participants were tested in a 12 m x 12 m virtual environment, wearing a head-mounted display (40 deg H x 60 deg V), with head position measured by a hybrid sonic/inertial tracking system. To dissociate the two strategies, the heading direction specified by optic flow was shifted 10 degrees (randomly to the L or R) from the actual direction of walking. In the first experiment, participants walked to a target located 9 meters away in physical space, placed at one of three angles (3, 8, or 13 degrees) away from the initial heading. Velocity of optic flow was manipulated by changing the "gain" between physical and virtual space so that the flow velocity was either 0.5, 1, 2, or 4 times the physical walking speed. Preliminary results indicate that the optic flow strategy was more dominant at higher flow velocities than at low velocities. In experiment 2, participants again walked to a target located 9 meters away in physical space while avoiding one to three obstacles en route, in the same visual gain conditions. Fajen & Warren's (submitted; VSS 2001) dynamic model of steering and obstacle avoidance will be expanded to incorporate both egocentric direction and optic flow strategies.

NIH EY10923, NSF LIS IRI-9720327

Abstract 434 9:30 AM

Sensitivity to the gain of optic flow during walking
Melissa J. Kearns, Frank H. Durgin, & William H. Warren Brown Univeristy, USA, Swarthmore College, USA, Brown University, USA

Optic flow is one source of visual information relied on for various locomotion tasks, including steering, obstacle avoidance, and path integration. In the real world the information from optic flow is redundant with information from body senses (vestibular, proprioceptive, and efferent signals). People are relatively accurate in reproducing distances traveled based solely on optic flow (Bremmer & Lappe, 1999). However, when body senses are also available, they tend to dominate (Kearns, Warren, Duchon, & Tarr, in press; VSS 2001). In addition, participants fail to notice large (+/- 50%) changes in the gain of optic flow during walking, if their attention is not drawn to it. This leads to the question: how sensitive are observers to such gain changes? If the body senses are more useful in determining the distance traveled, one might expect low sensitivity to gain changes in flow speed. On the other hand, if optic flow is a robust source of information about self-motion, one might expect sensitivity may be high. Participants wore a head-mounted display (60 x 40 deg) while walking on a straight path (6-8m per trial) in a virtual environment; head position was recorded with a sonic/inertial tracker. Gain-change thresholds were measured using a 2AFC task in a 2-up, 1-down staircase procedure. The baseline gain of flow was manipulated (50%, 100% (normal), 200%), with incremental differences in gain presented on each trial. Results indicate high sensitivity (comparable to similar tasks) regardless of the baseline optic flow rate, indicating that flow sensitivity is relatively constant even in less familiar ranges. In a second experiment, we examined whether the actual walking speed affects sensitivity to flow gain by manipulating the speed of walking (normal, fast, and slow) with a baseline gain of 100%.

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Abstract 435 9:45 AM

Retinal flow and visual direction information in the control of steering
John P. Wann & Richard M. Wilkie University of Reading

There has been an ongoing debate as to whether optic flow is sufficient to judge heading or whether extra-retinal information is required. A more recent debate has been whether human locomotion can be controlled purely on the basis of egocentric visual direction without reference to optic flow (Rushton et al, 1998 ; Warren et al, 2001). We created a driving simulation where retinal flow (RF) and visual direction (VD) information could be manipulated independent of one another. Observers sat in a projection booth with a 90 by 64deg FoV, with a simulation of locomotion at 8m/s across a textured ground plane, and used a force-feedback wheel to steer toward target gates. We systematically manipulated the information from optic flow or other directional cues in a balanced design so we could predict over-steer or under-steer if that particular cue was being used. The results supported the role of both RF and VD information in controlling steering with significant under/over-steer in the predicted direction when either information source was biased ($p < .01$). The weighting attached to either source of information appeared to be approximately equal for the conditions we created and reinforces the argument of Warren et al (2001), that if retinal flow is salient, it will be used in active locomotion. A further experiment manipulated extra-retinal (ER) information and supported a model where all 3 sources (RF, VD, ER) are combined in an additive manner to provide robust locomotor control. Research supported by the UK EPSRC GR/R14644.

Abstract 436 10:00 AM

Determining the running direction in catching balls
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*VSS 2002 Student Award

It has been claimed that in order to catch a ball, one uses the distinction between acceleration and deceleration of the optic projection of the ball to determine whether one has to run backward or forward. We questioned whether subjects can detect this information well enough to use it for this task.

We determined how well subjects could detect acceleration for short presentation times. About 25% change of the average velocity was needed to detect acceleration with reasonable confidence, independent of presentation time. Has the optical velocity changed that much at the time that ball catchers start to run?
We examined the results of a real ball-catching task (Oudejans, Michaels & Bakker, 1997) and found that subjects reacted before optic acceleration could have been detected. Thus, acceleration is not used to initiate locomotion in catching balls. This raises the question as to what alternative information can be used.
The combination of horizontal and vertical speed determines the distance that a ball is going to cover. Subjects can estimate this distance by using information about angular velocity and the ball's visual size divided by its rate of expansion (tau). We estimated a discrimination threshold for this 'perceptual predicted distance' from discrimination thresholds for angular velocity and tau as described in the literature. The perceptual predicted distances of the balls in the experiment of Oudejans et al. (1997) can be discriminated well enough to be a possible cue for determining the initial running direction.

Reference
Oudejans, R. R. D., Michaels, C. F., & Bakker, F. C. (1997). The effects of baseball experience on movement initiation in catching fly balls. Journal of Sports Sciences, 15, 587-595.

NWO MAGW grant 575-23-015

Abstract 437 10:15 AM

Human and Robotic Catching of Dropped Balls and Balloons: Fielders Still Try to Make the Image of the Projectile Rise.
Michael K. McBeath, Thomas G. Sugar, Shannon E. Morgan, Crystal D. Oberle, Keshav Mundhra, & Anthony Suluh
Arizona State University (McBeath, Morgan, and Oberle are Department of Psychology. Sugar, Mundhra, and Suluh are Department of Aerospace and Mechanical Engineering).

When humans navigate to catch balls that are projected toward them in the sagittal plane, they run along a path that keeps the tangent of the optical image of the ball rising at a constant rate. This heuristic, known as optical acceleration cancellation (OAC), produces a near least-energy running solution (provided the optical ball velocity maintained is approximately that initially perceived by the fielder), but it also will guarantee success at other constant optical velocities (provided the fielder can move rapidly enough). In this study, we examined optical behavior of fielders and robotic simulations in the less common case in which a target projectile is dropped, so the initial optical ball velocity is downward. We examined whether fielders attempt to maintain the initial downward optical velocity, or try to run fast enough to reverse the optical direction of the ball (and maintain an arbitrary rising optical speed). Robotic simulations indicated that either strategy can work for slow falling objects like balloons, but for normal balls, realistic lag times do not allow a fielder to move fast enough during the final portion of navigation. Tests with human fielders confirmed that navigating to the interception point of falling objects is quite difficult. Fielders generally selected a running path that did not allow the image of the projectile to descend. For falling balloons this resulted in fielders running rapidly until just a step or two before the point of interception. For falling balls, fielders typically ran as fast as they could. The findings support that fielders try to maintain a rising optical trajectory even in the extreme case of falling balls with initial downward optical trajectories. This further generalizes the range of cases in which OAC is used in interception and confirms that it is not the initial velocity, but the upward direction that appears to be the universal regularity that is maintained while catching.

Monday Poster Session: Attention; Multi-Stability; Perceptual Organization; Scene Perception; Self-Motivation; Spatial Layout; Visual Search

Attention

Abstract 438 B4.01

Reflexive attentional shift caused by indexical pointing gesture
Katsumi Watanabe National Institutes of Health, USA, Juntendo University, Japan,

Pointing with the index finger extended is a universal behavior in humans. But, the functional significance of index finger extension in pointing gesture has been rarely examined. We examined the efficacy of pointing gestures in evoking viewer's attentional shifts. [1] After various hand gestures were presented at the fixation point, eleven observers pressed keys to report the location of a target dot at the peripheral visual field quickly and accurately. When the target was presented 107 ms after the cue, reaction times were shorter to the target at the location where hand gestures pointed (i.e., where the fingers were oriented) ($p < .05$). This cuing effect was absent when the target appeared 1000 ms after the cue, indicating that the attentional shift is relatively short-lived and is not due to the observer's deliberate strategy. These results showed that directional hand gestures automatically trigger visual attentional shifts toward the pointing direction. Moreover, the indexical pointing gesture produced a significantly larger cuing effect ($p < .05$) than the other gestures, suggesting that there is a functional significance of indexical pointing in manipulating the viewer's attention. [2] To examine if the finger position (at the side of the thumb) or the finger length (relatively long) of the index finger accounts for the index-finger's advantage in manipulating attention, we shortened the index finger to the length of the little finger and lengthened the little finger to the length of the index finger. If only length matters, the lengthened little finger would show an enhanced effect as well. If position relative to the thumb is crucial, the shortened index finger would preserve the enhanced effect. Neither was the case. The attentional shift was boosted only with the normal index finger ($p < .05$). Thus the visual system seems to use

rather inflexible visual representation of indexical pointing gesture for modulating reflexive attention.

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Abstract 439 B4.02

Covert attention does NOT affect contrast sensitivity.
Joshua A. Solomon City University, London, UK

Many tasks are facilitated when the position of the target is known, even if the observer is fixating elsewhere. This facilitation is often ascribed to covert attention, which has been reported to increase contrast sensitivity, among other things. I sought to confirm these reports. On each trial, the observer saw two 30-ms flashes of a bright Gaussian (s = 0.37?) on a gray background and reported which of the two seemed brighter. The intensity of the brighter flash was randomly selected from a 5-dB range. Both flashes occurred in the same position, 3.6? away from a 1?-square fixation region. Trials in which fixation left this region were not analysed. Trials were also blocked by condition. In each cued condition, the position of the flashes never varied. It was indicated, 150 ms prior to each flash, by a 2? line segment with one end at fixation. In uncued conditions, the position of the flashes was randomly selected from one of four alternatives. These alternatives were indicated by the line segments used in the cued conditions. The four segments formed an X. Conditions were also either detection, in which there was no dim flash at all, or discrimination, in which the intensity of the dim flash was 5.2 times that required for 81% accuracy in the uncued detection condition. To achieve the same accuracy in the discrimination conditions, the brighter flash had to be 30% brighter than the dim flash, regardless whether the position were cued or not. That is, there was no effect of cueing on contrast discrimination. The cued detection threshold was 1 dB lower than the uncued detection threshold. This is consistent with signal-detection theory, which posits that four times as many independent channels are monitored in the uncued conditions. Neither separate paramaters for cued and uncued signal gains nor cued and uncued intrinsic uncertainty (nor both) could be warranted by c2 analyses. Thus there is no indication that covert attention can affect contrast sensitivity.

Abstract 440 B4.03

The role of strategic scanning in object-based attention
Sarah Shomstein and Steven Yantis Johns Hopkins University

Evidence has accumulated over the past decade suggesting that visual attention is often object-based (e.g., Egly et al., 1994). However, some recent studies have suggested that strategic effects such as attentive scanning can contribute to object-based effects. In the present study, we investigated the strategic contribution to object-based selection. We used a modified Egly paradigm in which we manipulated (1) the probability that a target would appear in each of the two uncued locations and (2) the cue to target SOA. Of the invalidly cued trials, the target appeared in the high probability location (absolute spatial location, i.e. upper right) 83% of the time and in the low probability location (i.e., lower left) 17% of the time. In both conditions, uncued targets appeared in the cued object half the time and in the uncued object half the time. At short SOAs, the object-based and probability effects were roughly additive. However, at long SOAs (400 and 600 ms), the object-based effects disappeared, and response times depended exclusively on the target probability. These results suggest that observers may adopt an implicit scanning strategy (in which unattended locations within an attended object have high priority) or an explicit scanning strategy (in which objectively high-probability locations have high priority) depending on task contingencies and the amount of time that is available to deploy attention. This provides further constraints on the mechanisms of object-based selection.

Abstract 441 B4.04

MEG reveals correlation between task difficulty and magnitude of the attentional blink
Kimron Shapiro, Frank Schmitz, Sander Martens, Katharina Mueller, Dan Loach, Elkan Akyürek, Bernhard Hommel, and Alfons Schnitzler University of Wales, Heinrich Heine University, Heinrich Heine University, Max Planck Institute, University of Wales, University of Leiden, University of Leiden, Heinrich Heine University,

In a recent talk (ECVP, 2001) we provided evidence of a plausible neural correlate of the attentional blink (AB) task. This was accomplished by studying the attentional blink (AB) paradigm using whole-head magnetoencephalography (MEG). The AB task presents two targets, T1 and T2, separated from trial to trial by two different temporal lags, as part of a rapid stream of visual information. In our implementation of the AB paradigm, Lag 2 separates the targets by 300 ms and Lag 6 by 900 ms. Target and non-target black letters are presented at fixation, at a rate of 7 items per sec, with the participant required to determine whether 0, 1, or 2 pre-specified targets are presented, then to identify each. The AB is revealed on trials when two targets are presented and, upon successful identification of T1, participants' ability to identify T2 is severely reduced, at Lag 2. Performance at Lag 6 is equivalent to baseline, as established on trials when only T1 or T2 is presented. MEG recording substantiates the behavioural result as it reveals a significant attenuation of neural activity on trials when T2 is presented but unable to be reported, most noticeably in dorso-lateral frontal cortex and in temporo-parietal areas. Activity when T2 can be reported (i.e., no AB occurs) is also attenuated, relative to Lag 6. Moreover, recent analysis has revealed a significant correlation between T1 activity and AB magnitude, suggesting the brain may indeed operate in a limited-capacity fashion.

Abstract 442 B4.05

Components of visual prior entry
Keith A. Schneider & Daphne Bavelier, University of Rochester, NY, USA

Purpose: The prior entry hypothesis suggests that attention accelerates visual processing, reducing the latency to perception for attended stimuli. Historical evidence for the hypothesis has been mixed, and the purpose of this study is to compare the contributions of attention, response bias, and sensory facilitation to the observed apparent prior entry effects.

Methods: In separate sessions, observers judged the apparent simultaneity (SJ) or temporal order (TOJ) of the onsets of two peripheral targets, to one of which attention was oriented with either exogenous, endogenous, gaze-directed, isoluminant exogenous or multiple exogenous cues. The cue lead times (CLT) and the presentation intervals (SOA) between the targets were systematically varied. Results: The points of subjective simultaneity (PSS), the SOA at which the observers were maximally uncertain about the order of the targets, shifted significantly for the TOJ as a function of CLT for all cue types in a manner expected from the temporal dynamics of attention, however, decision models that included response biases could completely account for these shifts. The SOAs at which the SJ was maximum were not significantly different from zero for the endogenous and gaze-directed cues and were smaller than the TOJ shifts in the PSS for the exogenous cues. For multiple exogenous cues, the shift in the SJ maximum decreased with the number of cues, from about 20 ms with one cue to an asymptote of about 10 ms for six or more cues. Conclusions: Prior entry may only occur for attentional cues that cause transient activity at the target location, and the effects of these cues are composed of roughly equal attentional and non-attentional components. The results from TOJ experiments are difficult to interpret due to the contribution of response biases, but the SJ can function as a reliable test of prior entry. Prior entry is not a general property of attention but rather more likely a bottom-up sensory phenomenon.

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Abstract 443 B4.06

Pop-out and preattentive processing are not equivalent: Taking apart a common assumption about visual attention.
Lavanya Reddy, Rufin VanRullen, & Christof Koch, California Institute of Technology, USA, California Institute of Technology, USA, California Institute of Technology, USA

Most theories of visual processing assume that a target will pop-out from a field of distractors if targets and distractors can be discriminated preattentively. The distinction between pop-out and serial search is classically inferred from set size effects in visual search tasks, while the attentional requirements of a visual discrimination task are often assessed using dual-task paradigms, by measuring interference from a concurrently performed attentionally-demanding task.

Here we show that there is no such equivalence: while simple feature discrimination tasks that can be performed preattentively lead to pop-out in visual search (e.g. color or orientation discrimination), and many tasks that require attention need serial examination in visual search (e.g. rotated L vs. T or red-green vs. green-red patches), other tasks do not trigger pop-out even though they can be performed preattentively (natural scene categorization, color-orientation conjunction discrimination). Furthermore, certain targets that pop-out among distractors need attention to be effectively discriminated when presented in isolation (rotated L vs. +, cubes with different illumination directions). In other words, the distinctions "pop-out vs. serial search" and "pre-attentive vs. attentive processing" can be independent.

We suggest that (i) attentional requirements depend on the existence of specific neuronal populations selective to the target and distractor categories, independent of the level of processing involved (from V1 to IT), while (ii) set size effects in visual search are mainly determined by the level of complexity and the locus of the discrimination; pop-out occurs for targets that are discriminated in early areas (V1-V2) and not in higher areas (V4, IT) due to a combination of 2 related factors: receptive field size (leading to competitive interactions in higher-level visual areas) and non-classical receptive field interactions (e.g. grouping in lower-level areas).

Abstract 444 B4.07

Optical recordings reveal a functional architecture for spatial attention in the posterior parietal cortex of the behaving macaque
Milena Raffi & Ralph M. Siegel CMBN, Rutgers University, Newark, NJ, USA

The influence of spatial attention in the parietal cortex was evaluated using optical imaging of intrinsic signals at 605nm. The most dorsal aspects of area 7a and dorsal prelunate (DP) were imaged. Recordings were made in the right hemisphere of a macaque trained to fixate a 0.1 red dot and perform a cued detection task. Two 10 expanding optic flow stimuli were simultaneously presented 10 to the left and right (or above and below) the target. The monkey responded to a change in the structure of one of the two stimuli. A 2 white cue instructed the monkey as to which stimulus would change. A behavioral catch-trial control was also used for which the cue was incorrect. Behaviorally, there was a decrease in the reaction time of 25-50 msec when the monkey was correctly vs. incorrectly cued indicating a spatial attentional shift. The evoked optical response across the posterior parietal cortex depended on the locus of attention with the appearance of columns corresponding to the location of the attentional cue. We quantified these effects using a linear regression analysis. The columns were seen in all the experiments performed over 10 months and had the same dimension in both horizontal and vertical paradigm. These attentional columns were not seen in controls when just the cue was presented and the animal attended only to the central fixation point. For verification, multi-unit recordings were made using both the attentional task and the control task. The great majority of neurons showed no dependence at the onset of the stimuli upon the cue condition. A control paradigm in which the animal had to detect a central fixation point dimming showed that the cue alone had little or no effect on the firing rate. Thus the observed columns are not likely to result from the cue stimuli, but rather the spatial focus of the attention. The columns represent a novel functional architecture correlated with attention.
Supported by: NIH EY9223 and Whitehall Foundation.

Abstract 445 B4.08

No contingencies: Attentional prioritization by big or bright singletons
Michael J. Proulx II & Howard E. Egeth Johns Hopkins U., USA

Goal-directed and stimulus-driven processes interact to control visual selective attention. However, there is much

disagreement about whether stimulus-driven processes can lead to involuntary attentional capture. We conducted four experiments to assess attentional prioritization by stimuli that were singletons with respect to size or brightness (cf. Yantis and Egeth, 1999). One would predict that these features, which were unrelated to the target-defining features of the participant's task, would not receive attentional priority according to the contingent involuntary orienting hypothesis (Folk, Remington, & Johnston, 1992).

We tested this hypothesis with a standard visual search for a vertical target bar among distractor bars tilted 30 degrees to the left or right of vertical. The singleton (a long bar or a bright bar) had a 1/n probability of being the target, with n the display size of 3, 6, or 9. Each participant only observed singletons of a single type in Experiment 1. In Experiment 2, each participant viewed both types, in mixed trials. In Experiment 3 the salience of the singletons was increased to test whether this translated into increased attentional prioritization. A neutral experiment without singletons was also conducted.

The singletons consistently attracted attentional priority as the slope of the reaction time versus display size function was substantially shallowerwhen the target was the singleton than when it was not. However, they did not receive full attentional priority, as those slopes were significantly greater than zero, even with the very salient singletons used in Experiment 3. These results indicate that although abrupt onsets may be unique in receiving full attentional priority (i.e., near zero slope), brightness and size singletons do attract a significant degree of attentional priority under conditions where this would not be expected on the basis of the contingent involuntary orienting hypothesis.

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Abstract 446 B4.09

Does active attention affect the detection of the pop-out target?

Takuma Murakoshi, & Yoshihisa Osada Rikkyo University, Rikkyo University

Purpose: We have previously shown (ARVO, 2000, 2001) that active attention has an effect on passive attention. This study investigates the effects of active attention on the detection of the pop-out target with a dual task condition that requires a subject to pay attention to a RSVP stream voluntarily. The goal of this study is to clarify how active attention affects the detection of the pop-out target.
Method: First, RSVP stream was presented on the center of the monitor. Then a pop-out search array consisted of twenty-four items was presented (30ms) around RSVP stream. Subjects pressed one of two keys to report whether the pop-out target was presented or not. Five subjects were tested in two experiments. In dual-task condition of the first experiment subjects had to detect the RSVP target which color was different from other stimuli in addition to report the presence of a pop-out target. In dual-task condition of the second experiment subjects had to detect the RSVP target which shape was different from other stimuli in addition to report the presence of a pop-out target. RSVP stream had nine items which color was red, green or blue and shape was circle, triangle or square. Half the trial contained one uniquely colored stimulus and half contained no pop-out target in a pop-out search array.
Result: When subjects attended a color feature to detect the RSVP target (dual-task condition of first experiment), their performances in the detection of the pop-out target were not impaired. However when subjects attended a shape feature to detect the RSVP target (dual-task condition of second experiment), their performances in the detection of the pop-out target were impaired.
Conclusion: In our experiments a pop-out target was uniquely colored stimulus and subject's performances in detection of the pop-out target were impaired when they attended a shape, but were not impaired when they attended a shape. This suggests that active attention affects a feature module which subjects do not attend.

Abstract 447 B4.10

But it's the only thing there! Sustained inattentional blindness for a solitary stimulus

Steven B. Most & George A. Alvarez Harvard University, Harvard University

When actively attending to targets in a display, observers often fail to notice an additional, unexpected stimulus (Mack & Rock, 1998). This "inattentional blindness" occurs for salient objects visible for extended periods of time (Most et al., 2001). Here we show that inattentional blindness can occur even when the unexpected object is the only item visible in the display. On each trial, observers tracked two white circles among six black circles that moved randomly and independently around the display. Each trial contained a 1200 ms blank interval in which all items became invisible by fading out, but the circles' positions continued to be updated according to the same rules as when they were visible. Observers were required to extrapolate the target circles' trajectories during the blank interval to enable recovery of the objects when they reappeared. Upon reappearing (by fading in), all circles were identical, and observers indicated which items they had been tracking before the blank. This task was difficult but possible: with practice, 95% of the observers were able to select at least one of the target items accurately. On a critical trial, an additional, unexpected black circle faded in at fixation at the beginning of the blank interval and remained until the original items reappeared, at which point the unexpected circle faded out. Even though the unexpected circle was the only object in the display during this 1200 ms interval, 25% of the observers failed to notice it. This rate is consistent with previous inattentional blindness research (Mack & Rock, 1998), but is especially striking given that no other objects were visible.

Abstract 448 B4.11

Gain mechanisms for colour and luminance contrast are modulated by independent attentional mechanisms

Concetta Morrone, Valentina Denti & Donatella Spinelli Università Vita-Salute San Raffaele, Italy, Istituto di Neurofisiologia del CNR, Italy, Istituto Universitario Scienze Motorie - Rome, Italy

We investigated the effects of attention on visual processing of luminance and colour contrast by measuring contrast

discrimination thresholds for peripherally displayed gratings (1 c/deg) in attended and unattended conditions. In the attended condition the task was performed on its own, in the unattended condition together with a central search task. Stimuli for the search task and for the contrast discrimination were modulated in either luminance or colour (equiluminant red-green). When both the central and peripheral stimuli were modulated in luminance, contrast discrimination thresholds in the unattended condition were about 3 times higher in the unattended than the attended condition for mid to high base-contrasts, but not for low or zero base-contrasts (agreeing with previous results). Similar results were obtained when both central and peripheral stimuli were modulated chromatically. The attentional effects were well modeled by a multiplicative gain change of the contrast response functions underlying the discrimination data. However, when the stimuli in the central search task were modulated in luminance, that task had no effect on chromatic contrast discriminations; and when they were modulated in colour, the task had no effect on luminance contrast discriminations. The results suggest that luminance and colour discriminations are controlled by separate attentional processes that modulate independently their gain mechanisms. They may also imply that the magno- and parvo-cellular pathways, preferentially stimulated by the luminance and chromatic stimuli, have independent attentional resources.

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Abstract 449 B4.12

Orientation cues used to determine group center-of-attention

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A hierarchical system of orientation cues enables observers to discern the focus of attention of other individuals. The present study assesses the value and strength of the information provided by the primary (internal facial features) and secondary (external outline shape) cues in determining both individual direction-of-attention and group-center-of-attention. In the first experiment, participants viewed natural black-and-white photographs and silhouettes of four different individuals in eight different orientations. Participants' task was to indicate where they thought the image was "looking." In the second experiment, participants viewed natural black-and-white photographs and silhouettes containing groups of three individuals, and their task was to indicate individual orientation and group-center-of attention. The results indicated that internal cues enhance viewers' ability to discern the group center-of-attention, but that outline shape alone is largely sufficient to determine the focus of attention. The overall findings support the concept that group center-of-attention is discernable through the use of simple orientation cues.

Abstract 450 B4.13

Can attention bias bistable perception? Differences between rivalry and ambiguous figures

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Controversy surrounds whether binocular rivalry involves the same mechanisms as those that mediate the bistable perception of ambiguous figures (e.g., Necker cube). During binocular rivalry, discrepant monocular images compete for exclusive perceptual dominance. Using fMRI, Tong and Engel (2001) recently found powerful rivalry-related modulations in monocular visual cortex (V1). This physiological evidence supports the notion that interocular competition mediates binocular rivalry. However, it is still controversial whether some top-down processes may access V1 and mediate stimulus competition. Here we show that attentional modulation of dominance durations during binocular rivalry is limited compared to bistable perception of a Necker cube. In two separate binocular rivalry experiments, we presented rivaling orthogonal gratings or complex meaningful stimuli (i.e. house vs. face). Subjects were instructed to either passively observe the stimuli or try to see one monocular stimulus for as long as possible while reporting their online perception. Stimulus contrast of one monocular image was manipulated. In no case could subjects increase the dominance duration of the desired percept, although they did show a limited ability to shorten the duration of the undesired percept. However, when subjects viewed a Necker cube from one of three fixation-point positions, in all cases subjects could both greatly increase the dominance duration of the desired percept and decrease the dominance duration of the undesired percept. Although previous studies have shown that subjects can control the alternation rate of binocular rivalry (Lack, 1971), our study is the first to test subjects' ability to attentionally bias one visual representation over another. The results suggest that unlike other bistable visual phenomena (e.g., Necker cube), binocular rivalry is resolved in early visual stages and cannot be accessed by high-level attentional processes.

Abstract 451 B4.14

Full time-course of visual/auditory central/peripheral cueing of visual spatial attention: AP > VP=VC > AC

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Time-course is a performance signature of attention systems (1). In this study, an attention reaction paradigm (2) measures the time-courses of visual central (VC), visual peripheral (VP), auditory central (AC), and auditory peripheral (AP) cuing of spatial visual attention. Observers viewed four synchronized letter streams at the corners of a 28 by 28 deg box, while fixating at the center. In each stream, an independent random permutation of 22 letters appeared at 10 /s. Observers were instructed to report the earliest three letters available from the target stream, with payoffs decreasing with cue-report SOA. Four types of cues were used: an arrow at fixation (VC), an arrow adjacent to the target (VP), a tone coming from behind the target location (AP), and tones of four different frequencies at fixation (AC). Experiments were blocked by cue type, in Latin Square order. For VP and VC conditions, the first reported items occurred at about 100 ms and item report peaked around 200 ms post- cue (median 171 ms). In the AC condition, the reported items were from 100 ms to 400 ms (median 226 ms). Most interestingly, in the AP condition, the earliest reported items were simultaneous with the cue and the peak was at 100 ms post-cue (median 96 ms)! The full time-courses,

or report distributions, were well described by gamma functions: the same shape for VC, VP and AP, a different shape for AC. Moreover, while VC and VP were fit with exactly the same parameters, the best fitting gamma function for AP was shifted backward (started earlier) by 75 ms relative to VC/VP. We conclude that the time courses of VC, VP and AP share the same distribution, but differ in offsets: completely equal for VC and VP and 75 ms faster for AP. AC is qualitatively different. As in (3), but contradictory to common belief, VC and VP have the same temporal characteristics. Calculations of the attention gates (2) led to the same conclusions.

1. Posner (1980), QJEP, 32, 3-25.
2. Reeves & Sperling (1986), Psych Rev, 93, 180-206.
3. Lu & Dosher (2000), JEPHPP, 26, 1534–1548.

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Abstract 452 B4.15

Attention enhances spatial resolution by shifting sensitivity to high spatial frequencies

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Introduction. In a texture segmentation task in which performance peaks at mid-peripheral locations and drops at both central and peripheral locations, attention improves performance at peripheral locations but it hinders it at central locations. This indicates that attending to the target location enhances spatial resolution - improving performance where the resolution is too low (periphery) but impairing it where resolution is already too high (central locations) for the task (Yeshurun & Carrasco 1998, 2000).
Goal. To evaluate the hypothesis that attention enhances spatial resolution by increasing sensitivity to high spatial frequencies, we employed a backward band-masking paradigm while manipulating transient covert attention by precueing the target location.
Method. In a 2IFC task, observers were presented with a precue (60 ms) that indicated either both target location and display onset (peripheral cue) or just display onset (neutral cue). This was followed by a 60 ms ISI and then the texture pattern was presented for approximately 50 ms. A target patch appeared at varying eccentricities along the horizontal meridian. Immediately after the display presentation a post-mask appeared for 100 ms; there were 3 types of masks: a) a wide-spectrum frequency post-mask, b) a low-pass mask, or c) a high-pass mask.
Results and Conclusion. The high-pass mask diminished the central performance drop for both the neutral and the peripheral precue conditions. In contrast, the low-pass mask augmented the central performance drop in the peripheral precue condition. These results are consistent with the finding that selective adaptation to high spatial frequencies diminishes the central performance drop and eliminates the attentional impairment (Carrasco & Loula, 2000). Both studies provide evidence for the spatial nature of the central performance drop and indicate that attention enhances spatial resolution by shifting sensitivity to higher spatial frequencies.

Abstract 453 B4.16

Response mapping in a task switch

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The role of response mapping is investigated with response repetition, response gesturing and stimulus location.
In the present study, two experiments were conducted to determine whether complete or partial response repetition influences the task switching cost, which is the difference in performance between switched and non-switched task sequences. Participants were required to react to a location with closed or open squares by pressing keys corresponding to three locations. The target stimulus in the probe (one arrow in Experiment 1 and three squares in Experiment 2) followed the three squares in the prime. An endogenous cue was presented in order to decide switch or non-switch in the probe target in Experiment 1 or in the display between the prime and the probe targets in Experiment 2. In Experiment 1, participants responded to the probe target based on the prime response, and in Experiment 2, they did so based on a visual cue. In some trials, there was a switch from the prime task (response to closed square followed response to open square), in some trials, the same task was repeated (response to closed followed response to closed). The results highlight the three important points to consider in the role of response mapping. First, a switch cost occurred only under response repetition. Especially, this response repetition may be concerned with translation into action. Second, the presence of response in the prime inhibited response to the target in the probe, compared with an absence of response. Third, a switch cost occurred when the target stimulus had the spatial information with the presentation of squares. These results suggest that a task-set reconfiguration reflects response repetition and activation on the stimulus location.

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Abstract 454 B4.17

Competition and cooperation in spatial attention: The joint effect of regularity in target location and exogenous cueing

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Implicit probability cueing of target locations is a robust phenomena in which participants respond faster to targets that appear in predictive locations. Probability cueing differs from traditional endogenous cueing paradigms in that there is no explicit directional cue and participants are largely unaware of biases in their behavior. Sudden onsets, on the other hand, have been shown repeatedly to be an effective exogenous cue. We explored how implicit probability cueing of target location and exogenous cueing by an onset stimulus interact in a visual search task. Our findings suggest that these two cueing conditions produce strong main effects: Responses were faster to targets in high- than low-probability locations and faster when the exogenous cue preceded the target compared to a distractor. Furthermore, when the target location was preceded by the exogenous cue, response was facilitated compared to a random-probability control when that location was also the high-probability location and inhibited when it was a low-probability location. However, when targets were in the high-

probability location, an exogenous cue at the target location did not facilitate response whereas an exogenous cue at a distractor location inhibited response relative to a no-onset control. That is, the exogenous cue did not increase the competitiveness of a location for processing when attention, due to the probability cue, was already drawn there, but it did increase the competitiveness of distractor locations. This suggests that the effect of probability cueing, even when participants are unaware of it, is extremely powerful in orienting attention to a location, but is not impervious to bottom-up attentional capture by salient stimuli. The results are interpreted within an attentional framework in which mechanisms sensitive to different properties such as spatial regularities and sudden onsets interact in competitive and cooperative ways.

Abstract 455 B4.18

Attentional modulation of target-flanker lateral interactions persists with increasing flanker contrast.
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Purpose
Detection of a central low-contrast Gabor target often improves when it is flanked by suprathreshold collinear patches. We recently reported that such 'lateral interactions' depend on whether the collinear flankers are attended for a secondary task (Freeman *et al*., 2002, Nat. Neurosc. 4(10):1032-1036). Here we tested whether attended flankers facilitate the target more because they have higher effective contrast than when unattended. If true, increasing flanker contrast should overcome the attentional effect.

Method
Two pairs of flankers were displayed in an 'X' configuration around a central target Gabor, which was collinear with one flanker-pair and orthogonal to the other. A Vernier task was performed on one flanker-pair while the other pair was task-irrelevant. The contrast of all flankers was varied together over a wide range of values.

Results
Central target contrast sensitivity was enhanced only when flankers collinear with the central target were attended, while unattended flankers had little or no residual influence on central target detection. This advantage for attended collinear flankers tended to persist, and in some cases the attentional effect even increased with higher contrast flankers.

Conclusion
These findings suggest that attention does not merely lower the effective contrast of the unattended flankers. An account based on attentionally-weighted long-range interactions between receptive fields in early visual cortex is supported by these results.

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Abstract 456 B4.19

Identification of feature conjunctions does not increase the perceptual demands on attention
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Feature Integration Theory (Treisman & Sato, 1990) assumes that targets defined by multiple features (conjunction) increase attentional demands at the perceptual level of processing (perceptual load) due to a feature integration process, relative to targets defined by a single feature. Consistent with this, Lavie (1995) showed that interference by a response incompatible distracter (RID) was less when discriminating the presence of a conjunction compared to a single-feature, indicating that the former demanded more attentional resources and hence reduced the resources available to process the distracter. However, a failure to equate discriminability between the dimensions defining the conjunction and single-feature targets may account for these results. We compared RID between conjunction and single-feature targets while equating discriminability between the dimensions defining each target type. Displays consisted of probe and distracters that varied in color (red, green) and shape (H, K), with shape being less discriminable. Observers judged the presence/absence of target features (color, shape, or color-shape) within the probe and ignored adjacent distracters. RID differed from the probe on one or more target dimensions. Target "present/absent" reaction time and accuracy (joystick movement left/right) were recorded. Results showed equivalent RID interference for conjunction (color-shape) and single-feature targets (shape) when each required identification of the less discriminable, shape dimension (target dimension discriminability equated). RID interference was greater for conjunction targets only if the conjunction alone required identification of the less discriminable, shape dimension (target dimension discriminability not equated). Thus, discriminating the presence of a feature conjunction does not increase perceptual load due to a feature integration process.

Abstract 457 B4.20

Visual attention and co-activation of response decisions for features from different dimensions
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The role of visual attention in task performance has been extensively debated. Several studies have offered different loci in the stream of visual processing, where attention may influence the performance (e.g., Allport, 1989; Tsal & Shalev, 1996). Following the Dimensional-Action model (e.g., Cohen & Shoup, 1997), we hypothesize that a major role of attention is to transfer response decisions from targets on which it is focused to high level centers dealing with response execution. This hypothesis predicts that response decisions for two targets will interact only when attention is focused on both targets, and only when the response to the targets is defined by different dimensions.
Three experiments, using the redundancy gain paradigm, tested and confirmed this prediction. A special aspect of our study was the analysis of the cumulative probability density function (CDF) of the RT. This method allowed us to explore the data beyond the RT means, and study the entire distribution.
Experiment 1 showed that co-activation of two cross-dimensional targets occurs only when the targets are positioned in the same location. Experiment 2 manipulated the focus of

attention and showed that co-activation could occur even for targets positioned in different locations if they are both within the attentional focus. Experiment 3 showed that this attention-induced co-activation does not occur for targets from the same dimensional module.
These results suggest that a major role of attention is post-perceptual and involves gating of selected responses to executive functions.

Abstract 458 B4.21

Semantic benefit is additive in the attentional blink
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The attentional blink (AB) is a failure to identify the second of two targets presented in a stream of distractors with a stimulus onset asynchrony (SOA) of 200-500 ms. While the blinked target is unavailable for report, previous studies suggest that the target is processed to a semantic level. In two experiments we asked whether semantic priming modulates the attentional blink. The first experiment instructed subjects to attend to a category of words (e.g., animals or vegetables) for a block of trials. Both, one or neither of the targets in the single stream RSVP task was a word from the attended category; subjects were told to report both word targets among symbol distractors. The second experiment used a dual stream RSVP task to investigate the effects of priming. Each trial was primed by a word that was either semantically related to one of the target words or not semantically related to either word; subjects were again told to report both words. In both experiments AB was found for the second target at an SOA of 213 ms. A significant benefit for targets that were in the attended category (a .08 advantage) or were semantically primed (a .24 advantage) occurred equally for first and second targets at all SOAs. The results suggest that the semantic benefit is purely additive and does not selectively assist targets that are subject to AB.

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Abstract 459 B4.22

Orientation integration: What gets lost during attentional diversions?
Steven Dakin UCL

Purpose: To see if and how focused visual attention improves performance on orientation integration and "pop-out" tasks. Methods: I compared the effect of attentional load on two tasks: estimation of “odd-man-out” orientation (as a function of the number of vertical distractor elements) and judgment of mean or “overall” orientation (as a function of orientation variability). Stimuli consisted of an annulus of Gabor elements preceded and followed by a spatial-frequency matched noise mask. Subjects either reported if the mean or “odd-man-out” orientation was clockwise or anticlockwise of vertical. In high attentional-load conditions subjects also performed a secondary “attentional blink” task: to report the orientation of a centrally-presented white ‘T’ embedded within a sequence of black ‘T’s rotating at 19 frames/sec. QUEST maintained 83% correct performance on the secondary task by manipulating T-contrast within a mask. In low attentional-load conditions subjects viewed identical stimuli but were instructed to ignore the rotating T sequence. Results: Divided attention elevated thresholds in both tasks (for both naïve and experienced observers) but elevation was greater for the odd-man-out task. An equivalent noise model accounted for data from the mean orientation condition, where divided attention has the effect of modestly reducing subjects’ sampling efficiency (the number of features they can monitor) but does not change estimated internal noise, i.e. their uncertainty about each feature (orientation in this case). Performance on the “pop-out” task was inconsistent with subjects using the mean orientation of all elements. Naive subjects showed substantial learning during the course of this experiment. This had the effect of both reducing internal noise and increasing sampling efficiency. Not

Abstract 460 B4.23

Repetitions of location and object cause larger repetition blindness for letter
Yasuyo Chiba, & Kazuhiko Yokosawa University of Tokyo, Japan

In rapid serial visual presentation, when two items are identical, participants often fail to report both occurrences (repetition blindness: RB). Epstein & Kanwisher (1999) reported that when the letters were presented within four-location arrays, both repetitions in letter identity and in location caused RB. However, in their experiments, an array of pound (#) signs was presented through trials. Because of the consistency of the array configuration, repetition not in location but in events within the same object file might actually cause location RB. In this study, a situation was created where repetitions in location and within the same object could be defined separately and an experiment was conducted on the effects of both repetitions for letter RB. Four pound signs moved concentrically around a fixation. By replacing one of the pound signs at a time, three or four letters were serially presented and participants were asked to report the letters. There were three presentation formats: Under a location-repeated condition, two items were presented at the same location; under an object-repeated condition, two items were presented within the same object; under a control condition, all items were presented at different locations and within different objects. Trials were scored correct if two items were reported that were identical in presentation format, letter identity, or both. Under all presentation formats, participants had difficulty reporting letters of the same identity. In contrast with Epstein & Kanwisher, location RB was not found. Larger letter RB occurred under the location-repeated and the object-repeated conditions compared with the control condition. These results indicate that the repetition effect in location is not independent of repetition in letter identity. The results of a further experiment support this idea.

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Absract 461 B4.24

Covert attention speeds information accrual more along the vertical than the horizontal meridian
Marisa Carrasco, Brian McElree, & Anna Marie Giordano
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Background: 1) Transient covert attention improves discriminability and accelerates the rate of visual information processing in feature and conjunction searches (Carrasco & McElree, 2001). 2) Contrast sensitivity and spatial resolution are better along the horizontal than vertical meridian, and covert attention improves discriminability at all locations to a similar degree (Carrasco et al., 2001; Talgar & Carrasco, In Press).
Goal: We investigated whether: a) the rate of information processing differs for different locations at a fixed eccentricity; b) the effect of transient covert attention on the dynamics varies as a function of location.
Methods: We used time-course functions derived from the response-signal speed-accuracy trade-off (SAT) procedure for an orientation feature discrimination task. Each trial began with a precue (67 ms), which was either informative (small circle, indicating the target location) or neutral (a circle in the middle of the display). After a 53 ms ISI, Gabor patches, with 0 or 7 distracters, appeared for 40 ms. The target and distracters were presented at 8 equidistant locations from fixation at 4º eccentricity. A tone sounded at 1 of 7 SOAs, ranging from 40 to 2000 ms, to prompt observers to respond.
Results: a) SAT asymptotic accuracy (d') was higher and the rate of information processing was faster at the locations on the horizontal than the vertical meridian; b) precueing the target location improved discriminability to a similar extent across the visual field but accelerated information accrual more on the vertical than the horizontal meridian.
Conclusion: These results indicate that performance is superior on the horizontal than the vertical meridian because discriminability is higher and temporal dynamics are faster. Interestingly, whereas covert attention affects discriminability to a similar extent across the visual field, it speeds up information accrual more at the least privileged locations, i.e. on the vertical meridian.

Multi-Stability

Abstract 462 B4.25

Conscious selection of bi-stable 3D percepts described by neural population codes
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Understanding conscious visual perception is one of the main challenges in vision science. Here we developed both an experimental paradigm and a model to study conscious selection of bi-stable percepts in stereoscopic vision. The paradigm exploits a visual stimulus in which we independently manipulated two signals that our brain uses to retrieve the 3D layout of a scene. One of the signals is binocular disparity (i.e. according to the geometry of vision with two frontal eyes), the other is monocular perspective. The stimulus consisted of a slanted planar grid. When the slants specified by disparity and perspective had the same polarity subjects perceived one single grid, the perceived slant being a reconciliation of disparity-specified and perspective-specified slant. But when disparity- and perspective-specified slants had opposite polarities subjects perceived either a disparity-dominated or a perspective-dominated 3D representation of the slanted grid. A novel feature of the paradigm is that our observers were able to attentively select one of the two alternative percepts at will in a well-controlled way. Our paradigm provides, therefore, not only a promising tool to study conscious vision psychophysically but also to study it physiologically through either neurophysiology or fMRI. The experimental data were well described by a neural-population-code model in which perceived slant is determined by the combined activity of three neural populations (representing disparity, perspective and residual slant signals, respectively).

Abstract 463 B4.26

Subjective contours and binocular rivalry
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PURPOSE Are the temporal dynamics of rivalry influenced by globally organized subjective contours?
METHODS AND RESULTS Rival targets (a bullseye vs a "pacman") were presented i) alone, ii) in global context wherein two additional "pacmen" created the vivid perception of an illusory triangle, and iii) in a context in which those additional "pacmen" were present but did not create an illusory figure. Predominance of the rival pacman was uninfluenced by context, even when that pacman comprised one element of an illusory figure. In a second experiment context was introduced during dominance or during suppression of the pacman, but again global context had no influence on its predominance. In a third experiment, foveally viewed rival targets -- a "bullseye" and a "radial grating" -- underwent reciprocal periods of dominance and suppression. Observers depressed and held a key when the radial grating was dominant completely and released the key when the bullseye became dominant. On some trials, a real contour moved laterally through the visual field and on other trials a subjective contour moved laterally through the visual field. Real contour motion within the eye containing the suppressed stimulus reliably terminated its suppression. Movement of a subjective contour, although perceptually salient, failed to terminate suppression more frequently than did local transients associated with production of that contour.
CONCLUSION Dominance and suppression periods of rivalry are insensitive to figural information specified by illusory contours, implying that neural events underlying those perceptual states occur early in visual processing. It remains to be learned why global grouping is sensitive to global context while durations of dominance and suppression are not.
EY13358 and EY13924-01

Abstract 464 B4.27

Stimulus strength and dominance duration in perceptual bi-stability. Part I: the unperceived stimulus affects the very first dominance epoch

Nava Rubin, Jean-Michel Hupé, Ming Meng & Frank Tong
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Levelt (1967) found an intriguing relation between the strength of binocular rivalry stimuli and their dominance durations. When one eye's stimulus is strengthened (eg by increasing contrast), the mean dominance duration of that eye does not change; instead, the mean duration of the other (unaffected) eye decreases. This observation imposes significant constraints on models of rivalry. Here we propose that it is particularly useful for testing different accounts of the role of adaptation in rivalry. Adaptation is commonly thought to be involved in bi-stable alternations. But the relative role of a decay in strength of the dominant (perceived) stimulus versus a recovery from adaptation of the suppressed (unperceived) stimulus is not known. We addressed this by examining the duration of the very first dominance epoch. Methods: contrast was manipulated for each eye independently in a full-factorial design. Trials were sorted based on which eye was dominant first, and the mean duration of the first epoch was calculated for each eye. Results: Levelt's observation holds already in the first dominance epoch; the mean duration of the first stimulus seen depended on the contrast of the (as yet unperceived) stimulus projected to the other eye. In the next abstract (Part II, Hupé and Rubin) we present evidence that Levelt's result can be generalized to bi-stable motion displays, and there, too, we find that the effect of the unperceived percept on the dominance duration of the other percept is present already in the first dominance epoch. Conclusions: these results cast a doubt on models which make use of recovery from adaptation of the suppressed stimulus to explain Levelt's result. In the very first dominance epoch, the suppressed stimulus is not yet adapted: it is not only unperceived at that moment -- it has not been perceived (dominant) at all yet. These observations impose new, stronger constraints on models of bi-stable perception.

Abstract 465 B4.28

Chromatic rivalry between achromatic objects
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Binocular rivalry occurs when a stimulus (e.g., horizontal bars) that is clearly visible, when presented to one eye, is periodically rendered invisible when a different stimulus is simultaneously presented to the other eye (vertical bars, for example). While the physiological basis of rivalry (and fusion) has been much debated, two general theories have been suggested. One theory argues that rivalry represents a competition between interpretations (or perceptions) that are independently generated by the different stimuli presented to the two eyes (which is comparable to viewing monocular ‘ambiguous’ figures). The second hypothesis suggests that the visual information from one eye is suppressed early in the visual pathway prior to the stage of binocular confluence (e.g. the lateral geniculate nucleus or layer IV of primary visual cortex). To test the validity of these and other possible explanations, subjects were first presented with two panels that elicit sensations of opposing saturated colors. When independently presented to the right and left eyes in dichoptic viewing, the images rival in perception. When, however, the right and left eye are presented with panels that have the same average chromaticity as in the previous experiment, but in a context that is more consistent with seeing the same object in the same location in space, the spectrally different stimuli fuse in perception for most observers. This effect is striking since extracting specific elements of the fused image, and presenting them independently on uniform chromatic surrounds causes the spectral elements to rival in perception. These results suggest that different spectra induce rivalry when the context of the stimuli are consistent with viewing different objects in the same location in space, but fuse when the information presented to the two eyes is consistent with viewing the same object in the same location. More generally, fusion and rivalry are not determined simply by the physical similarities and differences of the stimuli as such, but are manifestations of the coherent nature of the stimulus context.

Abstract 466 B4.29

Local eye rivalry can yield global, interocular dominance
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During binocular rivalry, observers sometimes perceive one complete visual object (e.g., a bullseye) even though component features of that perceptually dominant object (e.g., semi-circular halves of the bullseye) are distributed between the two eyes and are in rivalry against other, dissimilar features (Diaz-Caneja1; Kovacs et al2). This interocular grouping cannot be explained by models of rivalry in which one eye or the other is completely dominant at any given moment. But perhaps global interocular grouping is achieved by simultaneous local eye dominance, wherein portions of one eye’s view and complementary portions of the other eye’s view become dominant simultaneously. To test this possibility, we performed two experiments using the "monkey/jungle" display created by Kovacs et al2. In one experiment, we measured dominance durations for multiple, local zones of rivalry and then created 1-min animations of a global "montage" in which dominance within local regions was governed by the distributions of dominance measured empirically. These animations included significant periods of time during which global interocular grouping was evident; observers viewed these animations intermixed with actual rivalry displays, and the resulting tracking data confirmed the similarity in global dominance of the two display types. In a second experiment we used the eye-swap technique to confirm that within given, local spatial regions of rivalry it was the region of an eye – not a given stimulus feature – that was dominant. We conclude that interocular grouping during rivalry does not rule out local, eye-based rivalry, although it is likely that top-down influences may additionally promote interocular grouping. EY13358
1. Diaz-Caneja, E. (1928) Ann. Oculist, October, 721-731.
2. Kovacs. I., Papathomas, T. V., Yang, M., & Fehér, A. (1997) Proc. Natl. Acad. Sci. USA. 93, 15508-15511.

Abstract 467 B4.30

Stimulus strength and dominance duration in perceptual bi-stability. Part II: from binocular rivalry to ambiguous motion displays

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In binocular rivalry, strengthening the stimulus to one eye does not affect the mean dominance duration of that eye, but instead decreases the dominance durations of the other eye (Levelt 1968). Here we show that this fundamental result can be generalized to another domain of perceptual bi-stability. Methods: Plaids made of rectangular-wave gratings were used. Plaids are bi-stable stimuli that can be seen as a single pattern moving coherently or two grating sliding over each other (transparency). We manipulated the strength of the transparent percept without affecting the coherent percept, relying on two facts: (i) during the transparency states, the sense of motion is dominated by the 'front' grating; (ii) there is a preference to see motion along cardinal directions (e.g. Andrews & Schluppeck VR 2000; Hupé & Rubin ARVO 2001). The plaids consisted of one cardinal and one oblique grating, with unambiguous depth ordering via occlusion cues. Shuffling the cardinal grating from back to front therefore enhanced the transparent percept, but did not affect the coherent percept (during coherency the two plaids looked indistinguishable). The mean duration of the transparency and coherency epochs were measured over 60 sec trials. Results: For all eight observers, strengthening the transparent percept led to a shortening of the mean duration of the coherency epochs, without affecting the duration of the transparency epochs, in analogy to Levelt's result. This suggests that there may be general rules governing the dynamics of bi-stable perception. Specifically, it suggests a suppressive/inhibitory coupling between rivaling stimulus interpretations as a general principle in the brain. Our results also suggest that measuring the mean durations of the coherency and transparency epochs may provide a way to asses whether a given manipulation affected motion integration or motion segmentation processes, or both. To date such independent assessment has not been possible.

Abstract 468 B4.31

Figural contours and border-ownership constraint in binocular rivalry

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Binocular rivalry is typically studied with a dichoptic stimulus whose half-images have similar figural contour (eg square frame) but different internal patterns (eg horizontal vs vertical lines). But given the importance of figural contours in defining the perceived binocular surface shape, one needs to examine how figural contours affect rivalry. To show that figural contours promote rivalry dominance, we used a large (10x10 deg) vertical grating surface as the binocular background. (i) Upon this a 1 deg circular horizontal grating patch (figural contour) was added to one half-image. When this display was viewed, little rivalry was observed. Instead, a relatively stable horizontal patch was perceived against the larger vertical grating. (ii) But if a thin lined circle, or a circular illusory contour, was added to the other half-image corresponding to the circular patch, a vigorous rivalry ensued. Curiously, when (i) was repeated with a binocular background consisting of either a checkerboard or random dot texture with rich microstructure or local edge information, vigorous rivalry was observed. Thus, our findings suggest that monocular, real or illusory, figural contours can tilt the dominant rivalry percept, in favor of the image that owns the figural border. In a second experiment, we showed that such border-ownership constraint also applies to the typical rivalry stimulus. Capitalizing on the rivalry dominance-spreading observation (Blake et al, 1992; Wilson et al, 2001), we tested observers with a red horizontal grating (LE) and a green vertical grating (RE). A border-ownership constraint predicts that the small occlusion-valid areas at the figural contours of each half-image (LE: red at the right margin; RE: green at the left margin), as centers for dominance-spreading, will be more immune to rivalry suppression. Confirming this, our observers reported more dominance for the occlusion-valid areas for stimulus duration of 100 msec and longer.

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Abstract 469 B4.32

Feedback resolves ambiguous stimuli and mediates perceptual coupling

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Two ambiguously rotating objects with shared rotational axes tend to be perceived as rotating in the same direction. Last year we reported that the coupling between two objects is sharply reduced as one of the objects is made unambiguous. This finding is a problem for explanations of perceptual coupling based on either bottom-up cooperativity between similar representations, or based on the influence of top-down processing imposing scene constraints. Our model of grouping proposes that cortical feedback acts to resolve a percept from ambiguous or competing information, and that (i) the strength of feedback is proportional to the ambiguity in the visual stimulus, and (ii) feedback acts globally, consistent with neuroanatomical evidence that cortical feedback connections are largely divergent and less topographically specific relative to feedforward projections. This implies that perceptual coupling is a side effect of global feedback from a model of the object or scene that is evoked to assign an interpretation to the objects. Coupling is low between ambiguous and unambiguous objects because an unambiguous object elicits little or no feedback. This model is consistent with evidence that cortical feedback serves to improve figure-ground discrimination in situations where the stimulus has low salience (Hupé et al., 1998), and that attention to a particular property or feature in one part of the visual field results in a global priming effect for that property (Treue & Trujillo, 1999). One prediction of this idea is that viewing a partially biased ambiguous object generates greater feedback when the object is perceived as rotating opposite to its bias because stronger feedback is required to select and stabilize the percept that has weaker evidence. Thus, when a partially ambiguous object is perceived as rotating against its bias, the degree of rotational coupling

with an ambiguous object should be increased. This prediction confirmed in an experiment.

Abstract 470 B4.33

The rate of binocular rivalry -- Visual field asymmetries
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At the core of the binocular rivalry phenomenon lies the spontaneous alternation between the two percepts. Understanding what drives that alternation is a major and key part of understanding the neural basis of binocular rivalry. A starting point in this direction is to characterize the factors that determine the rivalry alternation rate. It is known that some stimulus factors (e.g., contrast) can influence the rate of rivalry, here we tested whether stimuli projected to different parts of the cortex have different rivalry rates. Is there a visual field asymmetry of the rivalry dynamics? Eight near peripheral locations were tested: two eccentricity levels (1 and 4 degrees) at the four major meridians. A red circular grating and a green radius grating were dichoptically presented to the two eyes. Observers were asked to track their perceptual experience by making keypress responses to indicate which of the stimuli came into view. Results from 10 observers (two authors and eight naive observers) show that the alternation rate in binocular rivalry is faster when the stimuli were presented to the right visual field compared to when they were presented to the left visual field. Similarly, rival stimuli in the lower visual field generated faster alternations than that in the upper visual field. There are a number of potential reasons that can lead to the observed rivalry asymmetry. For example, visual attention maybe biased towards the lower and the right visual fields, or at the site of binocular rivalry, the time course of neuronal responses could be faster for information from the lower and right visual fields than that from the upper and left visual fields. In any case, this visual field dependence suggests that the process of binocular rivalry is influenced by retinotopically specific mechanisms.

Perceptual Organization

Abstract 471 B4.34

Curvature and the Perceptual Organization of Texture Flows
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Locally parallel dense patterns - or texture flows - define a perceptually coherent structure important for image segmentation, edge classification, shading analysis, and shape interpretation. The classical psychophysics of texture flows is dominated by straight, exactly parallel patterns, in which orientation change is interpreted as a region boundary. We show how the geometry of texture flows extends this limited model by introducing two curvatures, one in the "tangential" direction and the other in the "normal" direction, and how these curvatures are naturally related to long-range horizontal interactions in primate V1 neurophysiology. The resulting model leads to psychophysical stimuli that demonstrate (i) amodal completion of texture flows and (ii) the coherence of flows with orientation changes and singularities. Thus not all orientation changes, and flow discontinuities, should be interpreted as boundaries. Implications for shading analysis are also developed.

Abstract 472 B4.35

Visual interpolation of sampled contours in three-dimensional space is local
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Observers interpolate sampled contours with high accuracy and little bias. Recent results support the claim that the human interpolation mechanism is local: it uses only the nearest points in interpolating across a gap in a sampled contour. We present experiments designed to test this hypothesis directly by measuring the influence of each point on interpolation of sampled parabolic contours in space.
Each sampled contour consisted of eight points that fell on an otherwise invisible parabolic contour. The binocularly-presented contour was constrained to be in the fronto-parallel plane or in a plane rotated 70 degrees from the fronto-parallel plane about a vertical axis. It subtended approximately 20 x 5 degrees of visual angle when the contour plane was fronto-parallel.
On each trial, observers adjusted a setting point, constrained to lie on an invisible setting plane orthogonal to the contour, until it appeared to lie on the contour. In certain trials, one of the fixed points on the contour was displaced by a small amount (4 min arc when in the fronto-parallel plane) in a direction orthogonal to the contour (either normal to the contour plane or in the contour plane). The influence of each of the eight fixed points was computed as the vector difference between the mean of 8 settings with that point perturbed and the mean of 16 unperturbed settings, divided by the magnitude of perturbation. We found that influence falls to zero very quickly with distance from the adjustable point. These results support the hypothesis that the human interpolation mechanism is local, involving as few as four points. Perturbations in the contour plane did not lead to systematic changes of setting out of the contour plane and vice versa. We show that, with such small magnitudes of perturbation, our influence measures serve as estimates of the Jacobian of the human visual interpolation system. Such measures sharply constrain possible models for human visual completion of contours.

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Abstract 473 B4.36

Illuminant complexity and grouping by proximity
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Rock et al. (Perception, 1992, 21, 779-789) showed that grouping can be computed post-constancy, after discounting a complex scene’s variations in illumination. Unpublished

studies by Kubovy and his co-workers have shown grouping among heterogeneous dots; hence, constant lightness is not a prerequisite for grouping. These experiments suggest that illuminant complexity can affect the discounting of variations in illumination. Our stimuli were rectangular dot-lattices presented at random orientations in a circular aperture. In these lattices |a| is the shortest inter-dot distance, which we held constant, and |b| is the second shortest inter-dot distance, which we varied. We convolved (a) lattices in which the dots and the background were of uniform luminance with (b) sinusoidal luminance gratings, while keeping the luminance ratio of background to dots constant at 1.2. The stripes of the gratings were parallel to the orientation of b. We used a high (3.37 c/d) and low (0.017 c/d) spatial frequency grating (while keeping the maximal change in luminance per pixel constant) to see if observers would disregard the sinusoidal "shadow." The observers were given a phenomenological 4AFC to indicate the grouping in the dot lattice, in three conditions: (i) no grating and (ii) high- and (iii) low-frequency gratings. Discounting did not occur with a high spatial frequency grating (grouping was biased by the orientation of the stripes), but it did occur with a low spatial frequency grating (grouping was not different from grouping in the no-grating condition). This suggests that a complex, non-monotonic, shadow cannot be "discounted," preventing constancy from occurring, whereas a monotonic shadow allows for post-constancy grouping. [Supported by NEI grant No. R01 EY 12926 to the University of Virginia.]

Abstract 474 B4.37

Areas involved in figure-ground segregation based on luminance, colour, motion, and stereoscopic depth visualized with fMRI.

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Figure-ground segregation is an important first step of visual object recognition. We compared the strength and distribution of cortical BOLD responses to the presentation of different figure-ground stimuli with that to homogeneous stimuli. The segregation was based on differences between figure and ground in either luminance, colour, motion or stereoscopic depth. In the case of colour- and luminance-based stimuli, figure and ground were either separated by an abrupt luminance or colour border or else defined by the arrangement of dots of different colour/luminance. Eight observers participated. Stimuli were presented by means of a video projector to the foot end of a Siemens Vision 1.5 Tesla scanner and flickered at 4 Hz. Stereoscopic stimuli were presented in red for the right and in green for the left eye and observers used red/green spectacles for this part of the experiment. Data were analysed using Brain Voyager software. Luminance and colour based figure-ground segregation were correlated with activation in both striate and extrastriate cortex. Motion- and stereo-based segregation, on the other hand, mostly activated extrastriate areas. So while figure-ground segregation based on different elementary features may share some common neuronal mechanism(s), a large part of activity for segregation not based on luminance or colour takes place in extrastriate areas, suggesting partly separate mechanisms for figure-ground segregation for different submodalities.

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Abstract 475 B4.38

Tests of a competitive interactive model of figure assignment

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Figure-ground perception arises from competition for ownership of a shared edge. Peterson et al. (2000) proposed that configural processes operating on opposite sides of an edge inhibit each other; inhibition of the more weakly cued side accounts for its status as a shapeless ground. Testing for inhibition, Peterson and Kim (2001) asked observers to decide if line drawing targets portrayed real or novel objects. Targets were preceded by unmasked novel silhouette primes. For half the real targets, the contours of the prime sketched a portion of the same basic level object on the ground side (primed targets). For the other half, the contours of the prime did not sketch a real object (unprimed targets). All the novel targets were unprimed. Object decision latencies were longer for primed than for unprimed real targets, consistent with the proposal that object memories matching the ground side of prime silhouettes were inhibited. However, it remained to be shown that when the same portions of real objects were seen as figures rather than as grounds in the primes, their memories were not inhibited, a necessary prediction of the model. We altered Peterson and Kim's (2001) prime silhouettes so that (1) regions seen as grounds were seen as figures and (2) half the primes portrayed portions of real objects, the other half portrayed portions of novel objects; prime type did not predict the target type. For both real and novel targets, primed trials were those on which prime type matched target type; unprimed trials were mismatches. For real targets, the match occurred at the basic level; for novel targets, the match occurred at the superordinate level. In Exps. 1 & 2, using different SOAs, object decisions for real targets were speeded on primed trials, whereas those for novel targets were unaffected by prime type, $p < .05$. In Exp. 3, we used masked primes and tested for priming when match and mismatch were defined semantically for real objects.

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Abstract 476 B4.39

Orientation modulates the effectiveness of amodally completed primes

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To further demonstrate that orientation affects amodal completion (Srebotnjak 1984; Sekuler 1994; Sgorbissa & Gerbino 1999) we studied how variable-duration primes (100, 400, 1000 ms) affect matching of simple patterns (crosses and fish-like polygons). Four primes were utilized: a modal cross; a shape that could be amodally completed as a cross (global completion with maximum shape regularity) or as a fish-like polygon (local completion with good continuation at T-

junctions); a modal fish-like polygon; a disk (unrelated to test patterns). According to the microgenetic approach (Sekuler & Palmer, 1992), amodal completion is favored only at long presentation times. Previous findings as well as the field model of visual interpolation (Gerbino & Fantoni, 2000) suggest that perception of a fish-like shape should occur only when orientation along cardinal axes supports the good continuation of T-junction stems. Primes and test pairs were shown in two orientations (x vs. +). A relative facilitation measure was defined to indicate an RT advantage for either global (crosses) or local (fish) test pairs. The effect of orientation on priming varied at different prime durations. Priming effects at short prime durations are consistent with detection and comparison of features, rather than on configural processing. Priming effects at long prime durations, when interpolation is complete, are consistent with the proposition, included in the field model of visual interpolation, that good continuation is more effective when T-junction stems are oriented along cardinal axes. In principle, the relative strength of local vs. global completions might depend on the differential effect of orientation on good continuation alone, regularity alone, or both. Present data do not allow us to reject any of such hypotheses.

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Abstract 477 B4.40

Contour grouping and the search for emergent features
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What causes visual contours to group into unitary configurations? And how can we tell when a pair of contours actually groups? Our approach looks for configural superiority effects (CSEs: better discrimination between contours when they are in the company of other, non-informative contours than when in isolation) and Garner interference (GI: worse discrimination between contours when they are in the company of other contours that vary in the presentation sequence, compared with contours that do not vary). Previous research (Pomerantz et al., 2001) supports this approach with two types of contours sets: adjacent curved lines differing in direction of curvature, and adjacent straight lines differing in orientation and position. To illustrate the former: compared with discriminating ")" from "(", perceivers are faster when a 2nd, identical contour is added alongside each curve; i.e., they are faster at discriminating "( )" from "))", which constitutes a CSE. Similarly, they are faster discriminating ")" from "((" when an accompanying but irrelevant contour always curves the same way compared with when it varies in direction from trial to trial, which constitutes GI. We extend this research to even simpler stimuli than straight and curved lines to explore the most elementary forms of grouping in vision. Specifically, we aim to demonstrate new CSEs (supplementing those above and also the well-known word- and object-superiority effects of Reicher and Weisstein & Harris). We also aim to identify the emergent features (EFs: properties of groups of contours that are not properties of individual contours, e.g., proximity, symmetry, or closure) that may underlie CSEs. Arguably the most primitive EFs are proximity and orientation, which emerge in a field containing only two dots and which may be more discriminable than are the features of either single dot. We propose some 16 EFs and present evidence from CSEs and GI that they play significant roles in human vision.

Abstract 478 B4.41

Contour Integration Across Attributes Occurs in Parallel, Within Attribute Maps
Frederic J.A.M. Poirier, & Barrie J. Frost Queen's University, Queen's University

Introduction. Multiple cues are often processed separately in different streams or modules, then integrated together. Integration theorists debate whether integration occurs in a "master map" (a dedicated brain area) or via connections between modules encoding separate attributes.
This experiment was a critical test of master area theories. Poirier & Frost (2001) previously found that orientation after-effects (OAE) transfer equally well to the same or different attribute pairs from adaptation pairs. Here, we measured the ability of the system to maintain opposite OAEs contingent on attribute pairs. Most master map theories do not allow for multiple OAEs within the master map.
Methods. We generated two vertically oriented gratings, each of the same spatial frequency, defined by changes in different attributes (luminance, color, texture, or motion). Then they were cut in horizontal strips, and interleaved with a ¼ phase difference (alternate strips contained a piece of grating defined by a different attribute). Global orientation of each single attribute-defined grating became ambiguous because it had ½ phase difference, but with integration across the two attributes, an unambiguous orientation was apparent.
A second similar display used the other two available attributes, and was oriented in the opposite direction. Participants adapted to both displays in temporal alternation within a trial, and were tested randomly with either attribute pair aligned vertically to see if they resulted in the OAE.
Results. Preliminary data shows that some participants could maintain simultaneously two OAEs in opposite directions, contingent on attribute pairs.
Discussion. These results are suggestive of adaptation within and between selected attribute maps rather than in a master map. We suggest a model where modules higher in the hierarchy receive already-integrated information from lower levels, and further processing can elaborate the pattern of integration.

Abstract 479 B4.42

The independence of counting and contrast
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The task of detection requires that at least one target component (i.e. "feature") be detected, while the task of identification requires the detection and integration of multiple features into a recognizable object. Enumeration seems to be an intermediate stage between feature detection and object identification. As in identification, it requires the detection of multiple features, but as in detection, it does not require the encoding of relative feature positions. As we count 1,2, 3…10, enumeration inherently seems to be a serial detection of items. However, when we enumerate briefly presented objects, we

have a capacity to accurately report 4-5 items. Enumeration within this range is called subitizing.
In subitizing, do we automatically spatially integrate features? Feature detection is dependent on contrast. As the visibility of the features is decreased the number of activated feature detectors is less. If subitizing only requires detection, then as we decrease the contrast, the subitizing capacity (4-5 items) should also decrease. However if the subitizing capacity is independent of contrast, it must be processed by a second stage of integration that is independent of the first stage of feature detection.
In order to determine whether subitizing requires feature integration, we measured accuracy as a number of Gabor patches presented at different contrasts. The Gabors were presented for 50 ms along an imaginary circle at 5 deg viewing eccentricity. We found that the maximum accuracy changed with contrast, but the subitizing capacity (4 items) is immune to the effects of contrast. This means that subitizing requires feature integration.

Abstract 480 B4.43

Underestimation of velocity after occlusion causes the aperture-capture illusion
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PURPOSE: In dynamic occlusion displays with an aligned rod that moves behind two misaligned windows, participants perceive the rod as being misaligned in the direction of the windows (the Aperture-Capture Illusion [ACI], VSS 2001; Hecht, 1924). Last year we presented evidence that the ACI is not caused by a misperception of velocity in the leading aperture. Here we present evidence that the ACI is at least in part caused by an underestimation of the velocity of the occluded portion of the rod. METHODS: In the first series of experiments, subjects viewed a horizontally translating vertical bar, whose top and bottom appeared sequentially through vertically separated and horizontally offset apertures. We manipulated the size and number of the windows to gauge their effect on the ACI. In the second series of experiments, subjects saw a horizontally translating dot move through an aperture and then disappear behind an occluder (cf. De Valois, VSS 2001). A vertical line was placed outside of the aperture along the dot's trajectory. After the dot disappeared, the line flashed and a beep sounded then subjects made a 2AFC decision about whether the dot would have been to the left of or to the right of the line at the time of the beep. RESULTS: In the moving rod experiments, the ACI was almost entirely eliminated by having many small apertures rather than two large ones. In the moving dot experiments, subjects consistently underestimated the velocity of the dot after occlusion. CONCLUSIONS: The ACI may arise from an underestimation of velocity after occlusion. This misperception of velocity after occlusion causes the portion of the rod seen through the leading window to appear closer to the aperture than it really is. In the moving rod experiments, having several small apertures allows for re-sampling of the moving rod's motion, improving perception of the rod's spatial position.

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Abstract 481 B4.44

The spatial perception of continuous curves with discrete light spot stimuli
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In depth perception studies, it has been observed empirically that a physically equidistant curve is not perceived as equidistant. An experiment is reported here regarding this perceptual phenomenon, in which discrete light spots on an arc of a circle appear to an observer at the circle's center as neither a continuous "egocentrically equidistant" curve nor a continuous "constant curvature" curve, whereas these phenomenal curves are perceived as different from each other. In spatial perception, a pair of parallel lines has two geometrical interpretations, "parallel" and "equidistant". Classical empirical phenomena such as the equidistant and parallel alleys suggest that these interpretations are respectively psychophysical entities that are different from each other and the physical entity. Similarly, an arc on a circle also has the above -mentioned interpretations, "egocentric equidistance" and "constant curvature". Are these interpretations also psychophysical entities? Our neural network model, the ISLES model, explains the phenomena of equidistant and parallel alleys as the results of developmental learning at each level of the psychometric scale. In this model, when the perception of parallelity is developmentally learnt from observations of physically parallel lines, the invariant is the order, and the psychometric scale for learning is an ordinal scale. When the perception of equidistance is learnt, the invariant is the interval, and the psychometric scale for learning is an interval scale. The ISLES model also predicts the difference between the phenomenal curves,"egocentric equidistance" and "constant curvature" in the same way. The prediction leads from only the hypothesis that the psychometric scale for learning curvature should be an ordinal scale whereas the psychometric scale for learning egocentric distance should be an interval scale. These results suggest the existence of homogeneous mechanisms in spatial perception of geometrical constancies.

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Abstract 482 B4.45

Dynamics of contour integration and segmentation
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Contour integration and contour segmentation are two opposite requirements of visual perception that presumably involve competitive processes. To study this issue, we used two collinear line-segments separated by a gap (35' and 8.8' of arc), translating clockwise or counterclockwise along a circular path, and measured the ability of human observers (n=13) to recover the direction of line-ends that signal contour discontinuities. Occlusion by invisible masks that partially covered the line-segments was used to measure direction discrimination independently for inner line-ends (ILE) and outer line-ends (OLE). The results –percent correct and response time- indicate that processing ILEs' motion takes longer (by 60 msec;

p<0.005) and yields more errors (by 18%; p<0.005) than processing OLE's motion. These differences are greatly reduced when line-segments are spatially offsets or are at an angle (60) to each other, suggesting they strongly depend on segments' alignment. Psycho-pharmalogical testing was then used to assess the contribution of inhibition to these effects, using Lorazepam, a benzodiazepine that facilitates the fixation of GABA on GABA-A receptors. Observers (n=16) were tested in the ILE and OLE conditions before, during and after an intake of Lorazepam (0.038 mg/kg). In top of an expected global sedative effect of Lorazepam –yielding lengthened response times and increased error rates-, processing the motion of ILE and OLE was differentially affected, suggesting that Lorazepam boosted inhibition biases the competition between contour integration and segmentation. A simple model, in which facilitation through long-range horizontal connections (contour integration) competes with short-range end-stopping (contour segmentation), is proposed to account for the data.

Abstract 483 B4.46

Oblique effects in grouping: Surprising individual differences

Michael Kubovy & Martin van den Berg University of Virginia

In our work on grouping by proximity we noticed effects of lattice orientation on grouping by proximity. In a systematic study of this phenomenon, 25 observers (Os) were presented with 30 repetitions of a hexagonal lattice (in which dots are equidistant along three orientations, 120 degrees apart) at all possible orientations. In a phenomenological 4AFC, Os chose one of four grouping orientations. The 900 trials of each O fell by and large into one of three categories: vertical orientations preferred over all others (V), horizontal orientations preferred over all others (H), and vertical and horizontal orientations preferred over oblique ones (VH). In a more detailed analysis we noted that although some Os' choices were stable, some varied considerably, gradually moving from category V to category H, and back. Our findings are consistent with the operation of two independent mechanisms of roughly equal strength involved in the processing of vertical information: (a) A vertical sensitivity mechanism (VSM), which makes us exquisitely sensitive to deviations from the vertical or to misalignments along the vertical. Increasing the activity of VSM would increase the likelihood V trials. (b) A vertical emphasis mechanism (VEM), which makes vertical lines look longer (and produces the V–H illusion). Increasing the activity of VEM would increase the apparent distance between dots along the vertical and decrease the likelihood of V trials. When VSM is stronger than VEM, V-trials will occur; when VEM is stronger than VSM, H-trials will occur; when VSM and VEM are in equilibrium, small and momentary fluctuations in their strengths could either lead to VH data -- or to fluctuations over time. [Supported by NEI grant No. R01 EY 12926 to the University of Virginia.]

Abstract 484 B4.47

Factors affecting contextual modulations of the Gestalt configural cues

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The Gestalt configural cues of convexity and symmetry affect the likelihood that a region will be seen as a figure as opposed to a background. In previous research, we found that the effectiveness of the configural cue of convexity increased as the number of convex regions in a display increased from 1.5 - 2.5 - 3.5 regions (Kim and Peterson, 2001). We observed these "context effects" even when perceived figure assignment was measured indirectly, when symmetry competed with convexity, and when observers were required to base their figure response on the regions closest to fixation regardless of the number of regions in the display (Peterson & Kim, 2001). We suggested that context effects might reflect long-range connections between units assessing region-wide convexity because the effectiveness of the convexity cue did not increase with the number of local convexities within a region. We now extend these investigations by examining whether or not the configural cue of symmetry is affected similarly by context. We also examine the extent to which context effects require that the cued regions be similar in color. In addition, we use a priming paradigm to investigate whether or not the context effects operate over a temporal gap.

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Abstract 485 B4.48

Transient stimuli alter perceptual organization

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More and more evidence seems to indicate that suddenly presented transient stimuli can alter the perceived organization of an already present stimulus. For example, Sekuler et al. (Nature, 1997, vol. 385, p. 308) showed that a sound presented near the point of coincidence can make two moving dots bounce instead of passing each other. Moreover, Shams et al (Nature, 2000, vol. 401, p 788) reported that observers saw multiple flashes whenever a single flash was accompanied by more than one beep.
In this study we looked at the effect of transient interrupts on ambiguous stimuli. Among these were the Necker cube and Wertheimer's 'windmill' (a cross that rotates in steps of 45 degrees, which is directionally ambiguous because the clockwise displacement equals the counterclockwise displacement). The results show that when a transient stimulus, like a suddenly appearing dot, a sound, or a change of color changes the perceptual experience completely. For example, The Necker cube inverses its perspective. Moreover, if Wertheimer's ambiguous windmill is tracked with attention – and as a result a clear motion direction is perceived - the direction reverses in the opposite direction as soon as the transient stimulus is present. These results show that interpretations given to ambiguous stimuli - that is, when the visual system has disambiguated the presented stimulus – are overruled in favor of a competing solution, even when the interrupting stimulus enters trough another modality.

Abstract 486 B4.49

Is there a right way up for vertical symmetry?
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Responses to vertical symmetry are quicker than responses to either horizontal or diagonal symmetric stimuli. However, within vertically symmetric stimuli, we demonstrate a preference for search for stimuli that are upright – where upright stimuli are defined by having a broad base. When participants have to search for vertical symmetry in multiple item displays, their responses are about 50 ms quicker when the items are upright, than when the items are upside down. There was no effect of uprightness in single item displays. The data suggest that 'uprightness' can serve as a guiding factor for visual attention, consistent with prior results indicating ecological constraints on search and visual selection.

Absract 487 B4.50

A wave-function integration of absolute and relative metric information in visual interpolation
Carlo Fantoni & Walter Gerbino U. of Trieste, Italy

Our field model (Gerbino & Fantoni, 2000; Fantoni & Gerbino, 2001) predicts that the interpolated trajectory between two T-junctions is affected by the size of the retinal gap. Kinetic occlusion displays indicate that interpolation is spatially as well as temporally local. When a diamond with partially occluded vertices undergoes a rigid size transformation, interpolated contours appear increasingly flattened as the retinal gap decreases, making the occluded diamond more and more similar to a disk. Observers estimated the perceived roundness of partially occluded diamonds in kinetic patterns proportionally reduced to a fraction (ranging between 95 and 55 %) of their initial size. Four values of support ratio were used (20, 30, 40, 50%). Data indicate that the perceived roundness of the occluded shape increases as a non-linear function of the amount of reduction. The roundness effect is modulated by the support ratio. As the support ratio decreases , the average roundness effects increases and its rate of convergence to the maximum increases. This trend is adequately explained by a wave function (WF) model described by a differential equation including reduction and support ratio as parameters. The flatness of the wave function depends exponentially on the support ratio. The WF model predicts psychophysical data on static and kinetic completion as well as the perception of curvature of totally specified forms, with 100% support ratio. The WF model provides a general solution to the problem of integrating absolute and relative metric information relevant to shape perception.

Abstract 488 B4.51

The effects of stimulus-driven attention on subjective organization
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Background: Perceptual organization results from objective (stimulus-driven) and subjective (task-driven) organization. Objective organization is derived primarily from bottom-up gestalt principles; subjective organization can be considered a top-down attentional process. In a localization search task, a Subjective Boundary Effect (SBE) indicates that performance is impaired when the target appears at locations adjacent to subjective boundaries, which are induced by the task instruction (e.g., report whether the target appeared on the left, middle or right three columns; Carrasco & Chang, 1995).
Goal: To pinpoint the level of visual processing at which the SBE is established, we investigated whether stimulus-driven covert attention would attenuate the SBE. We assessed the effect of a transient, peripheral pre-cue on overall performance in a localization task, and on the SBE, in particular.
Methods: In a 2-IFC task, observers searched for a tilted (45) line among vertical or horizontal distracters and indicated which interval contained the target. Prior to each interval, a pre-cue indicated either both target location and display onset (peripheral cue) or just the display onset (neutral cue). Subjective organization was controlled by instructing observers to parse the display vertically. Objective organization was reinforced using the gestalt principles of proximity, good continuation and color, and could either be parallel or orthogonal to the direction of the subjective organization. These configurations are known to minimize and maximize the SBE, respectively.
Results & Conclusions: There was an overall effect of attention, observers performed more accurately and faster in the peripheral pre-cue condition. The SBE emerged for all configurations of subjective and objective organization; however, the peripheral pre-cue did not attenuate the SBE. The resilience of this phenomenon suggests that the SBE is established in early visual processing.

Abstract 489 B4.52

Grouping of ambiguous objects requires vigilance
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Dynamic dot quartets (DDQs) appear to jump along the horizontal orvertical sides of an implicit square. The axis of motion is ambiguous and bistable, but an array of DDQs all appear to share a single axis of motion at any instant (Ramachandran and Anstis, 1983). To study the grouping of ambiguous objects, we exploited the fact that DDQs can be clamped into a definite perceptual state by manipulating the ratio of path lengths. In a typical experiment, all the DDQs in an array are clamped for several seconds, and then the aspect ratio is changed to one, and the post-clamp switching dynamics observed. Last year we reported that this procedure leads to an orthogonal axis aftereffect (OAE) with the following characteristics: 1. there tends to be a short latency post-clamp perceptual switch; 2. the OAE duration grows with increased adaptation; 3. the OAE is not retinally-specific; 4. Most observers cannot see simultaneous aftereffects following simultaneous orthogonal clamps. Together these imply that the OAE does not depend on adaptation of local motion detectors, but rather on an inferred global transformation. We now report that the OAE depends critically on attention. An attention-demanding task was added to the standard perceptual clamp experiment. Two seconds into the clamp phase a Landolt C appeared that switched among four orientations at 1 Hz and disappeared at the end of the clamp phase. Observers reported

the direction of the C when it was visible, and the DDQ axis otherwise. In control trials observers ignored the C and reported only DDQ motion axis. In these trials the OAE peaked 7-10 seconds into the test phase and disappeared within 20 seconds. In contrast, in trials with the attention-demanding C task, the OAE was completely abolished in all observers. The attention-dependence of the OAE supports the evidence from our previous experiments that the OAE depends on active invocation of a transformation of a scene model.

Abstract 490 B4.53

Perceptual saliency of points along the contour of everyday objects: A large-scale study

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In 1954, Attneave (Psychological Review, 61, 183-193) stated that the points along the contour where the curvature changes maximally (i.e., curvature extrema) are most informative about an object's shape and identity. Apart from two informal demonstrations by Attneave (one on a random shape and one drawing of a sleeping cat), no further research has been done to support this claim. In a large-scale study (N = 161) each subject received one of four matched sets of 65 outlines, presented one by one on a computer screen. Using a computer mouse, subjects had to mark as many important points along the contour as they wished. The outlines were derived from a standard set of 260 line drawings (Snodgrass, J.G., & Vanderwart, M., 1980, Journal of Experimental Psychology: Human Learning and Memory, 6, 174-215). We then applied a smoothing technique and a saliency threshold to the dataset to eliminate noise, and varied their parameter values to examine their effects. Curvature extrema were selected most frequently, with negative minima (m-) somewhat less frequently than positive maxima (M+), especially with a relatively large smoothing parameter. Inflections were almost never chosen as salient points. The distance from a marked point to its nearest neighbor curvature singularity was shortest for more salient points, and was generally shorter for m- than for M+ points. This result implies that m- points are easier to locate than M+ points on contours of everyday objects. We will also examine the role of more global shape factors influencing the saliency of a point on an outline shape.

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Abstract 491 B4.54

The processing of visual attributes in human visual cortex: an EEG study

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Although objects are usually defined by many different visual attributes (color, brightness, motion, or texture), these attributes are bound together to yield a unified and coherent perception. Two schemes are usually opposed to account for this phenomenon: One postulates that visual features are first analyzed by separate, independent populations of neurons within the first cortical visual areas, and that the different representations are recombined at a later stage to generate a coherent percept. The other holds that individual cells in the visual pathways can code for several stimulus dimensions simultaneously.

To test these hypotheses, we recorded the EEG of human subjects during an object detection task: The subjects had to detect a square embedded in an array of visual elements (the background). The square differed from the background either in color or in texture, and we compared the signals recorded in these two conditions. We recorded 32-channel scalp EEGs from 9 subjects to study whether changes in an object's visual attributes would be reflected in the spatial distribution of scalp potentials, a modification of the signals' temporal structure, or both. We used source localization algorithms and coherence analysis to analyze our data, and compared them to the subjects' behavioral results.

Our analysis of the spatial properties of the EEG responses has not revealed any significant difference between the two conditions. However, there does appear to be a difference in the latency of the evoked potential components. When equated as multiples of detection threshold, the potentials evoked by color-defined objects have a shorter latency than those defined by texture. Our results suggest that objects defined by either texture or color are processed within the same cortical areas, but that their perception is mediated by different neural circuits within these areas.

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Abstract 492 B4.55

Contiguity requirement of metacontrast masking depends on frame of reference

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Classical metacontrast masking requires test and masking stimuli to be spatially contiguous. This dependence suggests that the masking interaction occurs in a retinotopic cortical representation such as area V1. However, many other characteristics of metacontrast, such as the influence of attention, suggest a higher level for the interaction. To resolve this apparent contradiction, we examined whether contiguity is required in retinal coordinates or in an object centered frame of reference.

We measured the detectability (2AFC) of a 0.35 black test square presented 2 below fixation in the presence of 2 masking squares of the same size above and below the test square (28 ms presentation times, asynchrony 0, 28, 56, or 84 ms). Spatial selectivity was assessed by presenting the masking squares at various horizontal positions while the test square position remained fixed. The background was either a blank white screen or a 5 white square ("panel") that moved from left to right across the screen at 14 /sec. If retinal position is critical, the maximum of masking should always occur at the position of the test square. If the background is the critical frame of reference, the maximum of masking under the moving panel condition should be displaced to the right.

Strong masking was found for asynchronies of 28 and 56 ms. Eight out of 11 subjects showed sufficiently narrow spatial

tuning of masking to compare the peaks of masking with and without the moving panel. For 56 ms asynchrony 5 subjects showed a displacement to the right, 3 showed no change. For 28 ms asynchrony, none of the subjects showed displacement.

The displacement of the spatial masking functions indicates that metacontrast masking depends on the frame of reference in which test and mask are represented, suggesting that the interaction occurs at a higher level than the retinotopic visual cortex.

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Abstract 493 B4.56

Perceptual grouping into visual "objects": a detailed chronology
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This study seeks to discover which spatial relations among image elements (e.g., line segments or edges) tend to induce grouping, that is, cause image elements to bind together into perceptual "objects." Many candidates have been proposed: non-accidental properties such as collinearity, cotermination and parallelism; relatability; more global factors such as symmetry and skew symmetry; and many others. Empirical investigation of these factors has, however, been hampered by the lack of "objective" methods for determining the perceived organization of an image. The current research uses a new method for studying perceptual grouping, based on the finding that perceptual comparisons between two spatially separated probes are faster if the two probes lie on the same perceptual object (as in "object-based attention"). We use this effect to determine the degree to which two image elements are, in fact, "bound" or grouped together by the visual system. We conducted a large omnibus experiment testing the grouping strength of pairs of line segments in many spatial configurations, testing a wide variety of potential grouping factors, including collinearity, relatability, cotermination, parallelism, symmetry, skew symmetry, contact, geometric codimension, and others. We also varied the time (SOA) the configuration was presented prior to the appearance of the probes, allowing us to determine the time-course of the influence of each potential grouping factor. These data paint a detailed picture of the chronology of object formation, as the grouping percept gradually develops over the first few hundred milliseconds of processing. Generally, the data reveal that grouping begins with more local spatial relations (e.g. collinearity and relatability) and gradually spreads to more global or higher-order relations e.g. symmetry). Generally, grouping seems to be induced by the degree of "regularity" exhibited by the configuration,rather than by any one essential property.

Abstract 494 B4.57

Integration of local features into visual shapes in the human visual cortex
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The perception of visual shapes entails that local features are integrated into global visual forms. The human lateral occipital complex (LOC) has been implicated in shape processing. We tested whether the LOC is involved in the integration of local features into visual shapes using event-related fMRI at a 1.5T scanner. The stimuli consisted of a. random patterns; that is, displays of randomly oriented and positioned gabor elements and b. target shapes; that is, displays with a closed contour of collinear gabor elements embedded into a background of randomly oriented gabors. We observed stronger fMRI responses in the LOC for target shapes than for random patterns, suggesting that the LOC represents visual shapes and not simple image features. We further manipulated the detectability of the target shapes by varying the alignment of the gabor elements. Misalignment of the local gabors resulted in decreased target detection performance and fMRI responses in the LOC. In contrast, we observed improved detection performance and increased responses in the LOC when the segmentation of the target shapes from their background was facilitated by additional visual cues, such as motion or disparity. Our findings suggest that neural populations in the LOC are involved in the integration of local image features and the representation of visual shapes.

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Scene Perception

Abstract 495 B4.58

An fMRI investigation of visual preference habituation
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How does the brain assess the potential "interest" of a visual scene? Our research is aimed at understanding the neural basis of the motivational system underlying visual information acquisition that maximizes the intake of novel, but interpretable information. As a way of investigating this system, we have been measuring subjects' preferences for a variety of full color scenes and the effects of repeated exposure on their preference ratings. Previously, we reported that visual preference declines with repeated presentation for a wide variety of scenes of different initial preferences (OPAM, 2001). Our working hypothesis is that the gradient of enkephalin receptors in the ventral visual pathway (sparse in V1, dense in IT; Lewis et al., 1981) mediates visual and cognitive pleasure, producing a preference for those scenes that richly activate new associations in the anterior regions of the ventral visual stream. Competitive learning in these latter stages would result in less neural/enkephalin activity as a stimulus is repeated (see Miller et al., 1993), and thus reduce preference. In this study, we use event-related fMRI to investigate the changes in neural activity associated with initial scene preference and the decrease in preference over repeated exposure. Subjects were asked to view a set of 60 images presented for one second separated by a variable ISI. Each image was shown a total of five times over the course of the experiment. Using preference ratings collected from another set of subjects outside the magnet, we

grouped the scenes into high, medium, and low preference sets. We observed differential activity in occipitotemporal regions of the cortex associated with both preference level and exposure. We discuss these results in the context of whether visual preference is computed locally, and how this signal might be used to guide selective attention to areas of the visual world which contain novel, but interpretable information.

Abstract 496 B4.59

What do we see in a glance?
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OBJECTIVE. Prior studies have suggested that rapid visual recognition proceeds from course-to-fine spatial scales. Here we examine whether this holds for local recognition tasks and to what degree this processing can be understood in the spatial frequency domain. METHOD. We adapted the priming method of Tjan et al. (1999). In the test phase, subjects were briefly presented with colour images of natural scenes, each divided into 64 100x100 pixel subimages, and preceded and followed by 1/f colour noise masks. In the first condition, test images were presented intact; in a second condition the 64 subimages were randomly scrambled. After each test image, subjects were shown 2 subimages and asked to indicate which was drawn from the test image. QUEST was used to estimate the test image stimulus duration for 82% correct performance. RESULTS. Expt.1 compared subimage recognition for intact and scrambled test images. Scrambling was found to increase the stimulus duration required for local recognition. Thus global information plays a major role in fast scene recognition, even for local scene components. In Expt.2, test images were masked in a checkerboard fashion, so that only alternate subimages were visible. We found that recognition was independent of whether the test subimage had been visible or masked. Thus fast recognition appears to depend upon local information only insofar as it contributes to the global statistics of the scene. Expt.3 compared recognition for normal images and images inverted in both orientation and contrast. Inversion was found to significantly degrade recognition performance. Moreover, for inverted images, the effect of scrambling disappeared. Since the spatial frequency spectra of normal and inverted images are essentially identical, these results suggest that coarse-to-fine analysis in scene recognition cannot be understood in the spatial frequency domain. Rather, fast scene recognition appears to depend upon more semantic global information.

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Abstract 497 B4.60

Depth perception from familiar scene structure
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In the absence of cues for absolute depth measurements as binocular disparity, motion, or defocus, the absolute distance between the observer and a scene cannot be measured. The interpretation of shading, edges and junctions may provide a 3D model of the scene but it will not inform about the actual 'size' of the space. However, observers have no problem in estimating the absolute depth of an image.

To evaluate the ability of subjects to estimate the mean depth of a scene from monocular information we run two experiments: First, ten subjects were asked to evaluate the mean depth of 500 pictures (covering the full range of depths; from close-up views of objects to panoramic views of large open spaces). For man-made scenes, the percent of pictures with an error in the interval of one decade with respect to the mean was 85%. For natural scenes, results were poorer: 67%. Second, we evaluate depth estimation in a ranking task. Ten subjects were asked to order 20 sets of 9 pictures each according to their mean depth. The rank correlation between subjects was 0.97 for man-made environments and 0.84 for natural scenes. The results show that different subjects provide almost identical orderings with pictures of man-made structures. Subjects performed significantly better with man-made than with natural scenes.

One possible source of information for absolute depth estimation is the image size of known objects. However, this is computationally complex due to the difficulty of the object recognition process. Here we propose a new source of information for absolute depth estimation that does not rely on specific objects: we propose a computational procedure for absolute depth estimation based on the recognition of the scene structure. The model, using a holistic representation of the scene, provides similar results to human performances (correlations between rankings provided by the algorithm and by subjects are 0.88 for man-made environments and 0.81 for natural environments).

Abstract 498 B4.61

Scene Classification and Parahippocampal Place Area Activation in an Individual with Visual Form Agnosia
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Purpose: Color information is more important for quickly and accurately classifying natural scenes when color is predictive of scene category (color-diagnostic) than for classifying man-made scenes (color-nondiagnostic). Color-diagnostic (CD) scenes are classified faster when presented in the appropriate color than when colors are inverted (hues inverted 180 in color space), while classification of color-nondiagnostic (CND) scenes is unaffected by color inversion (Oliva & Schyns, 2000). We asked whether an individual with visual form agnosia, who has a profound deficit in object recognition but spared color perception, could classify scenes and, if so, whether appropriately colored CD scenes would be classified faster and more accurately than color-inverted scenes. We also used fMRI (4 Tesla) to determine whether viewing different scene colorations produced differential levels of activation in the parahippocampal place area (PPA). Methods: Subjects included DF, a 45 yr old woman with profound visual form agnosia, and normal control subjects. fMRI data were collected using a block design including faces and different scene colorations.

Results: DF was able to classify scenes accurately but with high error rates for black & white scenes. Controls showed slowed classification for color-inverted scenes only when the scenes were CD. However, DF showed slower classification for color inversion for both CD and CND scenes. In all observers, viewing scenes produced greater activation in the PPA than did viewing faces, regardless of scene color content. Conclusions: The results demonstrate that an individual with visual form agnosia can readily classify scenes and this ability is reflected in activation within the PPA. For DF, color information is important for fast and accurate scene classification whether or not color is predictive of scene category. Furthermore, in both controls and visual form agnosia, PPA activation appears to be unaffected by scene color content.
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Abstract 499 B4.62

Priming layout of mixed scenes: Evidence of non-semantic, locally organized layout representations?
Thomas Sanocki, Kim Swartz, & Eric Sellers University of South Florida

The immediate priming paradigm can be used to examine how the brain represents scenic layout. A prime picture of a scene is presented for one sec, followed by a brief blank interval, and then a target picture of the scene. Two spatial probes are superimposed on the target and observers make a speeded spatial relations judgment about them. Spatial processing of the target is typically speeded by the prime, relative to controls. We infer that the prime activates a representation relevant to the spatial processing of the target. This representation is broad, fairly detailed, and somewhat high-level, being unaffected by changes in image position and other sensory details (e.g, Sanocki & Epstein, 1997, Psychological Science).

The prime-induced representation could be a scene schema—a network defined by relational information such as spatial relations among objects and surfaces, or by semantic relations such as belongingness. If so, primes should be much less effective when spatial or semantic relations are disrupted.

In the present experiments, we disrupted such relations by cutting the scenic pictures in half and switching the halves. Thus, spatial relations in the middle of scenes were disrupted by interchanging right and left halves (Experiment 1). Semantic relations were disrupted by mixing scene-halves, producing, e.g., a pool/basement scene (Experiment 2). Within each trial, the two sides were constant from prime to target. The spatial relations judgments were local to one or the other half.

Surprisingly, we found that observers were as effectively primed with the mixed stimuli as with normal stimuli. Observers could represent and use primes that were locally organized within halves but inconsistent spatially or semantically between halves. Local spatial organization was indeed critical: When halves switch right and left position between prime and target, the priming effect does not occur (Experiment 3).

Abstract 500 B4.63

Memory for an edge includes figure and ground assignment.
Mary A. Peterson and James T. Enns University of Arizona, University of British Columbia

Do memories of figures code the exclusive assignment of the bounding edge to one side or do they preserve evidence that both sides of the edge were assessed for figural status? A priming task adapted from Driver and Baylis (1996) examined shape memory following a single exposure to a novel figure. The prime was a small yellow figure displayed on the left or right side of a larger red ground with a crenellated edge separating figure and ground regions. Observers viewed the prime, without making any response, and then made a speeded same-different discrimination regarding two probe shapes that were shown one above the other, either facing in the same direction as the figure prime (figure probes) or the opposite direction (ground probes). On experimental trials, at least one of the probe shapes had the same crenellated edge as the prime (different response) or both did (same response). On control trials neither of the probe shapes had the prime's crenellated edge. In Exp. 1, the prime was exposed for 180 ms, followed by a 500 ms blank screen, and then the probes. In Exp. 2, the prime was exposed for 129 ms, followed by a 129-ms mask and then the probes. In both experiments, observers were faster to respond to experimental figure probes and slower to respond to experimental ground probes than to comparable control probes, $ps < .001$. This result goes beyond previous studies in showing that the memory for an edge includes more than the assignment of the edge to one side (positive figure priming); it also includes memory for the abandoned assignment of the same edge to the opposite side (negative ground priming). We refer to this as memory for the "edge complex," because in addition to the shape of the crenellated edge, it includes information about which side of the edge was seen as figure vs. ground. These findings reveal the dynamics of figure-ground assignment in the absence of shape familiarity, since they were evident following a single exposure to a novel shape.

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Abstract 501 B4.64

The effects of scene inversion and negation on change detection
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Previous research has shown that inverting and negating scenes can affect recognition memory for pictures. Our research focuses on the effects of inversion and negation on the ability to detect changes in scenes. Subjects were shown two successive presentations of a scene, separated by a blank interval. The subjects' task was to determine whether any object in the scene changed between the two presentations. Scenes were presented in one of four formats: normal, inverted, negated, or both inverted and negated. When the initial preview time was 500 msec, inverting and/or negating scenes significantly reduced subjects' change detection accuracy as compared to normal format presentation. Accuracy levels for scenes that were inverted, negated, or both inverted and negated were not significantly different. Errors were the

result of either failing to detect any change in the scene, or of misidentifying the object that changed. Overall, 58% of errors were due to failure to detect the change and 42% were due to object misidentification. Scenes which were negatedresulted in the highest percentage of misidentified objects, suggesting that negation interfered more with object identification than any of the other transformations. The effects of inversion and negation were a function of the amount of time the subject had to view the initial scene - when the initial preview time was increased to 1500 msec, all effects of inversion and negation were eliminated. Future experiments will investigate the influence of presentation time in further detail.

Abstract 502 B4.65

As good as it gets – testing a bayesian model of transsaccadic change blindness

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During fast or saccadic eye movements human perception of stimulus shifts is poor. This phenomenon is called “transsaccadic change blindness for displacement”. Employing neural network simulations, we have recently shown that even if the brain optimally used all signals available for shift perception it would exhibit change blindness. This concept predicts that the accuracy of the nonvisual eye position signal should inversely influence change blindness. To test our hypothesis, we asked seven subjects to perform horizontal and vertical saccades toward target stimuli that shifted either parallel or orthogonal during the saccade. As will be presented at the meeting, our results conformed the predictions of the model. This corroborates the view that change blindness reflects a mechanism of Bayesian inference from the noisy signals available in the brain and from the probabilities of the events underlying these signals.

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Abstract 503 B4.66

Anisotropic processing of natural scenes depends on scene content

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Purpose: Human visual sensitivity for high spatial frequency stimuli, varies as a function of orientation, with lowest sensitivities at oblique orientations (i.e. the oblique effect). However, we have recently shown (ARVO, 2001) that with stimuli of broadband spatial content (either noise or natural scenes), performance is worst at horizontal, best at obliques, and intermediate at vertical orientations. Here, we investigate this "horizontal effect" with images of outdoor scenes that were dominated by scene content of one of four orientations (0 , 45 , 90 , or 135) to determine whether the orientation of the predominant content (i.e. semantic content and/or phase relations) altered the ability to detect oriented structure. Methods: Sets of natural scenes were selected on the basis of having predominant content (Fourier amplitude) at one of the four orientations, and a fifth set of non-oriented content. The orientation bias in amplitude was removed by filtering the images to be isotropic. Ability to detect an added increment of amplitude (within an orientation band) at one of the four orientations was measured for the five scene types. Stimulus presentation was 400 msec followed by a noise mask and d' was calculated. Results: Regardless of the orientation of the content bias depicted in the original scene, the ability to detect an oriented increment was poor for the horizontal orientation, as reported previously. However, performance was worst for the orientation of the test increment that matched the natural scenes' bias, even though the amplitude bias had been removed prior to testing. Conclusions: We attribute the horizontal effect to an orientation bias inherent in the visual system's processing of broadband stimuli that may have evolved to discount the horizon thereby emphasizing other content. The present results suggest an additional orientation bias that is related to the phase spectrum (or semantic meaning) of the scene.

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Abstract 504 B4.67

Automatic line-drawings extraction from complex scenes

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Line drawings contain most of the shape-related information in complex scenes. From a technical standpoint, however, automatic extraction of line drawings from raw images has proven extremely difficult, primarily because shape contours are influenced by widely dispersed visual features acting in subtle geometric combinations. To address this problem, we developed a recurrent network architecture inspired by the interconnection circuitry of primary visual cortex, which incorporates several representational biases tailored to the task of long-range visual contour integration. A learning scheme was used to train the modifiable parameters of the network to capture the statistical regularities of contour shape. Two separate inhibitory subsystems, one feedforward, one feedback, modulate contour predictions. We find that when the trained network is applied to complex images, well-organized contours are selectively boosted and texture edges are selectively suppressed, leading to a rough line-drawing-like sketches of the visual scene.

Abstract 505 B4.68

The role of object stability in change blindness and change blindness blindness

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People are poor at detecting changes in their visual environment (change blindness). In addition, people predict they will notice more changes than they actually do (change blindness blindness). Here we explore whether change blindness, and possibly change blindness blindness, is affected by object stability. Object stability refers to the plausibility or probability that an object will change from one moment to the next. For example, it is plausible for a red car to be at a stop

sign one moment and a silver car the next moment (unstable object change), but implausible that there will be a stop sign at an intersection one moment and then a yield sign the next moment (stable object change). In Experiment 1 we asked participants to detect changes (to stable or unstable objects) in naturalistic scenes. Participants were better at detecting changes for unstable objects than for stable objects. In addition, we asked whether observers are blind to the role stability plays in change detection. In Experiment 2 participants viewed the same scenes as in Experiment 1, and judged whether they would detect each of the changes. In contrast to change detection findings, observers predicted better change detection for stable objects than unstable objects. This inaccurate belief may explain why there are different levels of change detection for stable and unstable objects. If subjects expect relative ease in detecting changes to stable objects they may focus on these objects less closely, thus leading to increased change blindness for stable objects.

Self-Motion

Abstract 506 B4.69

Responses to heading stimuli in macaque VIP
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Higher-order areas in the "motion system" of dorsal extrastriate cortex have been implicated in the analysis of "optic flow" stimuli, which can support perception of observer heading. The ventral intraparietal area (VIP) is near the top of this system, receives dense input from areas MT and MST, and has briskly directional visual responses to optic flow stimuli. Furthermore, visual responses in VIP can encode stimuli in "head-centered" coordinates, suggesting integration of eye position and visual inputs. Such integration would be particularly useful in recovering heading in the presence of gaze rotation caused by smooth pursuit eye movements.

In a preliminary test of the role of VIP in optic flow and heading perception, we measured the responses of VIP neurons to a battery of optic flow stimuli, including linear motion, complex ("spiral space") motion, and heading stimuli simulating a range of observer motions varying in the horizontal plane. Heading stimuli simulated observer translation towards a cloud of points in 3 dimensions, and subtended about 70 by 50 degrees of visual angle. The range of headings was centered over the cells' RFs, and responses were measured with and without superimposed horizontal smooth pursuit.

Most VIP responses are significantly modulated by varying horizontal heading. Typically, tuning is monotonic and sigmoidal across the range of headings tested. The shift of this tuning in the presence of smooth pursuit is very modest, indicating nearly complete compensation for smooth pursuit eye movements. Our results suggest that VIP is involved in heading perception and in the compensation for observer-caused gaze rotations.

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Abstract 507 B4.70

Pursuit adaptation alters perceived head-centred motion
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Following prolonged unidirectional smooth pursuit, a stationary, fixated test appears to move in the opposite direction to the adapting eye movement. The site of the adaptation is almost certainly extra-retinal and thought to be a consequence of the suppression of pursuit afternystagmus (Chaudhuri, 1991, Vis. Res. 31, 1639-1645). We investigated the effects of pursuit adaptation on perceived motion during an eye movement, since this is a judgement mediated by extra-retinal, eye-velocity signals. In the adaptation phase, observers pursued a small target for 60s as it made 60 unidirectional sweeps across the central 8 of the screen. Each trial in the test phase comprised a single test sweep during which a global motion pattern was displayed for 500ms, followed by 6 top-up adaptation sweeps. The test sweep was either in the same or opposite direction to the adapting eye movement. The global motion pattern was made up of signal and noise dots and observers were instructed to judge the overall direction of the dot pattern with respect to the head. Coherence (% signal dots) was controlled by a staircase which converged on the point at which the dot pattern appeared stationary on the screen. Results showed that at this null point, the retinal motion of the signal dots was opposite to the accompanying pursuit. Compared to a no-adaptation baseline, coherence was set lower following pursuit adaptation in the same direction as the test sweep. Conversely, coherence was set higher than baseline when the pursuit adaptation was opposite to the test sweep. This was true for both horizontal and vertical pursuit conditions. The results suggest that extra-retinal, eye-velocity signals decrease following pursuit adaptation in the same direction as the test sweep, but increase following pursuit adaptation in the opposite direction. This may arise from the need to suppress pursuit afternystagmus during the test sweep.

Abstract 508 B4.71

Do enriched visual displays improve infants' discrimination of optic flow patterns simulating self-motion?
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Both a looking time habituation and a modified forced-choice preferential looking (FPL) technique indicate that infants younger than six months of age discriminate optic flow patterns that simulate only large (>20º) changes in the direction of observer-motion along a simulated ground plane. Two experiments were conducted to examine whether infants' sensitivity differs under display conditions where information about heading direction and motion in depth is enriched. In Experiment 1, 3-, 4-, and 5-month-old infants were tested using FPL to measure discrimination between optic flow displays that simulated translation at 5 m/s along different trajectories of motion (12-90º) through a cloud-like pattern of random dots that filled two 15º (H) by 30º (V) regions at the 90 cm viewing distance. In Experiment 2, 3- to 6-month-olds were tested using similar techniques but with visually rich displays generated using a 3D animation rendering system. The displays incorporated visual cues to depth and direction change such as optic expansion, texture gradients, horizon cues, accretion and deletion of contours, and motion parallax. The

data from both studies confirm the previous findings that heading direction discrimination thresholds are large (20-70º) in young infants and decline only modestly with increasing age. Enriched visual displays do not result in substantially lower discrimination thresholds relative to previous reports of responses toward ground plane patterns. Consequently, the relatively poor discrimination abilities found previously appear not to be due to specific display-related factors, but instead may reflect a diminished sensitivity to changes in the direction of self-motion that are specified by visual information.

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Abstract 509 B4.72

Visually-perceived eye level with reversible pitch stimuli

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Visually perceived eye level (VPEL) and perceived pitch were measured while subjects viewed two sets of stimuli that were either upright or pitched top-toward or top-away from them. The first set of stimuli, a pair of vertical lines, caused systematic changes in perceived pitch and upward and downward VPEL shifts for the top-toward and top-away pitches, respectively. Neither the perceived pitch nor the VPEL measures with these stimuli differed between monocular and binocular viewing. The second set of stimuli was constructed so that when viewed at the appropriate pitch angle, the slopes of the lines in the retinal image of each stimulus were similar to those generated by a pair of vertical lines pitched symmetrically in the opposite direction. When viewed monocularly, these stimuli appeared pitched in the direction opposite their physical pitch, yet produced VPEL shifts consistent with the direction of their physical pitch. These results clearly demonstrate a dissociation between perceived pitch and VPEL. The same stimuli, when viewed binocularly, appeared pitched in the direction of their physical pitch and caused VPEL shifts consistent with this pitch direction. The retinal images of these stimuli, however, corresponded to those of vertical line stimuli pitched in the opposite direction. This finding is therefore inconsistent with the hypothesis that VPEL is determined solely on the basis of the orientation of lines in the retinal image.

Abstract 510 B4.73

Effects of terrain-texture resolution on the perceived speed of simulated self-motion

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We investgated the effects of terrain-texture resolution (spatial frequency bandwidth) on the perceived speed of simulated self-motion. To do so, we used a set of random processes to create a “base” texture with features that varied in size, orientation, and intensity. This texture was then subjected to two low-pass filters with different cutoff frequencies. When the resulting high- and low-resolution textures were mapped to flat terrains using standard bilinear-magnification and mipmap-trilinear-minification filters, the spatial patterns on the near terrains differed while those on the distant terrains were virtually identical. To assess speed perception, we used a 2IFC method of constant stimuli in which one temporal interval contained a 1-s standard motion sequence and the other contained a 1-s test motion sequence. Three standard speeds were presented in separate blocks. For each standard speed, the log relative test speeds ranged from -0.10 to 0.10, in steps of 0.05. Given the 60-Hz update rate of the image generator, over half of the spatialtemporal frequencies in the high-resolution, near terrain were temporally aliased at the highest standard speed.

We found that when the textures in the standard and test sequences were the same, the speed discrimination threshold was lower for the high-resolution texture than for the low-resolution texture. When the standard and test textures differed, the two psychometric functions were displaced by approximately ±0.07 log units, respectively: Simulated motion over the high-resolution texture appeared faster than simulated motion of the same speed over the low-resolution texture. The magnitude of this effect varied little with standard speed. In contrast to previous research (Lindholm et al., 1993), only 2 of the 6 observers showed an increase in perceived speed clearly attributable to temporal aliasing.

Abstract 511 B4.74

Judging perceptual stability during active rotation and translation in various orientations

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Translation and rotation are detected by different patterns of optic flow and by different divisions of the vestibular system. A given movement (eg. yaw rotation or up/down translation) involves different sensors depending on the orientation of the movement with respect to gravity. Here we assess the contribution of these different sense systems to the "whole system" response to self motion. Our subjects' task was to distinguish self produced from external visual motion during rotation around the yaw, pitch and roll axes and during translation in the x (naso-occipital), y (sideways) and z (up and down) directions. The axis or direction of motion was parallel or orthogonal to the direction of gravity.

Subjects wore a helmet-mounted display whose position was monitorred by a mechanical head tracker with minimal lag. The visual display was modified in response to head movement. The ratio between head and image motion was varied randomly using the method of constant stimuli. Subjects indicated whether the display appeared earth-stationary or not.

For both rotation and translation there was a large range of ratios that was tolerated as perceptually stable. The ratio most likely to be accepted as stable corresponded to visual motion being faster than head motion. For rotation there were no consistent differences between yaw, pitch or roll axes and the orientation of the axis relative to gravity also had no effect. For translation motion in the x direction was on average matched

with less visual motion than y or z motion. Although there was no consistent effect of whether motion was parallel or orthogonal to gravity, posture, relative to gravity, did have an effect.

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Abstract 512 B4.75

Extracting self-created retinal motion

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INTRODUCTION. Self movement generates retinal movement that is perceptually distinct from other movement. There are two types of models for how this distinction might be achieved. In the first, after self motion is detected, an internal estimate of the expected retinal movement is subtracted (a linear process) from retinal image movement. Remaining movement is interpretted as indicating external movement. In the second model, subjects internally compare observed visual motion with their internal representation: a non-linear ratio judgement which depends on the magnitude of the expected movement. A discriminable difference indicates external movement. These models respectively predict linear and non-linear distributions of the probability of regarding a given retinal motion as perceptually stable. METHODS. Our subjects' task was to distinguish self-produced from external visual motion during rotation around the yaw, pitch and roll axes and during translation in the x, y and z directions. They wore a helmet-mounted display whose position was monitorred by a mechanical head tracker with minimal lag. The visual display was modified in response to head movement. The ratio between head and image motion was adjusted by the subject until the display appeared earth-stationary. RESULTS. The distribution of ratios judged to be perceptually stable were fitted with a normal and a log normal distribution. For the rotation data a better fit was found using the log normal distribution suggesting that the non-linear ratio model is a better description of the underlying neural computations involved. No clear difference was found for the translation data.

Sponsored by CRESTech and NSERC.

Abstract 513 B4.76

The effects of color coding and attentional selection on perception of heading with transparent optical flow

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Superimposing two transparent, radially-expanding optical flow fields with distinct foci of expansion (FOE) produces systematic misperception of one's heading direction (Dyre, Richman, & Fournier, 2000, ARVO). We examined whether coding flow fields in distinct colors mediates this misperception pre-attentively or through attentional selection. Observers viewed simulations of translation through two independently-moving rigid volumes of randomly spaced dots. The heading directions specified by the judged and non-judged flow fields (FOE and FOE′) were separated horizontally by 0-16 deg. Some displays had red dots assigned to one flow field and green dots to the other; other displays had red and green dots mixed across both flow fields. Exp. 1 provided no instructions about the colors of the dots; Exp. 2 instructed observers to attend all the dots, or just the red or green dots, but provided no information about color assignment. Observers reported the perceived direction of FOE and whether they perceived one coherent flow field or two transparent flow fields. Separations ≤ 4 deg. most often resulted in coherent motion; those > 4 deg. most often produced transparent motion. Neither color assignment nor attentional instructions affected the number of flow fields perceived. Repulsion errors of the perceived FOE direction away from FOE′ accompanied transparent motion. Color assignment alone did not affect repulsion errors, but directing attention to one flow field unique in color significantly increased repulsion errors and even produced repulsion errors for trials where coherent motion was perceived. In contrast, for trials where attention was directed to both flow fields and coherent motion was perceived, heading errors of attraction toward FOE′ occurred. These results suggest that misperception of heading with transparent optical flow is due to both motion contrast and induced motion, and that attentional selection by color enhances the contribution of induced motion.
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Abstract 514 B4.77

Blind subjects explore and navigate the visual world using video images encoded in musical form

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Purpose: To enable blind subjects to explore and navigate the visual world with reasonable confidence. Blind subjects need the same information as a sighted person, about FORM, SPATIAL location, and MOTION in order to explore and move about their environment with confidence. Without vision, information about (i) form is usually acquired through touching 3D objects situated within arms length or (ii) spatial location which is usually limited to the range that is covered through the use of the guide cane etc. Motion perception is difficult without vision, unless the target is a sound source, or the subject uses an echo-locating device. The advantage of vision is that it is a distance sense where visual images provide most of the information on form, location and movement required to explore and navigate the environment.
Method: We have developed a method that allows the subject to segment, and isolate selected features from video images of natural scenes that are pertinent to the perception of visual forms, (ARVO 1998. 2000, Proc. Roy.Soc.B. vol.266 p.2427, 1999 vol 267.p2231), distance, and motion. These are encoded in musical form and the subject can listen to each in isolation or in combination. Blind, previously sighted subjects (lacking light sense), and blindfolded sighted subjects were given the task of locating and identifying a number of visual targets, randomly distributed about the laboratory. For instance, one task required them to locate a football (soccer) and goalposts,

walk up to the football and kick it into the goal, which they could do quite easily.
Conclusion: Using a combination of feature extraction, image segmentation, and other strategies: looming, parallax etc blind previously sighted subjects are able to accomplish tasks that sighted people take for granted.

Spatial Layout

Abstract 515 B4.78

Optic flow influences the visually perceived eye level
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As one walks forward in the visual space, an optic flow field is generated with its focus of expansion (FOE) centered at one's physical eye level (Gibson, 1950; Warren, 1998). Yet, it is uncertain if optic flow helps define the visually perceived eye level. To investigate, we measured perceived eye levels when viewing an optic flow field consisting of a volume of 150 dots (30 x 6 x 6 m) moving at a constant speed of 15 m/s, that was generated in a virtual environment (V8-HMD/IS-600/SGI). When the FOE was set at 15 deg below the physical eye level, perceived eye level was 6.1±1.7 deg (n=6) below the baseline. We then adapted observers to this optic flow field (FOE-15 deg down) for 25 minutes. Subsequent measurements performed outside the HMD in a dark room revealed a downward shift in visually perceived eye level of 4.1±0.8 deg. Perceived object location in the dark (measured by asking observers to walk blindly to the target and then gesture the remembered height) was systematically affected – object locations (3.75 and 5 m, placed either on the floor or 0.5 m above) were judged as farther and higher by an average angular declination error of 2.0±0.3 deg. Together, these experiments further confirm that the eye level is used as a reference for judging target locations in the dark (Ooi et al, 2001), and is shifted downward as an aftereffect of adaptation to an optic flow field with lowered FOE. Equally significant, our findings indicate that optic flow information partly contributes to the synthesis of one's visually perceived eye level, which is used as a reference for the perception of direction as well as distance.

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Abstract 516 B4.79

A ground surface based space perception in the virtual environment
Bing Wu, Zijiang J. He, & Teng Leng Ooi U. of Louisville, USA, Southern College of Optometry, USA

The ground surface can be used as a reference frame for coding object location (Gibson, 1950; Sedgwick, 1986). Confirming this, Sinai et al (1998) found that humans make errors in judging distance when a continuous ground surface information is disrupted. Their study was conducted in the real world where it is difficult to control for aberrant environmental variables, particularly those on the ground surface. Here, to obviate the problem, we used a virtual reality system (V8-HMD/Intersense/SGI) to measure absolute distance judgment in three ground conditions: (i) gap - target placed on the far side of a gap in the ground (2-8 m in depth, 0.5-2 m deep); (ii) texture discontinuation - target placed on a cobbled stone texture that was flanked by grass texture, and vice versa; (iii) occlusion - target placed on the grass beyond a brick wall whose dimension was 0.5 (height) x 1 (depth) x 5 (width) m. For each condition, observers viewed the test target (5, 7, 9, 11 m) with the HMD, judged, and remembered its absolute distance. They then turned 180 deg to face a matching object on a continuous ground surface, and perceptually matched the distance of this object with the remembered distance of the test target. Further, to reveal the impact of self-motion on distance judgment, these tests were conducted both with the head-tracker turned on and off. Overall, we found that compared to baseline (continuous ground), observers significantly overestimated distance in the gap condition, while underestimated distance in the texture discontinuation and occlusion conditions. And interestingly, for the gap condition, observers showed significantly larger overestimation errors with self-motion feedback in the scene. Thus, our current study in virtual reality not only confirms Sinai et al in the real environment, but also points to the effect of self-motion in space perception.

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Abstract 517 B4.80

Posterior Visual Space Perceptual Distortions in Ecological Applications
Martin Voshell & Flip Phillips Skidmore College

Purpose: The goal of this research is to extend upon our initial findings (Phillips and Voshell in these proceedings) regarding distortion in the static structure of posterior visual space. Our initial experiments led us to believe that there are perceptual biases in given situations to consistently underestimate and overestimate direction. Continuing upon this vein of external validity in the lab, we immersed observers in more realistic and ecological situations of posterior direction estimation.

Methods: A virtual field was projected onto a screen and artificial pylons were randomly placed in the field. Pylon location varied in depth and lateral positioning. In the first experiment observers were instructed to freely use either shoulder in their pointing task. In the second experiment, observers were instructed to position the automotive mirror as they would in a car and then to proceed with their pointing task using only the mirrored image. In each case, observers made a direction judgment and adjusted a pointing device towards each target.

Results: Results for the bilateral shoulder viewing were consistent across observers. In Experiment I, when the observers had free choice of aim utilizing both shoulders, they consistently overestimated the positions of targets respective to side, and this perceptual spread was hyperbolic in nature. When observers used an automotive rear-view mirror, a consistent shift in object perception was encountered. Observers underestimated ipsilateral stimuli and gradually

started overestimating stimuli as more stimuli were presented contralateral to the mirror.

Conclusion: These findings suggest there are inherent distortions in VS that phenomenalogically affect how posterior visual space is perceived. Of a more ecological and applied nature, by taking in regard the distortions both inherent in mirror navigation and non-mirror navigation we may attempt to determine an ideal approach to such activities as backing up in a car.

Abstract 518 B4.81

Representing and partitioning visual space: applying isovist field theory to human perception
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For several decades, isovist field theory (also known as viewshed analysis) has been an increasingly popular method of representing visual space in architectural and geographical analyses. Little attempt has been made, though, to apply this method to the psychology of perception, despite its marked similarity to James Gibson's notions of vistas and transitions within the optical array. To this end, in an initial experiment, priming images of a particular viewpoint towards a portion of the visual space were presented. Subjects were significantly ($p<0.05$) more accurate in reproducing the spatial locations of objects in the scene when a briefly presented view of the objects (300ms) was taken from within the viewshed of a primed scene, compared to an equidistant view taken from outside the viewshed. The intervisibility of locations in space appears to act as a cue for orientation to the layout of the environment. In a second experiment, subjects showed a high degree of consistency in their judgments of the informativeness of particular viewpoints within a large, complex space. No significant change in preference was found for views which maximized the overall area of visibility, but informativeness ratings were greatest for those views which contained transitions between adjacent vistas. Further analysis revealed that the viewpoints judged to be most valuable for navigation and orientation can often be represented by unique isovists (those which completely define the space that can be seen from a particular vantage point) within the spatial layout of the structure. Methods for defining "functional isovists" (changes in the viewshed across time and movement of an agent) are developed, and can account for the results of this experiment. The relationship between isovist methods of quantifying space and human perceptions will be discussed, as well as the usefulness of this technique for interpreting the spatial experience of active agents in the environment.

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Abstract 519 B4.82

Remembering rooms but not viewpoints
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Forty distinct scenes of furnished rooms were generated on a computer and three "snapshots" of each room were taken from different viewpoints in a horizontal arc. When a single scene was presented for .5 s followed by a mask and immediately tested for recognition, participants could correctly identify the old (previously viewed) room when presented old and new rooms and also could pick out the original viewpoint when presented old and new viewpoints of the room. When subjects viewed two successive rooms followed by a pair of 2-alt forced-choice tests, accuracy for old/new room judgements remained high (95%; chance=50%), whereas accuracy for old/new viewpoint judgements of a single room dropped to 71% for 30 degree viewpoint changes and 77% for 60 degree changes. In a second experiment in which only viewpoint changes were tested the results were similar. Thus, memory for the viewpoint from which a spatial layout is seen is much less robust than memory for the content of the scene.

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Abstract 520 B4.83

Memory for scenes: May I have the spatial envelope, please?
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We had subjects perform picture memory and boundary recognition experiments with real world scenes to determine how spatial envelope properties affect scene memory. The spatial envelope (Oliva and Torralba, 2001, Int.J.Comp.Vision, 42,145-175) characterizes scenes on various spatial dimensions including rankings from open to enclosed spaces, from flat to perspective views, from low to high complexity (e.g. roughness) and from close-up to far views. These space properties represent the scene holistically and do not require object segmentation or recognition. In the picture memory experiment, 20 Ss judged test scenes as old or new. New stimuli could be similar or dissimilar from old in spatial envelope "space". When new stimuli were dissimilar from old, performance could be predicted by ranking scenes on the complexity dimension of the spatial envelope. Performance increased with visual complexity (from d'=1.1 to d'=2.1). When the spatial envelope of each new scene was similar to one of the old scenes and when the semantic categories of these pairs were the same (e.g. two kitchens), performance was poor for relatively simple scenes (d' = 0.5) but better for more complex scenes (d' = 1.15). In the boundary recognition experiment, Ss drew or adjusted boundaries of scenes after viewing them for a few seconds. Intraub's classic finding is that Ss draw more than they have seen. Our results suggest boundary extension is influenced by the spatial envelope of the scene. Ss seemed to fill out truncated spaces in relatively closed/rough spaces and to remove voids in relatively open spaces. We conclude that some of the scene properties captured by the spatial envelope model are systematically related to the properties that are preserved when a visual image is compressed into a memory trace.
This work was supported by NIMH MH56020

Abstract 521 B4.84

Is spatial anisotropy weakened by translational head motion?

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Researches pointed out the common occurrence of a phenomenon of severe undershooting of depth extents and accuracy or slighter undershooting of frontoparallel extents, namely spatial anisotropy. Despite of this strong undershooting of depth extents, many other studies were concerned with a source of information for depth perception that may work for more accurate judgments, known as motion parallax. The present study is concerned with the effects of motion parallax on spatial anisotropy of exocentric distances in distal layouts. We introduced four types of head movements, free, restrained (control groups), translational, and rotational head movements, in order to investigate that issue, and two viewing conditions, monocular and binocular, for scrutinize interactions between motion parallax and binocular disparity. Observers verbally estimated exocentric distances from a layout composed of two dimensions, saggital and frontoparallel, whose center of expansion was located 49.213 ft (15 m) away the observation point. Repeated measures ANOVA over verbal estimates showed that depth extents were strongly undershot and frontoparallel extents were slightly undershot, $F(1, 36)=109.240$, $p=.000$ (control groups), even with induced motion parallax, $F(1, 36)=35.312$, $p=.000$ (translational and rotational). No effects were found for binocular disparity, $F>1$. We also submitted data on linear regression analysis ($D' = b + aD$), matching depth and frontoparallel estimates. Perfect fit was only obtained for translational head movement under monocular viewing, $t(9)=.541$, $p=.602$. Our results indicated that motion parallax produced by translational head movement is a powerful cue for depth in large outdoors spaces, even though we found that spatial anisotropy remains a strong perceptual phenomenon. Our data also indicated that motion parallax is a strong cue for frontoparallel extents when produced by rotational head movement. Supported by Grants from CNPq (460045/00-8 and 523572/94-8) and FAPERJ (E-26/150.699/99).

Abstract 522 B4.85

Decomposition of the the influence of the frame, III. The whole is less than the sum of its parts

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The classical rod-and-frame experiment (Witkin and Asch, 1948) employs a roll-tilted square frame that generates a substantial influence on the frontal plane orientation visually perceived as vertical (VPV). Since the original discovery of the frame's influence, the frame has been treated as a unitary perceptual object – a gestalt. We ask whether the frame's influence is any more than the additive combination of separate influences produced by the lines which constitute the sides of the frame as would be expected from a gestalt. VPVs were measured for 4 erect subjects monocularly viewing either a 1-line, 2-line, or 3-line section of the frame, or the full 4-line frame on a frontoparallel plane in otherwise total darkness. VPV was measured by S's setting of a 5 deg. long line to appear vertical. The visual stimulus was presented at each of 7 roll-tilts [–22.5 deg. (ccw) to +22.5 deg. (cw)]. Two frame sizes were used: For the large frame each side was 48 deg. long (eccentr=24 deg.); for the small frame each side was 16 deg. long (eccentr= 8 deg.). VPV changed linearly with roll-tilt for each of the 16 conditions. For the large frame, the average slopes of the VPV-vs-roll-tilt function (measuring sensitivity to induction) for the 1-line, 2-line, 3-line, and 4-line cases were 0.24, 0.27, 0.28, and 0.29, respectively; for the small frame, the average slopes were 0.13, 0.19, 0.23, and 0.24, respectively. Thus, the influence of the large frame was very near to the average of the influences of the individual lines; for the small frame the influence manifested a great deal of (linear) summation between the influences of the individual lines. However, for both cases, the full frame was considerably less influential than the simple additive combination of the influences of the individual lines; no higher level gestalt property is involved. Both small and large frame results fell along the same negatively accelerated function of the total length of the lines in the inducing field. We note that the individual lines of the roll-tilted frame also produce systematic influences on visually perceived eye level (VPEL), another dimension of egocentric space perception. Recently we described a 3-stage computational neural model (Vis Res, 2001) that accounts quantitatively for VPEL data with inducing lines of different orientations, lengths, and different numbers of lines. A similar model would account for the VPV results.

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Abstract 523 B4.86

Contextual cueing effect in three-dimensional layouts

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Under incidental learning conditions, the spatial layout of visually presented objects can be acquired implicitly and can be used to facilitate visual search (contextual cueing effect; Chun & Jiang, 1998). We investigated the nature of the implicitly learned spatial layouts in stereo (3-D) displays. Experiment 1 examined whether the learned layouts are limited to 2-D configurations or can encompass three dimensions. Subjects received 720 trials of a visual search task with stereo shutter goggles so that half the items were in the frontal plane and the others were in the back. They searched for a rotated "T" among rotated "L"s. In the OLD condition, 12 different layouts were presented repeatedly for 360 trials. In the NEW condition, a new layout was generated on each of 360 trials. In the last 60 trials of the OLD condition, the disparity of the items was reversed. Reaction times in the OLD condition were faster than in the NEW condition even though the subjects were not able to recognize the OLD layouts (contextual cueing effect). More important, reaction times in the OLD condition increased significantly when the disparity was reversed, suggesting that the 3-D layouts had been implicitly learned during the initial 300 trials. Experiment 2 investigated whether 3-D layouts are encoded automatically or requires selective processing. Subjects searched for a target presented only in a specific depth plane (e.g., front, never in the back). A contextual cueing effect was obtained only when the location of the items in the attended plane was invariant and was consistently paired with a target location. In contrast, repeating and pairing the layout of the ignored items with the target location did not produce contextual cueing effect. These results indicate that visual

attention can be guided by implicit knowledge in 3-D layouts, provided that the layout is relevant and selectively attended.

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Abstract 524 B4.87

The effects of boundary extension on processing spatial relations in scenes

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Viewers tend to report memory for areas of a scene that were actually outside the perimeter of the perceived view (boundary extension). We examined whether the extrapolated information can facilitate processing of spatial relations. Participants viewed a prime followed by a target photograph. They judged which of two locations in this target picture was closer to the camera. In Experiment 1, the prime used was either the full target picture, a partial prime (showing a part of the target picture, not including the locations to be judged), a full control image (same size as target picture), or a partial control (same size as partial prime). Both the full target prime and the partial prime facilitated the processing of spatial relations, compared the controls. These primes were equally effective, indicating that extrapolated layout was as useful as perceived layout in facilitating spatial processing. Experiment 2 examined whether priming is sensitive to changes in the depth of the perceived view. The prime used was either the target picture, a 10% more close-up view (objects closer to camera), a 10% more wide angle view (objects farther from camera), or a control image. Relative to the control, all views showed equal facilitation, indicating that within this range, the depth of the view did not affect priming. Implications with regard to the representation of spatial layout are discussed.

Abstract 525 B4.88

The relation of vision and touch: Spatial learning of small-scale layouts

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PURPOSE
Little is known about the comparison of learning time and accuracy between visual and haptic exploration of spatial layouts. In this study, we compared performance on the time to learn and perfectly reproduce four small-scale layouts (floor plans) in four different conditions. These included: visually (computer-based) and haptically (Lego-based) environments presented from a global or reduced view depth. In the global conditions, the complete layout (corridor structure) was available for inspection by vision or touch, whereas in the reduced view conditions, participants had to explore the layouts section by section.
Understanding how environmental learning differs as a function of modality and view depth will aid in our development of virtual models for pre-journey navigation through buildings by blind/low-vision people.

METHODS
Eight normally sighted subjects trained and tested in all four of the complex environments. Their task was to learn the layout (42-60 corridor segments) including the location of five targets and then reproduce it on a Lego grid.

RESULTS
This table shows mean learning times and standard errors in minutes. There were significant main effects of modality and viewing condition ($p < .001$), and a significant interaction. The difference between the view depths in the visual condition was much larger than that for the haptic conditions.

Conditions:	Visual	Haptic
Global View	5.56 (1.28)	16.87 (2.90)
Reduced View	13.64 (1.85)	21.07 (1.71)

CONCLUSIONS
The results show that it is faster to learn an environment visually than by touch and that vision benefits most from global viewing. Interestingly, view depth had little effect on learning time in the haptic condition, suggesting that touch is slower and shows a weaker effect of stimulus size than vision because of its smaller effective viewing "window". Results will also be discussed in terms of how performance compares to low-vision navigation and to how well these learned environments transfer to real building navigation.

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Abstract 526 B4.89

Target localization in natural or jumbled environment: relative influence of scene and object spatial signatures

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Scenes of the outside world share a common characteristic: they have specific statistical properties distinguishing them from purely random images. In the frame of natural images, scenes exhibit a spatial structure and dominant orientation regularities evocative of their category membership (Guérin-Dugué, Bernard and Oliva, 1998, Perception, 27, 151 ; Oliva and Torralba, 2001, International Journal of Computer Vision, 42,145-175). These global properties lead to defining the concept of scene spatial signature.
The aim of the current study was to measure the influence of this specific global information of the scene on the localization of local targets. Three experiments investigated the relative weight of both global and local levels of information. A jumbling paradigm, borrowed from Biederman's study (1972, Science, 177, 77-80), allowed to control the local spatial organization around the target as well as the relative spatial arrangement of elements in the whole scene. Test images were filtered or unfiltered. Low-pass filtering of the images impaired the physical description of the target.
Results showed that, initially, when images were blurred, the global structure played a major role. However, after a learning period, subjects started using the invariant distinctive features of the target to localize it whatever the aspect of the scene.
In analogy to the scene spatial signature, these local information distinguishing the target from its close environment may define the object spatial signature. This perceptual learning process frees the subjects from having to

rely on global information. The present study shows that perceptual strategies are not determined once and for all. The visual system is flexible and juggles with the various information available at both global and local levels to adapt to visual constraints.

Abstract 527 B4.90

Gaze Level: Oculomotor input to perceived distance
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There is growing evidence that gaze angle may be used as a distance cue. The precise role of gaze angle is unclear but one hypothesis suggests that oculomotor information about vertical gaze position is evaluated for distance perception. Previous experiments used targets significantly below eye level and used prism to alter gaze demand characteristics. Having the target always below anatomical eye level allow only relative evaluation of the effects of upward gaze. In addition, while the prisms result in relative upward gaze, the optical relation of gaze to ground plain is not affected. A further issue is that during 'blind walking' (a task commonly used), visually perceived eye level (VPEL) most likely changes. This may influence distance judgments.

The current experiment measures distance judgment by 'blind walking' to a visual target 15 meters away. The target was adjustable to either VPEL or anatomic eye level and 5 degrees above and below the respective eye level.

Results indicate a main, linear effect (ANOVA) of gaze level with people estimating distances as greater with up gaze and less with down gaze. This effect was primarily due to the conditions in which the target array was centered at anatomic eye level (above>anatomic eye level> below; above=VPEL=below) suggesting that VPEL does play a role in distance perception under these conditions. These results support the hypothesis that oculomotor information, presumably from the obliques, provides information for distance perception.

Visual Search

Abstract 528 B4.91

Visual search strategies in a change detection task
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Visual Search Strategies in a Change Detection Task
Purpose: Serial visual search for a target amongst distractor items is widely believed to be a linear process (Treisman and Gelade, 1980). Visual search for change in simple orientation stimuli using a change detection paradigm also yields search slopes that reflect a linear process (Rensink, 2000). The present study investigates whether or not detecting change in more complex stimuli is also linear.
Method: 2 trained observers were shown an original and modified display presented in an alternating sequence, with each display shown for 1250ms separated by a 250ms blank screen. The stimuli were happy and sad schematic faces, with set sizes ranging from 2 to 10 items. Different ranges of set sizes were used in different experiments. A change in the facial expression of one of the faces occurred on half of the trials; reaction times to detect the change were measured.
Results: Change-absent search slopes increased by a factor of two at set size 4 or 6 (depending on the individual observer). In addition, reaction times for set sizes of 6 and 8 differed depended on the range of set sizes used in testing (eg. 2,4,6 versus 6,8,10), with reaction times for higher ranges of set sizes being longer.
Conclusion: These results suggest that observers use search strategies that depend on two factors: the context, or range in which the set size appears, and the capacity of visual short-term memory (vSTM). First, it appears that a display is searched more extensively when it is the smallest in a range of set sizes than when it is the largest. Secondly, the increase in slope at 4 or 6 items can be explained in terms of the capacity of vSTM, which is about 5 items (Rensink, 2000; Pashler, 1988): it may be that when this capacity is exceeded, search becomes less efficient.
Support: NSERC Canada

Abstract 529 B4.92

Effects of background color on asymmetries in color search
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Nagy & Cone (Vision Research, 1996) report the asymmetry that search for a more saturated target among less saturated distractors is easier than search for a less saturated target among more saturated distractors. The Saliency Model (Rosenholtz, Perception & Psychophysics, 2001) predicts that this asymmetry is due to the background color of the display relative to the target-distractor colors, and that appropriately changing the background color should reverse the color search asymmetry.

Observers searched for a known target among homogeneous distractors. The stimuli consisted of 0.14 deg. diameter disks at random locations within a 4.25 deg. diameter area. We measured the time for an observer to depress a response button indicating that they had determined whether a target was present. Seven equiluminant target-distractor pairs were used, ranging from unsaturated white to saturated red, with each member of a pair serving as target and distractor in different blocks of trials. Each pair was presentedon both achromatic and red backgrounds of a lower luminance.

With an achromatic background, reaction times were shorter when the target was more saturated than the distractors. When the same stimuli appeared on a red background, the asymmetry reversed. On both backgrounds, the size of the asymmetry increased with increasing chromaticity difference between background and target/distractor pair. The size of the asymmetry also increased with decreasing luminance difference between the background and target/distractor pair.

Both the direction and magnitude of a color search asymmetry depend upon the background color. Several models qualitatively predicts these results, including both the Saliency Model and a signal detection theory model in which the viewer observes the color difference between each element and the background, with noise proportional to the magnitude of the difference.

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Abstract 530 B4.93

The shape of pop-out depends on stimulus density, location, and orientation

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An orientation singularity is rapidly detected in a display of iso-oriented elements, but its location may be coded imprecisely. We describe the exact shape of such pop-out at different positions in the visual field. A trial consisted of a 1000 ms central fixation, followed by a 70 ms stimulus array of Gabor patches containing a single popout target (vertical from horizontals, or horizontal from verticals). This was replaced by a mask array of noise-patches that remained on the screen until the start of the next trial. A mouse-pointer appeared 500 ms after the masks, and the task was to click on the target location. Matched stimulus and mask arrays contained 9x9 or 5x5 patches, with about 4000 trials in each condition. Gabor patches were separated by 6 carrier-periods in the dense (9x9) array, and 12 carrier-periods in the sparse (5x5) array Results show that localization was more accurate in the dense array, where there were more distracters, and more potential target locations. Errors were frequently directed toward distracters near the target. Their distribution over the visual field was inhomogeneous, with most errors for targets at larger angles of visual eccentricity, above and below fixation. Some observers made systematic errors to horizontal neighbors of the horizontal target, and vertical neighbors of the vertical target, especially in the sparse array. Accuracy was greatest for targets far from the previous response location. Most subjects showed significant learning effects. However, the greatest determinant of error size and direction appears to be an individual propensity to make specific errors to targets in a particular location. This may reflect inhomogeneities in the underlying cortical topographic representation.

Abstract 531 B4.94

Effects of set-size and lateral masking in visual search

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The roles of peripheral (local) and central (global) processing limitations in visual search are still not well understood. In the present study, the number of displayed stimuli (set-size) and the distance between neighbouring stimuli were varied as independently as possible in order to measure the effect of both. Stimuli were presented briefly and observers had to indicate the presence or absence of the target stimulus. Percentage correct was used as a measure of performance. Symmetrically and asymmetrically bisected squares were used as stimuli. There were two experimental conditions: target differed from distractors either by presence/absence of a simple feature (1) or it differed by relative position of the same components only (2). The effect of distance between stimuli (lateral masking) was found to be similar in the both conditions. The effect of set-size (with lateral masking effect eliminated) was much larger for relative position stimuli. The results support the view that perception of relative position of stimulus components is limited mainly by the capacity of central processing.

Abstract 532 B4.95

Visual search with irrelevant background: Speeding or slowing search using endogenous cues.

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When relevant stimuli (target and distractors) are embedded among irrelevant background elements, visual search takes longer than without background elements. We know that cueing exogenously for the shape or size of the set of relevant stimuli can partially overcome the detrimental effect of the background elements. These results have shown that the ‘spotlight of attention’ has both variable shape and size. The question now is "can endogenous cues guide attention to relevant stimuli in a similar way"? Two configurations (horizontal vs vertical) of 4 relevant stimuli, one of which was the target, were presented with or without a matrix of 11x11 background elements. A variable time before the stimuli, either a valid or invalid endogenous cue was given (a letter "V" or "H"). In a second experiment, the configuration was always vertical, and a cue was again given to the subject. This time the cue was an arrow pointing to the left or to the right of fixation. The results suggest that valid cues correctly guide subjects’ attention to the relevant stimuli. This means that endogenous cueing can also change shape and location of the ‘attentional spotlight’, but longer delays are needed to process endogenous cues as compared to exogenous cues, which work well with shorter delays. We now know that top-down processes, just like bottom-up processes, can be manipulated. The present experiments have shed more light on the roles that attention plays in perception.

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Abstract 533 B4.96

Understanding conjunction and double feature searches by a saliency map in primary visual cortex

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Visual search is the task of finding a target among distractors. When the target has a feature that is absent in the distractors, the search can be very efficient, and is termed feature search, if the feature is in a basic feature dimension like color, orientation, depth, and motion direction (Treisman and Gelade, Cog. Psychol. 1980). When the target is only distinguishable by a particular conjunction of features, e.g., green and vertical, each of which is present in the distractors, the search is termed a conjunction search. Some conjunction searches, e.g., conjunctions of depth-orientation (Nakayama and Silverman, Nature 1986) and motion-orientation (Mcleod et al, Nature 1988), can be efficient, while others, such as color-orientation, may be difficult depending on the stimuli (Treismand and Gelade 1980, Wolfe, Vis. Res. 1992). Double feature searches are those for which the target differs from distractors in more than one feature dimensions, e.g. a green-vertical target bar among red-horizontal distractor bars. They should be no less

efficient than the two corresponding single feature searches (e.g., a green target bar among red distractor bars or a vertical target bar among horizontal distractor bars). The double feature advantage is stronger for some double features, such as motion-orientation, than others, such as color-orientation (Nothdurft Vis. Res. 2000). I use a V1 model to show how various efficiencies in these search tasks can be understood from a saliency map constructed by V1 (Li, TICS 2002). Contextual influences make V1's responses increase with the stimuli's saliencies, which determine the search efficiency. The model shows that a conjunction or double feature search is more efficient if cells tuned to the conjunction of features are present in V1 and if the intra-cortical connections preferentially link cells tuned to similar feature values in both feature dimensions. Our model links psychophysics with physiology and provides testable predictions.

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Abstract 534 B4.97

Scene familiarity facilitates visual search in monkeys

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Locating target items among multiple distractors can be facilitated as one becomes familiar with the visual scene containing such items. As a step to investigate the neural mechanisms by which information about visual scenes can be acquired and used to locate targets efficiently, we trained monkeys to produce hand movements according to the locations of targets among multiple distractors. Targets and distractors were selected from a set of 9 different stimuli (3 different shapes in 3 different colors). A visual scene was defined by the distribution of these 9 different stimuli in the display. The animal was trained to move a feedback cursor to a series of targets by making hand movements on a touch screen. The first target in each trial was presented by itself, whereas distractors were present for the remaining targets. The identity of the next target item was indicated to the animal by presenting a sample in the current target location. The sample was made 50% larger than the target to distinguish it from other stimuli, and the interval between the acquisition of a given target and the onset of the sample was always 250 ms. In two separate experiments, we tested whether familiarity of visual scene influenced the search performance. Familiarity of a visual scene was manipulated by repeatedly presenting a particular scene chosen randomly each day, and performance was measured by the time taken from sample onset to target acquisition. In the first experiment, the location of each target was randomly determined, and performance improved as the visual scene became familiar to the animal. In the second experiment, target location followed a particular order in a majority of trials, and performance was better for familiar scenes even when the sequence of target locations was learned. As in previous human studies, these results suggest that knowledge of a visual scene can facilitate spatial orienting during search tasks in non-human primates.

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Abstract 535 B4.98

Effects of bottom-up salience within the feature search mode

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Recent research suggests that bottom-up salience determines attentional priority only when subjects adopt the strategy of searching for a discontinuity (singleton-detection mode). In contrast, bottom-up salience is held to play no role in visual search when subjects look for a known-to-be-relevant target feature (feature-search mode). This conclusion is based on the finding that within the feature-search mode, a singleton distractor captures attention to its location only if it possesses the target feature. However, in such studies, only top-down factors (whether or not the distractor possessed the target feature) were manipulated, while bottom-up factors were kept constant, as the distractor was always a singleton. Thus, while these findings suggest that salience has no effect on performance outside the attentional set adopted by the observer for a specific feature, it remains possible that salience may enhance attentional priority within this set. This question was explored in two experiments by investigating whether or not a distractor possessing the target feature is more difficult to ignore when it is a singleton (high bottom-up activation) than when it appears within a heterogeneous background (low bottom-up activation). A distractor possessing the target feature produced stronger capture when it was salient, but only early in processing. Moreover, a singleton distractor outside the attentional set was inhibited rather than simply ignored. These results suggest that bottom-up salience plays a role within the feature search mode, and that overriding capture by an irrelevant singleton results from inhibiting this singleton's salient feature rather than from ignoring salience per se.

Abstract 536 B4.99

Brain activity involved in singleton search mode: an fMRI study

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Visual attention is controlled in two distinct, well-known systems: the top-down selection system and the bottom-up selection system. Though numerous studies have addressed these two selection systems, the difference in neuronal mechanism between them is still unclear. Especially, because the bottom-up selection system normally requires less effort and induces less brain activity than the top-down selection system does, it is difficult to detect the neural mechanism for the bottom-up system compared to that for the top-down system.

In the present study, we used a visual search task, involving two conditions: a feature search condition that would induce top-down selection and a singleton search condition that would induce bottom-up selection, first introduced by Bacon and Egeth (1994). In the first psychological experiment, the task-difficulty and the search-efficiency in each condition were matched to equate the amount of effort required for each condition. Subsequently, we measured brain activity for the two conditions. As a result, in addition to extended activation in frontal and parietal areas: bilateral FEF, bilateral ventral premotor areas, ACC, bilateral parietal areas, and bilateral visual cortices, for both conditions, a direct comparison

between the singleton search condition and the feature search condition revealed that the area around the bilateral intraparietal sulci were more involved in the singleton search mode.

Abstract 537 B4.100

How fast can you change your mind? Effects of target identity cues in visual search
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How quickly can top-down information about a target influence visual search? To find out, we varied the SOA between the appearance of a 100% valid cue and a conjunction search stimulus. There were 24 different possible pairings of target and distractors. "Picture" cues were exact copies of the target. "Word" cues were descriptions (“red horizontal”). Cue-stimulus SOA varied from 0 to 800 msec. A new target was picked pseudo-randomly on each trial with constraints that permitted runs of the same target for 2 or 3 trials. Two control conditions were run: No Cue (find the odd item) and No Variation (same target for100 blocked trials). The No Cue condition is a ceiling condition, producing RTs that average about 1300 msec. The No Variation condition is a baseline producing RTs that average about 600 msec. The top-down information of the cue moves the RT from the ceiling toward the baseline. A picture cue preceding the stimulus by 200 msec is adequate to bring RT down to the No Variation baseline. Even a 50 msec SOA picture cue had a substantial effect. Word cues were less effective. Unsurprisingly, they took longer to become fully effective. Even after an 800 msec SOA, the RT remained 200 msec above the No Variation baseline. However, if the same cue was repeated twice in a row, picture cue RTs were unchanged but word cue RTs became about 100 msec faster. With word cues, the stimuli on trial N acted as a prime for trial N+1. Seeing the target on trial N was not critical. The same priming benefit occurred on trial N+1 when trial N was a target absent trial as when it was a target present trial. Picture cues seem to provide their own prime. We conclude that one difference between picture and word cues may be the ability of picture cues to produce priming that word cues cannot produce.

Abstract 538 B4.101
The time course of attentional capture
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In numerous experiments, using a variety of techniques and tasks, observers have responded more rapidly to a target that was a new onset visual object than to a target created by transformation of an already present object. New objects are said to “capture” attention in that they are processed with higher priority than old objects. When new and old objects are pitted against each other, however, it can be unclear whether differential responding occurs because new objects gain attention (facilitation) or because old objects lose attention (inhibition). Furthermore, the extent of strategic control, if any, over facilitation and inhibition has to be determined for any particular task. We address these issues by studying the time course of old object inferiority in a previously described task (Gellatly & Cole, 2000, Journal of Experimental Psychology: Human Perception & Performance, 26, 889-899). In our first two experiments, new objects and old objects of varied “age” were presented together in mixed displays. Detection of old targets was worse than detection of new targets in almost every case, and deteriorated with increasing age. The results suggest that the older old objects become the less effectively they combat the attentional pull of new objects. However, our third experiment produced a very similar result with pure displays of either all old or all new objects, suggesting that old objects lose attention even when they are not in competition with new objects. This occurs even though observers gain no strategic advantage from inhibiting attention to old objects or their locations.

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Abstract 539 B4.102

Items in working memory do not automatically attract attention in visual search
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Numerous studies have indicated that attending to an object is a pre-requisite for establishing both long- and short-term memory traces for that object. This link between working memory and attention may also work in the other direction, so that the maintenance of an object in working memory might bias selective attention towards that specific object. However, this view was recently challenged by Woodman, Vogel and Luck (2001).

To directly measure the extent to which items in working memory attract attention, we recorded eye movements while subjects performed an attention-demanding visual search task for a pre-specified target, while maintaining a similar item in working memory for a subsequent visual search task. The items were line-drawings of objects in experiment 1 and colors in experiment 2. If items in working memory attract attention, it is predicted that distractors in the search array that match the item in working memory result in more interference during visual search. However, no such interference was found in the manual response times. Also, fixation durations on items in working memory were no longer than those on other distractors. Furthermore, the percentages of eye movements toward the item in working memory and towards other distractors did not differ.

We therefore conclude that items in working memory do not automatically attract attention during visual search. Apparently the visual system keeps the “search template” separate from other items stored for later use.

Abstract 540 B4.103

The distractor-color adaptation effect in color-singleton search: What color representation is being adapted?
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In a color-singleton search task, observers located an odd-colored target (e.g., a green diamond among red diamonds) and reported which side (left or right) was "chipped"; color repetition effects were thus examined independently of response priming. In randomly intermixed "adaptation" trials, all stimuli were the same color (e.g., all green) and observers made no response. Search (e.g., for a red target among green distractors) was faster (by about 90 ms) when only the distractor color was viewed in the preceding adaptation trial (e.g., all green diamonds) relative to when only the target color was viewed (e.g., all red diamonds), suggesting that color-singleton search is facilitated by adaptation to the distractor color. To understand what type of color representation was being adapted, adaptation trials were manipulated while search trials remained the same. This phenomenon is not due simply to adaptation to the distractor color per se because the effect disappeared when same-colored diamonds were replaced by a large color patch (with 11 times greater total area). However, it persisted when the diamonds were reduced in area by nearly 90% (to appear like colored dots), suggesting that this color adaptation is not energy dependent, but does require the presence of multiple colored items. By varying the number of adapting diamonds, we found that robust adaptation effects occurred so long as there were 2 or more adapting diamonds. Additional experiments showed that the effect was not specific to eccentricity or shape, and that the adaptation occurs rapidly (within 30 ms exposure). These results, taken together, suggest that distractor-color adaptation occurs where color representation is fairly independent of image attributes (color energy, position, eccentricity, shape, and size), but this adaptation does require that more than one colored item is presented. The role of target-distractor assignment in distractor-color adaptation will be discussed.

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Abstract 541 B4.104

Spatial resolution underlies the set size effect in conjunction search

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Most theories of visual search have attributed the presence of a set size effect – decreased performance with increasing set size – to the involvement of attentional mechanisms. According to these theories, conjunction search of two features has been considered a serial process requiring attention. However, this seriality may be due to the fact that at larger set sizes targets are more often presented at farther retinal eccentricities where spatial resolution is worse, thus leading to an overall decrease in performance as set size increases (e.g., Carrasco & Frieder, 1997). The present visual search experiment teased out the spatial resolution vs. attentional factors involved in conjunction search. We employed a conjunction search of tilted, low-frequency targets among distracters that shared either the same orientation or spatial frequency. Stimuli were presented in a square array subtending 3 to 14 eccentricity. All stimulus spatial dimensions – size, orientation, and spatial frequency – were held constant either at: the retinal level (control condition) or the cortical level (magnified condition). Analysis of accuracy performance for present targets revealed a set size effect in the control but not in the magnified condition. However, when the set size effect in the control condition was measured separately at each eccentricity, a confound emerged: the set size effect changed as a function of target eccentricity. Finally, analysis according to the location at which the target appeared revealed an eccentricity effect – performance gradually worsened with increasing eccentricity – in the control condition. This eccentricity effect was completely eliminated in the magnified condition. These results indicate that in this conjunction search performance was limited by spatial rather than by attentional constraints.

Abstract 542 B4.105

The "flicker" search task: A paradigm for investigating memory in visual search

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Following Horowitz and Wolfe (1998), observers searched for an oriented T among oriented Ls under static (standard search) and dynamic (items randomly relocating) viewing conditions. We modified these conditions by embedding both search tasks in a "flicker" display paradigm. Static and dynamic trials consisted of a repeating sequence of fifteen 72 ms stimulus frames, each separated by a gray field. In addition to making the static displays more visually comparable to the dynamic (e.g., by controlling for onset/offset noise, etc.), this presentation method also enabled memory to be assessed during search by varying the duration of the gray masking field (i.e., the ISI). A memoryless model of search would assume that processing stops with each display offset, making each new display a new search task. Such a model would therefore predict a decrease in search efficiency with longer ISIs, with both static and dynamic tasks being affected equally. A memory-based model would predict an attenuated effect of ISI in the static condition due to processing continuing into each masking interval and accumulating over frames. We tested these predictions for static and dynamic search using three ISIs (101, 402, and 703 ms), three set sizes (9, 13, and 17 items), and two target conditions (present vs. absent). Consistent with a memoryless model, search slopes increased with ISI in the dynamic condition. A far smaller effect of ISI was found in the static slopes, a pattern more consistent with a memory-based model. We can therefore conclude that search is exploiting processing occurring on a "remembered" display. Although longer ISIs afforded a greater opportunity for processing in both static and dynamic conditions, information resulting from this processing could only accumulate across the static displays. Because items in the dynamic condition were shifting locations, processing extending into the ISI would often be wasted upon presentation of the next dynamic frame.

Abstract 543 B4.106

Perceptual versus attentional factors in visual search

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Mirror-image symmetry, distractor heterogeneity, and search asymmetry all can affect visual search performance, but each

may affect a different stage of processing via different mechanisms. We tested 15 participants in a series of visual discrimination and search tasks to decompose processing into component parts. In each task the target was either a vertical (T:|) or tilted (T:/) line. To examine mirror-image symmetry between target and distractor, we compared a condition where the target was tilted clockwise and the distractors tilted counterclockwise (T:/ & D: \) to one where the distractors were vertical lines (T:/ & D:|). Target discrimination thresholds were much larger for the mirror-image condition, but once target salience was balanced across search conditions there was no difference in either the ability to divide attention (as measured by an attention-sharing index) or the magnitude of the set-size effects for the two conditions. To examine distractor heterogeneity effects, the target was a vertical line (T:|) and the tilted line distractors were either homogeneous (D: /) or heterogeneous (D: \ /) so that the distractors were mirror-images of each other. For the heterogeneous condition, the ability to divide attention plummeted and set-size effects were much larger. Finally, to examine effects of search asymmetry, we compared two conditions in which the roles of target and distractor were switched (T: | & D:/ versus T:/ & D: |). Search asymmetry affected a higher level of processing where the "deviant" stimuli (tilted lines) attract attention away from the prototypical stimuli (vertical lines). That is, when the target was correctly detected ("hits"), there was less confusion about the target's spatial location for the "deviant" target (T: /) than for the prototypical target (T: |). In the near future we will compare results of ongoing correlated fMRI studies to our psychophysical results.

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Abstract 544 B4.107

Searching through subsets of moving items

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We have been exploring the visual search paradigm under conditions where items to be searched move in an unpredictable manner in order to determine if the visual system can reference objects that occupy changing locations. In the present study, the moving search task was combined with a multiple-object-tracking task in which 3 to 5 items were tracked among an equal number of distractors and in which the critical item, when present, occurred in the tracked subset. Subjects tracked a number of placeholders, which, after a few seconds, changed into search items. We showed that under these conditions observers are able to confine their search to the tracked items. For example, when the search subset was a feature set, then even when the nontracked distractor set contained elements with each of the features that defined the critical item (i.e., that made the entire superset of items a conjunction search set), observers were faster at finding a present target. Additionally, subjects were faster for smaller conjunction subsets. This result shows that in the multiple-object tracking paradigm, observers do select the target set as a whole, confirming a finding of Burkell & Pylyshyn (Spatial Vision, 11, 225-258, 1997) that items selected by visual indexes can be accessed directly.

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Abstract 545 B4.108

Preattentive segmentation of figures from *gr*found in visual search

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Purpose: Evidence suggests in visual search tasks for a target item among distractors attention is effectively guided to objects. However in many laboratory search tasks blank backgrounds are used, while in the real world, objects must be segmented from complex heterogeneous backgrounds. How does background composition and complexity effect search performance? Is each item in a search display extracted in series from the background, or does a single "preattentive" process separate all possible target items before search proceeds? If each search object must be separately extracted from the background, increasing background complexity should increase RT x set size slope because there will be an added cost for each item in the display. If all search items are separated in one "preattentive" step, mean RT should increase with background complexity, but search slope should not. Methods: In each experiment we kept the search task the same (target = T distractor = L), while changing the composition and complexity of the search backgrounds. Backgrounds ranged from homogenous textures composed of spatial frequencies varying in similarity to the target, to patterns composed of the same T and L junctions as the search stimuli, to realistic scenes. Results: We found an additive mean RT cost with more complex background producing greater costs. The complexity of the background did not effect search slopes unless the background it self was a texture of distractors. Conclusions: The results suggest an initial preattentive process that parses potential targets from other visual information in the display, so that attention can be guided to the set of task relevant objects.

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Abstract 546 B4.109

Saccadic and perceptual accuracies in a visual-search detection task are similar over a wide range of external noise levels

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For stimuli containing external noise, performance can be limited by both external and internal noise. Previously we showed that, for a high external noise level, the accuracy of the 1st saccade and perception (for matched processing times) in a visual-search detection task are nearly the same (Stone et al, Neuro. Abs. 1999; Beutter et al, ARVO 2000). If saccades and perception share visual neural mechanisms (same receptive

fields and internal noise), then changing the external noise level should have similar effects on each. Methods: We recorded eye movements and perceptual responses of 2 observers on a 10AFC search task under 2 conditions. In a long condition (up to 4s), observers made saccades to search the display and we defined the 10AFC saccadic decision as the element location closest to the 1st saccade's endpoint. In a short condition (150ms duration to match saccadic processing time), central fixation was required, and we recorded the 10AFC perceptual decision. The Gaussian-blob target (SD=0.24deg), randomly chosen to be in one of ten 2.4deg boxes (5.9deg eccentricity) with SNRs ranging from 2.1 to 9.6, was added to a Gaussian white-noise background with one of 4 rms contrasts (4.6, 9.4, 18.4, 37.4%). Results: For all 4 external noise levels, the perceptual and saccadic accuracies were similar across all SNRs. The mean (over SNR and observers) relative efficiencies (squared d' ratio) of the saccadic to the perceptual decision were 1.0, 0.7, 0.6, and 0.7, for the 4 increasing external noise levels . For both saccades and perception, at fixed SNR, accuracy decreased as external noise decreased and was dramatically lower for the lowest noise level. Conclusions: Our data show that saccadic and perceptual decisions are similarly influenced by the ratio of internal to external noise, consistent with detection mechanisms with similar receptive fields and internal noise levels. Our results suggest a shared neural processing stage for both
saccades and perception.
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Monday PM Talks (North Hall)
Color

Moderators: John Krauskopf & Lindsay Sharpe

Abst #	Time	Authors
547	3:00	Krauskopf
548	3:15	Wachtler, Rotter, Hertel
549	3:30	Beer, Becker, Anstis, MacLeod
550	3:45	Werner, Sharpe
551	4:00	Uchikawa, Emori, Toyooka, Yokoi
552	4:15	Brewer, Wade, Wandell

Abstract 547 3:00 PM

Spatial and temporal modulation sensitivity of L and M cones

John Krauskopf New York University, USA

Cone contrast detection thresholds were measured for gratings modulated spatially and temporally about a white field using odd symmetric Gabors. A particular pairing of the spatial and temporal frequency carriers was used in each experimental session. Thresholds were measured using randomly interleaved staircases; for one set of stimuli only the M-cone input was varied. For a second set only the L-cone input was varied.

For targets of low spatial and low temporal frequency L- and M- cone sensitivities were approximately equal. The ratio of L-cone to M-cone sensitivity increased when temporal frequency was raised (confirming previous findings) and when spatial frequency was raised (a novel finding). To some degree the effects of spatial and temporal frequency are additive but the interaction is complex.

Supported by NEI grant EY06638

Abstract 548 3:15 PM

Trichromat-like representation of colors in dichromats: A hypothesis on the evolution of trichromacy

Thomas Wachtler, Stefan Rotter, & Rainer Hertel Albert - Ludwigs-Universitaet Freiburg, Germany, Albert-Ludwigs-Universitaet Freiburg, Germany, Albert-Ludwigs-Universitaet Freiburg, Germany

Color vision in trichromats is based on three types of photoreceptors with different spectral sensitivities. This trichromatic retinal substrate is often thought to underlie the three-dimensional structure of our perceptual color space, e.g. the perceptual color axes of "light"-"dark", "red"-"green", and "blue"-"yellow". Dichromats are missing one of these three photoreceptor types. In this context, it is usually assumed that their color percept lacks certain qualities, e.g. 'red-blind' protanopes lack the ability to perceive "red" (Vienot et al 1995). However, many studies have shown that dichromats use all of the basic color terms "red", "green", "blue", and "yellow", to describe their color percepts. This indicates that the number of perceptual color categories is not tightly coupled to the spectral dimensionality of the receptoral substrate. We investigated the color vision of protanopes and deuteranopes with the method of hue scaling, using monochromatic stimuli at different intensity levels. Our results confirm earlier findings and demonstrate the dependence of "red" and "green" percepts on intensity (Boynton & Scheibner 1967); for light above 560 nm, at low intensities dichromats describe their color percept as "red", at higher intensities however as "yellow". We present a model for the processing of the two photoreceptor signals in dichromats that, under physiologically plausible assumptions, yields a consistent labeling of chromatic stimuli as mixtures of "blue", "yellow", "green", and "red".We hypothesize that dichromatic ancestors of humans may have taken advantage of such a pseudo-trichromacy, and that the perceptual color axes of red-green and blue-yellow may have evolved even before retinal trichromacy. The hypothesis provides a unifying explanation for molecular, evolutionary, and perceptual features of color vision.

Abstract 549 3:30 PM

Polarity-specific masking of isoluminant colors

Dirk Beer, Mark Becker, Stuart Anstis & Don MacLeod
University of California San Diego

Adaptation can be specific for chromatic polarity. For example, adapting to isoluminant red spots on a gray background reduces the vividness of subsequently viewed red spots more than that of green spots (Beer and MacLeod, ARVO 2000). Becker and Anstis (OSA-UCI 2001) have demonstrated a dramatic, complete polarity specificity for luminance metacontrast masking of a spot by a ring: white rings mask white spots and black rings mask black spots, but opposite-polarity spots are not masked. This suggests fully independent ON and OFF channels for luminance perception. We now show that masking

of isoluminant colors is also polarity-specific: while isoluminant red (or green) rings do indeed mask red (or green) spots, there is very little cross-polarity masking. Red rings have little effect on green spots, and green rings have little effect on red disks. This selectivity is nearly as strong as that for Becker & Anstis's luminance stimuli, and much stronger than in Beer & MacLeod's pattern adaptation. These results provide additional strong evidence for polarity-specific chromatic signals for suprathreshold colors.

Abstract 550 3:45 PM

The spatial tuning of chromatic adaptation
Annette Werner & Lindsay T. Sharpe U. of Tübingen, Germany, U. of Newcastle, UK

A central issue for understanding chromatic adaptation is the influence of the spatial complexity of a scene. In previous experiments, we found that the early time-course (0.2-5 sec) of mid-spectral chromatic adaptation is accelerated by a cortical mechanism that responds to contrast in the adaptation-pattern (Werner et al., Vis. Res., 2000 (40): 1101-1113). Our new experiments investigate the properties of this spatial component of chromatic adaptation. The pattern (15.4 x 13.2 deg) was presented on a calibrated colour monitor and consisted of either hexagonal patches or horizontal stripes of different luminances. For the reference condition, ite was achromatic (u' = 0.197, v' = 0.468; Lmean = 19.3cd/m2). Chromatic adaptation was measured for the transition from D65 adaptation to a 5s green adaptation-light located in an equiluminant plane in colour space (chromaticities were chosen from cardinal axes after Krauskopf et al., 1982). The effect of chromatic adaptation was measured by a hue cancellation technique, which involved maintaining the achromatic appearance of a central hexagonal test-patch (2.2 x 2.4 deg). Our results show that mid-wavelength adaptation is a function of the magnitude of luminance contrast in the adaptation-pattern, indicating the influence of a mechanism of contrast gain control acting on chromatic adaptation. Furthermore, the contrast component of adaptation responds to the spatial complexity of the adaptation pattern rather than to local contrast per se, indicating a global rather than local mechanism. Finally, chromatic adaptation is selective for the spatial frequency and orientation of the adaptation pattern. The results are interpreted in terms of spatial adaptation gain control and as evidence for the co-processing of form and colour information at a cortical level. A possible relation to contrast gain mechanisms is discussed. This study was supported by DFG SFB 430, Tp A7.

Abstract 551 4:00 PM

Color constancy in categorical color appearance
Keiji Uchikawa, Yasuhiro Emori, Takashi Toyooka, & Kenji Yokoi Tokyo Institute of Technology, Japan
Purpose: Color constancy is not perfect so that color appearance of a surface gradually changes as an illumination changes. In the most previous studies color appearance of a color chip under a test illumination was matched to a color under a standard white illumination with an asymmetric color matching method. In those experiments color difference between a color in perfect color constancy and that actually obtained was utilized as an index for color constancy. However, color difference does not tell us how the test color appearance categorically changes. In the present study we carried out categorical color naming for color chips under different illuminants in order to reveal categorical color constancy. Methods: A LCD projector illuminated a test color chip (5deg x 5deg) chosen from the 424 samples in the OSA uniform color scales. The observer named the test color using only a basic color name in the Berlin-Kay 11 basic color names. The LCD projector (3000K, 6500K, and 25000K) could illuminate the whole area (50deg x 40deg), which included the test color chip and the gray surround (whole illumination condition). It could also separately illuminate the color chip with the test color temperature and the surround with the standard white (6500K) (spot illumination condition). This spot illumination made it possible to measure color appearance change of the test color chip caused by spectral component change of the test illuminant without adaptation or surround effects. Results: We found that the categorical color regions of the 11 basic colors were remarkably similar under the whole illumination conditions of 3000K, 6500K, and 25000K. In the spot illumination condition the categorical color regions significantly shifted according to the illuminants. Despite of these shifts categorical names remained the same for color chips in the focal color regions. Conclusions: Our color vision possessed robust categorical color constancy and categorical color constancy holed best in focal color regions.

Abstract 552 4:15 PM

Visual field maps and color signals in human ventral occipital cortex
Alyssa A. Brewer, Alex R. Wade, & Brian A. Wandell Stanford University, USA

Introduction: Human occipital cortex contains several distinct foveal representations, but mainly those on the ventral surface respond preferentially to color over luminance-matched stimuli. We made fMRI measurements to learn more about these ventral signals.

Methods: We examined the fMRI BOLD signal in human ventral occipital (VO) cortex using (1) traveling wave stimuli designed to measure eccentric and angular dimensions of retinotopy and (2) color and achromatic patterns matched in luminance but differing in S and L-M signals. Activation maps were transferred onto flattened views of visual cortex, and visual maps were identified to subdivide VO cortex. Regions responding preferentially to chromatic stimuli were located relative to these retinotopic regions.

Results: Large regions of VO cortex contain retinotopic maps. There is a map of the entire contralateral hemifield adjacent to ventral V3. This map fills 4 cm2 of cortex and includes a foveal representation that is confluent with that of areas V1/2/3. The homology of this area to macaque V4 is uncertain because the human map does not extend onto the dorsal surface nor does it surround V1. We propose calling this hemifield representation hV4. A separate and distinct foveal representation is present on the ventral surface anterior to hV4. This foveal representation, located 3 –5 cm from the confluent V1/2/3 foveal representation, is larger than the foveal representation in V1. It may be the foveal representation used to define V8, but the orientation of the surrounding map is

inconsistent with the V8 definition. Responses to colored stimuli exceed those to achromatic stimuli in V1, hV4, the distinct ventral foveal representation, and other locations within VO cortex.

Conclusion: There is an intricate collection of visual field representations and at least one large foveal representation in VO cortex. Ventral stream responses to S-cone and L-M signals exceed dorsal stream responses.

Acknowledgements
We thank Jochem Rieger. Supported by RO1 EY30164.

Monday PM Talks (North Hall)
Lightness

Moderators: Branka Spehar & David Brainard

Abst #	Time	Authors
553	5:00	Bonato, Cataliotti
554	5:15	Hartung
555	5:30	Brainard, Maloney
556	5:45	Gilchrist, Zdravkovic
557	6:00	Maloney, Boyaci, Hersh
558	6:15	Spehar, Clifford, Johnston

Abstract 553 5:00 PM

Pictorial and stereoscopic grouping effects on the luminosity threshold

Frederick Bonato, & Joseph Cataliotti Saint Peter's College, USA, Ramapo College of New Jersey, USA

The perception of self-luminous surfaces—that is, surfaces that appear to glow, has seldom been researched. Work in our lab has shown that luminosity perception, like lightness perception, is mediated by perceptual grouping processes that must be cortical in nature. For example, grouping by similarity plays a role. A target that differs in shape from other elements in an array exhibits a lower luminosity threshold than an identical target that shares a similar shape with background elements (Bonato & Cataliotti, 2001). In the current study observers adjusted the luminance of a target until it began to appear self-luminous (luminosity threshold). In one experiment, grouping by similarity was manipulated by embedding a sharp edged target in a Mondrian display whose regions were either sharp-edged or blurred. Results were consistent with our previous research: the target embedded in the blurred Mondrian resulted in the lowest luminosity threshold. However, in another experiment in which the target's perceived location in space was manipulated stereoscopically, the target that appeared to be in front of its background exhibited the highest threshold—a result inconsistent with our earlier work. Collectively, these results suggest that grouping processes affect the luminosity threshold differently in 2-D and 3-D displays. Further experimentation has supported this hypothesis leading us to the following conclusions: 1) in 2-D displays, regions that do not group well with their array result in lower luminosity thresholds, and 2) in 3-D stereoscopic displays, regions that appear isolated in space in front of their array tend to form a separate perceptual framework, resulting in higher luminosity thresholds. Results will be discussed in the context of lightness anchoring and perceived illumination level.

Supported by National Science Foundation Grants BCS-0002620 and BCS-0196505

Abstract 554 5:15 PM

Distinguishing shiny from matte

Bruce Hartung* & Daniel Kersten U. of Minnesota
*VSS 2002 Student Award

Determining whether a material is matte or shiny is theoretically under-constrained. Image intensity variations could be due to paint changes across a uniform matte surface or illumination variations reflected in a uniform specular surface. Remarkably, the human visual system easily distinguishes shiny from matte objects. How does it do this? We used measured natural illumination maps from Debevec's Light Probe Image Gallery[1] to investigate three sources of information for seeing an object as shiny: 1) Consistency between the background environment and the reflection; 2) "Naturalness" of the illumination environment; 3) Optic flow.

Because shiny objects reflect their environment, the pattern of colors across the object and the illuminating environment are correlated. We show that human vision often doesn't care: e.g. an object reflecting a museum interior appears to be shiny even when shown against forest, or other inconsistent backgrounds.

The sufficiency of internal region pattern for indicating shininess raises the question of what class of illumination maps are best for perceiving shininess? Dror et al.(2001)[2] have shown that natural illumination maps have characteristic non-gaussian, non-stationary statistical properties. We show that departures from "naturalness" can have striking effects on perceived shininess. For example, a shiny object in a "white noise" illumination world looks matte.

A rotating shiny object projects different optic flow patterns than a rotating matte object. We "painted" objects with illumination maps such that for any given static view, the object appeared shiny. However, when the apparently shiny object begins to rotate, it immediately appears matte, and when it stops, appears shiny again. The visual system sees material from motion.

[1] http://www.debevec.org/Probes/
[2] R. O. Dror, E. H. Adelson, and A. S. Willsky. Estimating surface reflectance properties from images under unknown illumination. In SPIE Conference on Human Vision and Electronic Imaging, San Jose, CA, 2001.

Supported by: NIH RO1-EY12

Abstract 555 5:30 PM

The effect of object shape and pose on perceived lightness

David H. Brainard & Shannon I. Maloney U. of Pennsylvania, U. of California Santa Barbara

Purpose: The shape and pose of an object with respect to a directional light source affect the luminance of the light

reflected from the object to an observer. If perceived lightness provides a stable representation of object surface reflectance (i.e. if there is lightness constancy), the visual system must compensate for the effects of shape and pose changes. Little is known about how well and over what range of scenes this happens. The experiments reported here were designed to help us learn more. Methods: Observers viewed grayscale objects placed in an experimental chamber. The illumination in the chamber was provided by a single incandescent bulb, located near the top of the chamber and not directly visible to observers. On each trial of the experiment observers indicated which of two surfaces, located on two distinct objects, appeared to have a higher lightness. In judging lightness, observers were explicitly instructed to consider surface reflectance rather than the luminance of the reflected light. Across trials the reflectance of the test surface remained fixed, while the reflectance of the match surface was varied using a staircase procedure. We determined the point of subjective lightness equality, which we refer to as the match reflectance. Match surface reflectance was changed during an intertrial interval by substitution of identically shaped but differently painted match objects. The observer's view was occluded by a shutter during the intertrial interval. Results: When the test and match surfaces were both planar, match reflectances varied greatly as a function of match surface pose. Match reflectances also varied as a function of match object shape (planar, cube, or sphere), although the most striking effect here was a large increase in individual differences when the match object was a cube. Conclusion: The data indicate that there can be large failures of lightness constancy with respect to changes in object shape and pose. EY10016

Abstract 556 5:45 PM

Highest luminance defines illumination level as well as lightness

Alan L. Gilchrist & Suncica Zdravkovic Rutgers University

Converging evidence indicates that lightness is anchored by the highest luminance in a framework of illumination, not the average luminance. New findings indicate that the perceived level of illumination in the framework is also defined by the highest luminance and not the average luminance. We projected a spotlight across the upper half of a display consisting of five adjacent dark gray rectangles. Thus an illumination boundary with an obvious penumbra divided the display into a spotlit upper half and a roomlit lower half. Spotlight intensity was adjusted to equate the luminance of the lightest (middle gray) rectangle in the spotlight with a white surface in room light. Observers reported seeing a shadow on the lower half of five light gray rectangles, not a spotlight on the upper half of five dark gray rectangles. Thus, the part of the display that shared the same highest luminance with the room was seen as having the same illumination level as the room. For each rectangle, lightness matches made to the upper half and the lower half were very different. But matches made to each rectangle as a whole (by a separate group of observers) agreed with the matches for the spotlit parts, further indicating that the spotlit region was in fact seen as ambient illumination. Several additional experiments confirm that, in a 3D scene, separate planes appear to be equally illuminated when they are equal in highest luminance, not average luminance.

Supported by NSF grant: BCS-9906747 and PHS grant: S06GM08 223

Abstract 557 6:00 PM

Human observers do not correct perceived lightness for perceived orientation

Laurence T. Maloney, Huseyin Boyaci, & Sarah Hersh New York University, USA

In any scene where the illumination model is not perfectly diffuse, the amount of light reflected from a small achromatic surface patch may vary as the patch changes orientation. To the extent that a visual system actively discounts orientation in estimating lightness ('perceived albedo'), we would expect that errors in perceived orientation are paired with compensating errors in perceived surface lightness. We test whether human observers, asked to judge both the lightness and the orientation of achromatic surfaces, exhibit such tradeoffs in complex scenes designed to induce large errors in perceived surface orientation.
The stimuli were images of complex scenes, all rendered with identical punctate+diffuse lighting models, all containing identical specular and matte objects in the same locations. Each also contained a trapezoidal, achromatic, matte test patch. Only the shape of test patch and its albedo changed from scene to scene. The shape was altered so as to lead the observer to misperceive the orientation of the test patch (false perspective cues). We constructed 14 different scenes that differed only in the shape of the test patch (7 levels) and its albedo (2 levels). On each trial, observers first estimated the orientation of the gray rectangle by adjusting a gradient probe superimposed on the test patch and then matched the lightness of the patch to a standard gray scale. Observers made these two judgments 20 times for each of the 14 scenes in random order (280 trials). Five observers participated in the study.
Observers made large errors in judging the orientation of the test patch (up to 40 degrees) as anticipated. Their judgments of lightness were highly reliable but did not covary with perceived surface orientation, suggesting that, even in complex scenes, human observers do not correct perceived lightness for perceived orientation.

Supported by NIH/NEI grant EY08266 and HFSP grant RG0109/1999-B.

Abstract 558 6:15 PM

The role of oriented filters and T-junctins in White's effect

Branka Spehar, Colin W.G. Clifford, & Alan Johnston U. of New South Wales, Australia, U of Sydney, Australia, University CollegeLondon, UK

In White's Effect the gray target surrounded more by black than white appears darker than the target of the same physical luminance surrounded more by white than black. Blakeslee and McCourt (1999) have proposed a multiscale spatial filtering (ODOG) model of White's Effect while, according to Anderson (1997), the effect is the consequence of a perceptual scission

determined by the contrast polarity of aligned contours at T-junctions.

As consequence of its response normalization stage, the ODOG model predicts that White's Effect should be abolished if the ratio of horizontal to vertical structure in the image is equalized. To test this prediction we constructed a variant of White's stimulus in which the background consists of zig-zag rather than straight stripes. This new stimulus is also designed to eliminate any effects of T-junctions on the difference in perceived lightness between the gray patches lying on the black and white bars. All the target patches have T-junctions at each corner, two of which are black along the top and gray/white across the stem and two of which are white across the top and gray/black across the stem.

The magnitude and direction of the lightness illusion in the standard and novel White's stimuli were measured by adjusting the luminance of comparison patches on a variegated background to match the perceived lightness of the gray target patches. We found a highly significant illusion in the novel White's configuration in the same direction as the standard White's Effect. Simulations show that the ODOG filtering model predicts instead a small effect in the opposite direction. This result is also hard to reconcile with accounts based on the structure and distribution of junctions within the image.

Monday PM Talks (South Hall)
Perceptual Learning

Moderators: Barbara Dosher & Takeo Watanabe

Abst #	Time	Authors
559	3:00	Dosher, Lu
560	3:15	Watanabe, Sasaki, Náñez Sr, Koyama, Mukai, Hibino, Tootell
561	3:30	Fiser, Aslin
562	3:45	Gold, Bennett, Sekuler
563	4:00	Eckstein, Abbey, Shimozaki
564	4:15	Fine, Jacobs

Abstract 559 3:00 PM

Threshold power laws of perceptual learning decouple improvements in noisy and noiseless conditions

Barbara Anne Dosher & Zhong-Lin Lu U. of California Irvine, USA, U. of Southern California, USA

Previously, we reported improvements in perceptual task performance in a range of external noise contrasts [1-2] and claimed a mixture of approximately equal improvements in stimulus enhancement in low noise conditions and of improvements in external noise exclusion in high noise conditions. In this paper we describe a detailed analysis of improvements over blocks of training on a peripheral orientation discrimination task that clearly document performance improvements of different magnitude in a zero external noise and a high external noise condition. Observers identified a target S or 5 in a rapid letter string at fixation and also discriminated the orientation of a peripheral Gabor patch. Adaptive staircases measured contrast thresholds for 79.3% and 70.7% correct performance. After an initial pre-test of performance in zero and high noise conditions, observers were trained in different schedules of zero noise and high noise trials (high then low, or vice versa, etc.). (A) Training in either noise condition improved performance in both noise conditions. (B) Contrast threshold followed power laws of improvement (e.g., linear decreasing log contrast threshold as a function of log total practice blocks in all conditions) in both zero and high noise, but (C) the slopes of the functions differed sharply (larger reductions in high noise and smaller in low noise). This strong deviation in the power function slopes in zero and high noise with practice block is consistent with our original claims for decoupled stimulus enhancement and external noise exclusion. A simple linear amplifier model (LAM) with improvements due to improved 'efficiency' with practice requires identical slopes in zero and high noise, and is falsified. In contrast, an elaborated perceptual template model (PTM) [3] is supported. The results are consistent with perceptual learning through channel re-weighting [1-2].

1. Dosher & Lu, PNAS, 1998;
2. Dosher & Lu, VR, 1999;
3. Lu & Dosher, JOSA, 1999.

Support: NIMH, NSF.

Abstract 560 3:15 PM

Psychophysics and fMRI reveal V1 as the locus of passive learning

Takeo Watanabe, Yuka Sasaki, Jose E. Náñez Sr, Shinichi Koyama, Ikuko Mukai, Haruo Hibino, & Roger B. Tootell Boston U., USA, Massachusetts General Hospital, USA, Arizona State U. West, USA, Boston U., USA,Boston U., Chiba U., Japan, USA, Massachusetts General Hospital, USA

Recently we reported that the direction of "invisible" coherent motion was sensitized through repeated presentation. This indicates that in some cases perceptual learning is formed without attention directed specifically at a presented feature (Watanabe, Náñez & Sasaki, 2001; Nature). Here, we examined which stage(s) of visual processing is/are involved in passive learning. The first experiment (psychophysics) consisted of a training stage and pre- and post-test stages. In each trial of training, we presented stochastic random-dot cinematograms (SRDCs) in which a global motion flow is perceived in numerous dots moving spatio-temporally randomly within a certain range of directions, as an irrelevant stimulus. The subjects performed a RSVP task and orientation indication tasks while viewing the SRDCs. The global motion flow direction was constant for each subject. In test stages we measured the discriminability of 9 directions and found performance improvement after training only in the directions within which local dots moved in the training stage, irrespective of the global motion direction. The results indicate that passive learning occurred only at the local motion stage. In the second experiment, fMRI procedures (Siemens 3T) were used to specify the cortical area for the local and global motion. Motion displays where dots moved in completely random directions for 16sec were followed by an SRDC for 16sec. In each block this procedure occurred four times within 90 deg ranges in SRDCs covering a total of 360deg. There were 80 blocks in total in the experiment. No significant difference in

the amount of signals between the random display and SRDC conditions was found in V1, while signals were significantly higher in MT+ and V3a for the SDRC condition. The results suggest that local motion is mainly processed in V1 and global motion in higher stages. From the results of the two experiments, we concluded that V1 may be the neural locus of passive learning.

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Abstract 561 3:30 PM

Extraction of parts and wholes from multi-element scenes
József Fiser & Richard N. Aslin University of Rochester

Objects are often composed of two or more parts whose relative spatial arrangement can vary while the elements within parts remain invariant under a variety of 2- and 3-D transformations. What determines which configuration of individual elements gets encoded as parts in the absence of low-level mechanisms, such as the similarity or common motion of elements? Previously, we showed that human observers can learn the spatial configuration of shape-pairs or -triplets embedded within multiple exemplars of complex scenes. Passive observation of several dozen exemplars was sufficient for learning that some shape-pairs or -triplets that occurred consistently in the scenes comprised a set of base elements, whereas other shape-pairs or -triplets that occurred inconsistently comprised 'accidental coincidences'. In the present study we extended these findings by showing that shape-pairs are encoded differently depending on whether or not they are embedded in a larger part. Subjects viewed a series of 120 displays consisting of 6 elements in apparently random configuration, but constructed from one of two 4-element shape-quads and one of two shape-pairs (from an inventory of 12 simple shapes). Each scene was passively viewed for 2 sec. A 2AFC post-exposure test revealed that subjects could easily discriminate shape-pairs and shape-quads which were not embedded in shape-quads from the exposure set from novel configurations of shape-pairs and shape-quads [$t(19)=3.56$, $t(19)=4.16$, both $p<.001$]. However, discrimination was at chance for shape-pairs embedded in familiar shape-quads when compared to novel configurations of shape-pairs [$t(19)=0.78$, n.s.], despite the fact that they appeared the same number of times as the non-embedded pairs. This pattern of results suggests that instead of the successive build-up of larger parts from smaller parts, subjects are biased to extract the largest configuration of consistently co-occurring elements in multi-element scenes ('parts'), and that within an extracted larger configuration ('whole') the independent accessibility of embedded substructures is diminished.

Abstract 562 3:45 PM

Visualizing perceptual learning
Jason M. Gold, Patrick J. Bennett & Allison B. Sekuler
Indiana University, USA, McMaster University, Canada

Perceptual learning changes the efficiency of observers' internal calculations (1,2). However, the exact nature of those changes has remained a mystery. Here, we use response classification (3) to measure observer calculations directly as learning takes place. The result is a set of 'classification images' that reveal how the linear components of an observer's calculations change with learning. Observers identified unfamiliar low contrast versions of either two male faces or two abstract textures embedded in high contrast Gaussian white noise. For each stimulus type, there were 12 sessions of 800 trials per observer, conducted over the course of 2-3 weeks. Contrast thresholds were measured during each session with an adaptive staircase procedure, which also served to maintain the signal-to-noise ratio throughout the experiment. Thresholds improved by up to a factor of 5 across the first 6 sessions and changed very little during the last 6 sessions. The correlation between human and ideal classification images increased by up to a factor of 4 between the first and the last half of the experiment, reflecting the increase in calculation efficiency with learning. In addition, the number pixels that reached statistical significance ($p<0.01$) in the human classification images increased by as much as a factor of 2, indicating that at least part of the changes that took place with learning involved increases in the area over which information was used. These effects produced visible shifts in both the size and distribution of features within the classification images, and are consistent with previous findings of an improvement in calculation efficiency with perceptual learning.

1. Gold J, Bennett PJ, Sekuler AB, Nature 1999, 402:176-178.
2. Dosher BA, Lu ZL Vision Research 1999, 39:3197-3221.
3. Ahumada AJ, Lovell J, JASA 1971, 49:1751-1756.

Abstract 563 4:00 PM

Short term negative learning produced by monitoring erroneous templates
Miguel P. Eckstein, Craig K. Abbey, & Steve S. Shimozaki
UC Santa Barbara, UC Davis UC Santa Barbara

In the very early training stages of many perceptual tasks, an observer is uncertain about the specifics (e.g., size, orientation) of the signal and occasionally an observer's performance will get worse over a number of trials before starting to improve. What causes this effect? We investigate this effect using a rapid perceptual learning paradigm (RPL; Abbey et al., VSS, 2001). In RPL paradigm used in this study, sessions consisted of sets of 4 learning trials. At the beginning of a learning set, 1 of 4 possible targets (elongated oriented Gaussians) were randomly chosen and used throughout the set. On each trial, the target appeared randomly at one of 8 locations in visual noise. The observer's task was to localize the target. At the end of the 4th learning trial of each set, the observer also had to identify the target. The RPL paradigm allows to compare the amount of learning in humans to that of an optimal Bayesian observer which updates the weightings assigned to the perceptual templates as the learning trials progress. We investigated how the learning is affected by the observer's correct or incorrect identification of the target at the end of the 4th learning trial. All three observers studied showed an improvement in localization performance with learning trial number for the learning sets with correct target identification (~ 8.7 % from the 1st to the 4th learning trial) and also across all learning sets (~ 7%). However, learning sets in which the observers incorrectly identified the target resulted in a decrease in localization performance (~ 8 %). These results suggest that when an

observer is uncertain about the signal, occasionally the external noise (and potentially internal noise) provides the observer with evidence for the presence of an erroneous target. This causes the observer to monitor the incorrect template (as evidenced by the incorrect target identification) and produces negative learning.

Support: NIH-RO1 53455 , NASA NAG 9-1157

Abstract 564 4:15 PM

Perceptual learning and task complexity
Ione Fine & Robert A. Jacobs U. of California, San Diego, USA, University of Rochester, USA

Recent physiological studies show that while neurons in higher visual areas such as IT are highly experience dependent, neurons earlier in processing show much smaller changes in tuning with practice. We report here two studies examining how these differences in neural plasticity at different stages in the visual system correspond to improvements in performance with practice across different tasks. In the first study, we measured learning for spatial frequency discrimination using a simple plaid stimulus in which discrimination could be mediated by low level mechanisms tuned for both spatial frequency and orientation. Observers showed almost no learning. We then added noise components to the simple plaid stimulus to create a 'wicker' pattern that required the selective integration of information across a wide range of spatial frequencies and orientations. We found significant learning in this mid level task; over eight sessions of training, observers' thresholds dropped to a third of their initial values. In the second study we compared learning across a wider range of tasks using data compiled across sixteen published psychophysical experiments. The tasks in these experiments ranged from low level spatial frequency and orientation discrimination tasks to high level object and face recognition tasks. Since these experiments used a wide variety of performance measures, we converted the measured learning effects into a standardized learning index based on d' before and after practice. Consistent with the first study, we found that the amount of learning varies widely between different tasks, with less learning in low level tasks than mid or high level tasks. We hypothesize that a variety of factors affect learning, including the number of perceptual dimensions relevant to the task, external noise, familiarity and task complexity.
Supported by NIH grants R01-EY13149 & EY01711, NSF grant SBR-9870897, & Burroughs Wellcome LJIS.

Monday PM Talks (South Hall)
Face Perception I

Moderators: Marlene Behrmann & Elinor McKone

Abst #	Time	Authors
565	5:00	Behrmann, Marotta, Harel, Hasson
566	5:15	Rivest, Moscovitch
567	5:30	Kaping, Bilson, Webster
568	5:45	O'Donnell, Gosselin, Schyns
569	6:00	Wilson, Wilkinson, Loffler
570	6:15	McKone

Abstract 565 5:00 PM

Activation in fusiform gyrus is not correlated with face recognition: normal cortical activation with impaired face recognition in congenital prospagnosia
Marlene Behrmann, Jonathan Marotta, Michal Harel & Uri Hasson Carnegie Mellon University, USA, Carnegie Mellon University, USA, Weizmann Institute of Science, Israel, Weizmann Institute of Science, Israel

Although there is general consensus that specific parts of the ventral temporo-occipital regions are consistently activated in functional imaging studies of face processing, it is still debatable whether this activation is sufficient for face recognition. We have explored this issue in the context of a group of three adults (two of whom are family members) with congenital prosopagnosia in the absence of any discernible cortical lesion. On detailed behavioral testing, relative to matched control subjects, all subjects were impaired on the Benton and van Allen Facial Recognition test, showed significantly slower reaction time on matching faces presented from the same and from different viewpoints, showed a reduced face inversion effect and were impaired at recognizing famous faces, despite normal visual acuity, intact low level visual processing and normal cognition. All subjects were also slower than their controls on tasks of object recognition requiring subordinate categorization. In spite of these marked behavioral impairments, fMRI experiments revealed clear face-related activation in the fusiform gyrus in all prosopagnostic subjects. This activation parallels the pattern observed in normal subjects. We conclude that face-related activation in the fusiform gyrus is not sufficient for face recognition.

Abstract 566 5:15 PM

Face recognition in three people, each with a different disorder: prosopagnosia, object agnosia, and pure alexia.
Josée Rivest & Morris Moscovitch Baycrest Centre for Geriatric Care, Canada

What aspects of face recognition, if any, are spared in a prosopagnosic (DC) whose object recognition and reading are intact? We compared DC's performance with that of a person with object agnosia and pure alexia (CK, see Moscovitch et al., 1997), and with that of a person with only pure alexia (WK), because reading, like object recognition, is presumed to be mediated by a part-based processing system which may also be involved in some aspects of face-recognition, such as recognition of inverted and fractured faces. We also included a control, DCB, matched for social and educational background to DC (his 2.5-years-older brother). DC could recognize only about 37% of all upright full-viewed faces, whereas CK, WK and DCB recognized about 80% of them. When these faces were inverted, DC and CK were impaired (9% and 14%) compared to DCB and WK (50% and 70%). For DC, this inversion weakness was true whether the internal or external facial features were inverted, but for CK, WK, and DCB, it was only true when the internal parts were inverted. When the faces were disguised and when parts were missing, DC only recognized about 27% of them, whereas CK, WK, and DCB had no difficulty. Only CK and DC were impaired on recognizing fractured faces. We conclude that (1) only the part-based object system contributes to some aspects of face

recognition; (2) it does so by interacting with an intact face-system; and, (3) damage to the face system leads to global face recognition deficits.

Supported by NSERC grant 0155930 (JR) and NSERC grant A8347 (MM).

Abstract 567 5:30 PM

Adaptation and categorical judgments of faces

Daniel Kaping, Aaron C. Bilson, & Michael A. Webster
University of Nevada, Reno, University of Nevada, Reno, University of Nevada, Reno

Variations in faces are often judged and classified in terms of discrete categories (e.g. identity, gender, race, and emotional expression). We examined how the boundaries defining these categories can be influenced by prior adaptation to images within a given category, in order to test whether adaptation effects can be manifest for the types of natural variations and judgments typically involved in face perception. Stimuli were frontal-view images of faces taken from the Ekman and Matsumoto image set. Pairs of faces were morphed (Gryphon Morph v. 1.5) to form a finely graded series of images that varied between two genders, expressions, identities, or ethnicities (Caucasian and Japanese). Observers initially adapted for 1 to 3 minutes to one of the two original faces, and then made a forced-choice classification of a composite morphed image (e.g. responding male vs. female, or happy vs. angry). The proportion of the two faces making up the morph was varied over trials in a staircase to define the category boundary at which the two judgments were equally likely. Adaptation produced strong shifts in category boundaries toward the adapting image, so that the original neutral point appeared biased away from the adapting image and thus toward the second, more novel image. For example, after adapting to a male face or an expression of surprise, a face that was previously judged to be neutral was rated as female or happy, respectively. These adaptation effects are consistent with a renormalization of facial categories according to the observers' recent visual experience. The fact that large aftereffects can rapidly occur for natural and common variations in faces suggests that adaptation may routinely influence face perception in everyday viewing.

Supported by EY-10834

Abstract 568 5:45 PM

The acquisition of facial expertise and how that mediates the information utilized to recognize the face.

O'Donnell, C.,Gosselin, F. and Schyns, P. G University of Glasgow, University of Montreal, University of Glasgow.

It is well established that the information required to recognize a novel face is markedly different from that utilized to recognize a face that we have expertise in. However, what has yet to be addressed is the process of expertise acquisition and its effect on the utilization of the available facial information as expertise increases over time. To address this is issue, we used Bubbles (Gosselin & Schyns, 2001), a technique developed to allow categorization performance to be assigned to specific image information.
In Experiments 1 and 2, we induced expertise by presenting observers with dynamic video sequences of 10 new identities that they were instructed to learn to a criterion of 100% correct. Expertise training was given on six consecutive sessions. Following each "expertise" session observers were presented with a Bubbles paradigm task on either upright or inverted face pictures (full frontal view) different from those used in the dynamic video sequences. The experimental stimuli were computed by randomly sampling with Gaussian bubbles either a 2D image plane (Experiment 1) or a 3D space composed of a 2D image plane and 5 non overlapping spatial frequency bandwidths of one octave each, starting at 90 cycles per face (Experiment 2). Observers had to identify the individuals they had just learned through these sparse stimuli.
In both experiments, we examined the use of the available face information, revealed by the Gaussian bubbles, with first and second order analyses. First order (local) analyses examined how each bubble drove performance, whereas second order (holistic) analyses examined bubbles conjunctions. The analyses revealed 1) an increasing tendency to use the optimal local and holistic information with increasing expertise, and 2) large upright vs. inverted effects in the local and holistic information utilized

Abstract 569 6:00 PM

Configural masking of geometric information in synthetic faces

Hugh R. Wilson, Frances Wilkinson & Gunter Loffler Centre for Vision Research, York University, Canada

We have recently developed a novel class of faces for visual experimentation. Each synthetic face is characterized by a set of 37 measurements taken from a digital photograph in either front or 20 side view, and the resultant face is optimally bandpass filtered (10 cycles/face width, 2.0 octave bandwidth). Previous experiments showed that the metric for face discrimination is Euclidean. Here we use pattern masking to explore the temporal dynamics of face discrimination.

In each experiment a synthetic face was flashed for 27 ms and was followed after a variable delay by either a noise mask, face mask, inverted face mask, or house mask. The subject then had to select which of two faces appearing on the screen had been presented. Masking by faces greatly disrupted face discrimination within a 140 ms window following stimulus presentation. Inversion of the masking face reduced this masking by half. Strikingly, however, noise had no masking effect at any delay for high contrast target faces. Reducing synthetic face contrast to 10% did lead to noise masking, but only when the noise immediately followed the target face. Finally, houses produced no masking at all.

These data can only be explained by configural pattern similarity and not by degree of contour overlap, thus indicating an extrastriate masking locus (perhaps FFA). Noise masking at low face contrasts, on the other hand, is consistent with a V1 locus for noise masking. The 140 ms required for optimal discrimination of synthetic faces provides sufficient time for feedback loops between higher cortical areas to play a role in face processing.

Supported in part by NSERC grants to HRW & FW.

Abstract 570 6:15 PM

Isolating the holistic component of face recognition.

Elinor McKone Australian National University, Australia

Several paradigms have demonstrated a qualitative difference between the processing of faces and other classes of visual stimuli: upright faces are processed as wholes, while other objects and inverted faces are processed as a collection of separable parts. Thus, it has been argued that holistic processing makes faces "special". The aim of an ongoing project is then to study holistic face processing directly, independent of confounds with part-based contributions to recognition. With standard experimental methods, this isolation is difficult to achieve. However, the existence of a brain-injured patient who retains only holistic processing for faces (CK can recognise upright whole faces, but not inverted faces or objects, Moscovitch et al., 1997) suggests that it should be possible. In McKone, Martini & Nakayama (2001), we introduced a first experimental technique that isolates holistic processing in normal subjects (based on categorical perception of face identity in noise). Here, I describe two very simple techniques that achieve the same aim – one based on identification accuracy with peripheral presentation, and one based on Mooney faces. Each produces good performance for upright whole-face stimuli, together with chance performance for inverted faces and for single face parts; for example, it is possible to find a stimulus position in the periphery where identification of upright faces is still good, but identification of the same faces inverted is completely at chance. To demonstrate the power of these techniques, I describe their use in exploring two properties of holistic face processing, namely its orientation tuning (with image plane rotation) and size tuning. Results have implications for theories of pattern recognition in general, and of face recognition in particular.

Tuesday

Tuesday AM Talks (North Hall)
Attention and Eye Movements

Moderators: Jay Edelman & Dana Ballard

Abst #	Time	Authors
571	8:30	Ballard, Sprague
572	8:45	Wyatt, Morrone, Ross
573	9:00	Simion, Scheier, Shimojo, Shimojo
574	9:15	Yang, McConkie
575	9:30	Edelman, Cherkasova, Nakayama
576	9:45	McPeek, Keller

Abstract 571 8:30 AM

Attentional resource allocation in extended natural tasks
Dana H. Ballard & Nathan Sprague U. of Rochester, U. of Rochester

To ambulate in an urban environment, we face the management of many simultaneous tasks, such as walking on a sidewalk, avoiding pedestrians, and crossing busy streets. The management of simultaneous tasks has been studied extensively, but those studies tend to focus on attentional loading in reaction time experiments that use stimulus presentations of less than one second. As a result, little is known about how attention is managed in extended natural tasks that take on the order of many minutes. The current study addresses the extended allocation of visual attention. We study the gaze control and locomotion control for a virtual humanoid agent walking in a realistic simulated urban world. The agent's behaviors are directed by visuo-motor routines that each handle a single well-defined task, such as staying on the sidewalk or avoiding an obstacle. The key element in our model is that behaviors ask for and are given access to the body on a probabilistic basis. The probabilities are continually adjusted to reflect the contingencies produced by the environment. The gaze access period is adjusted to reflect the modal time of human fixations in similar tasks. The locomotion access period is adjusted to fit human performance data. Such a model can explain how different behaviors can compete for both eye gaze resources in addition to locomotion resources of the body in a seamless manner. In our simulation, the humanoid walks along a crowded sidewalk and crosses streets. During this time the instantaneous allocation of resources to gaze and ambulation are recorded. To test our model, we have human subjects doing the same task. Humans wear head-mounted displays that allow them to navigate in the same virtual environment. Six-dof head-tracking as well as eye-tracking in the HMD allows us to compare the use of gaze and locomotion by the human subjects with our model. Our initial results suggest that the probabilistic allocation of resources is a good fit to the human data.

Abstract 572 8:45 AM

A blinding flash increases saccadic compression
Anna Ma-Wyatt, M. Concetta Morrone, and John Ross The University of Western Australia, Australia; Universita' Vita-Salute S. Raffaele, Italy; The University of Western Australia, Australia

Background Compression of space is found for targets flashed just before saccades, but not when they are flashed in the dark. Recently it has been suggested that compression depends on the availability of visual references after saccades (Lappe, Atwater and Krekelberg, 2000). Compression also depends on the method of reporting position, under some conditions being found for verbal report but not for blind pointing (Burr, Ross and Morrone, 2001). Methods and Results Subjects made a 15 horizontal saccade. A blue bar was briefly presented before the saccade. Stimuli were displayed on a touch screen, viewed through a liquid crystal shutter that closed at a variable delay (from 20-320ms) after the start of saccades. Subjects were tested with or without a bright flash after the shutter closed. Closing the shutter removed visual references and, without the flash, rendered the scene dark. The flash was perceived as bright glare, providing light but not restoring visual references. Subjects indicated the perceived position of the bar by verbal report or by touching the screen with a hidden hand. In the flash conditions, strong compression was found both for verbal report and for blind pointing, even at the shortest shutter

latencies. In the non-flash conditions compression was found for verbal report at most latencies and for pointing only at longer latencies. Conclusions Results from the flash experiment show that compression does not depend entirely on the availability of visual references. Results at different shutter delays without the flash show that the rapid onset of darkness is necessary for veridical pointing.

Acknowledgements: This work was supported by the Human Frontiers Science Foundation, the Australian Research Council and the Italian Ministry of Universities and Research

Abstract 573 9:00 AM

What We See Is What We Like – Intrinsic link between gaze and preference

Simion, C, Scheier, C, Shimojo, E, & Shimojo, S Biology, California Institute of Technology, USA, Computation and Neural Systems, Caltech, USA, Bunkyo Women U., Japan, NTT Comm. Sci. Lab., Japan

Deciding whether we like someone or something has profound influences on our attitudes and social behavior. Here we investigate how such cognitive/emotional decisions are related to perceptual-motor behavior such as gaze.
Using eye-tracking to measure gaze direction, our past experiments (VSS 01) revealed a bias when subjects compared two faces for attractiveness (faces in a pair were matched for baseline attractiveness). Specifically, the preferred face was looked at for longer time with the bias gradually and significantly increasing from chance level (50%) to 84% just prior to decision, revealing a "cascade effect". Thus, a cognitive causal pathway (we see an object more because we like it more) and a perceptual-motor pathway (we like it more because we see it more) seem to form a feedback loop, which precedes and ultimately results in, a conscious preference decision.

The present study examines the robustness and generality of this "cascade effect" in several different directions. We show that the effect is preserved, when (a) subjects are asked to compare faces that are significantly different in base attractiveness, (b) when they compare slightly modified versions of the same face, and when (c) the stimuli to be compared are abstract shapes (Fourier-descriptor generated figures) rather than faces.
The "cascade effect" was reflected in a gaze bias curve. Its shape in all cases could be captured with a 4 parameter sigmoid. Moreover, the saturation level of the sigmoid correlates positively with the difficulty of the task. This suggests that the fewer differential or cognitive cues available, the more subjects need to rely on the cascade mechanism to make their decision. We conclude that cognitive and perceptual-motor processes interact in preference judgments, and that the influence of the latter is more significant when cognitive factors are minimized.

Acknowledgements: this work was supported by California Institute of Technology.

Abstract 574 9:15 AM

The influences of reading direction on inhibitory control of eye movements

Yang, S.-N. & George W. McConkie Beckman Institute, University of Illinois at Urbana-Champaign

Since written language is linear, eye movements in reading are constrained to largely follow that direction. Difficulties in reading modify the pattern of eye behavior, typically prolonging eye fixation times, shortening forward saccades and increasing the number of regressive movements. These changes are usually attributed to direct cognitive control of eye behavior, moving the eyes to locations from which information is needed to resolve the difficulty. However, Yang & McConkie (2001, Vision Research) have argued for indirect cognitive influences, mediated by different types of inhibitory signals produced by the detection of processing difficulty and acting upon a bilateral system, probably involving the superior colliculus. The current study tested this proposal by comparing the eye movements of skilled Chinese readers as they read horizontal text and vertical text, both directions being highly familiar. As they read, during occasional saccades the text was replaced by alternate stimulus patterns with the normal text returning during the following saccade. These single-fixation stimulus patterns signaled the reader to make specific intentional saccades (forward, regressive, or stop). The effects were observed on the timing and directions of the saccades ending these critical fixations. The results indicate that 1) the oculomotor system uses automated and controlled inhibitory signals to regulate saccade generation, 2) inhibitory signals are directionally selective, only being applied to the forward direction, 3) the direction of eye movements affects saccade latencies, and 4) the direction of reading affects direction-selectivity by producing bi-directional effects on saccade generation. These results provide information about how the oculomotor system produces responses to reading difficulty and task demands during reading.

Abstract 575 9:30 AM

A spatial memory system for the guidance of eye movements in crowded visual scenes

Jay A. Edelman, Mariya V. Cherkasova, & Ken Nakayama Harvard University, USA, Beth Israel Deaconess Medical Center, USA, Harvard University, USA

The primary purpose of saccadic eye movements is to bring the image of visual objects of interest onto the fovea. However, this does not imply that all purposive saccades in a visual environment are visually guided, since visual crowding can render less salient objects in a visual scene invisible if they are located far from present gaze. Moreover, after repeatedly fixating such a non-salient element in a visual scene one senses that one's eye lands right on the target, despite its invisibility. We sought to confirm this phenomenological finding by recording saccades of 3 subjects using an S-R Eyelink video eyetracker (250 Hz) while they made saccades in a complex visual scene displayed on a computer monitor (~40 x ~30 deg). Prior to recordings, subjects freely viewed the display and were told the identity of possible saccade targets in the scene. In the invisible task, initial fixation position was varied trial-by-trial in a region from which all possible targets were invisible due to crowding and distance. Target was held constant within a block of 16 trials, and performance on the last 8/16 trials was analyzed. Saccade endpoint errors and peak velocities in the invisible task were compared with those in visually guided and

memory-guided delayed tasks. Phenomenology was confirmed: metrics in the invisible task were comparable to the visually guided task, whereas memory-guided saccades had greater endpoint errors and lower peak velocities. Additional experiments demonstrated that up to 3 targets could be stored simultaneously in this memory system. These results suggest that a scene-based memory system enables the generation of saccades to invisible targets as if they actually were visible. Such a system could prove useful both for the continuous monitoring of non-salient objects in a crowded visual scene and for refixating more salient stimuli without having to tax peripheral visual processing.

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Abstract 576 9:45 AM

Deficits in saccade target selection after temporary inactivation of superior colliculus

Robert M. McPeek & Edward L. Keller The Smith Kettlewell Eye Research Institute, USA

During tasks which require selecting one eye-movement target from among several possibilities, neurons recorded in the primate superior colliculus (SC) show responses consistent with a role in saccade target selection. However, it is possible that this SC activity is merely a passive read-out of target-selection processes occurring in cortical areas that project to the SC, such as the frontal eye field (FEF) and lateral intraparietal area (LIP). In order to determine whether the SC plays an active role in the target selection process, we induced changes in SC activity (using small injections of lidocaine or muscimol) and tested subsequent performance in single-target and target-selection tasks. When a single saccade target is presented inside the portion of the visual field affected by the injection, monkeys show relatively minor motor impairments, including smaller saccade amplitudes, lower movement velocities, and longer latencies. If the SC were not involved in saccade target selection, and were merely involved in movement execution, impairments in the target-selection task would be similar to those seen with a single stimulus. However, we found that local inactivation of the SC causes major target-selection deficits in a pop-out visual search task: when the target is presented inside the affected field, monkeys execute relatively accurate saccades, but the saccades are often directed to a distractor stimulus rather than to the target. No deficits are seen when the target is presented outside the affected field. Control experiments show that the target-selection deficits are not due to a low-level visual impairment within the affected field, nor can they be explained as a simple motor impairment, since saccades to single stimuli in the affected field can still be made. These results indicate that the SC plays an active, functional role in the network of brain areas underlying saccade target selection.

Supported by NIH EY06860

Tuesday AM Talks (North Hall)
Eye Movements and Mechanisms

Moderators: Jeffrey Mulligan & Stephen Heinen

Abst #	Time	Authors
577	10:30	Mulligan
578	10:45	Lindner, Ilg
579	11:00	Heinen, Kim
580	11:15	Schiller, Tehovnik
581	11:30	DeSouza, Everling
582	11:45	Miller, Bockisch

Abstract 577 10:30 AM

A model of oculomotor tracking suggests a biphasic motion response

Jeffrey B. Mulligan NASA Ames Research Center

We are currently attempting to use eye movement recordings to observe details of the time course of visual processing. Previously, we have used a correlogram analysis to quantify changes in pursuit arising from changes in color and contrast (ARVO '98). In this paradigm, an observer attempts to maintain fixation on a randomly moving target. Next, the smooth "de-saccaded" component of the eye velocity is cross-correlated with the stimulus velocity, and the resulting signals are averaged for many different random stimuli. This average signal may be thought of as the impulse response of the smooth pursuit velocity to stimulus motion. Curiously, this impulse response is sometimes biphasic: 150 msec after a rightward target motion, the eye may move to the right, but 50 msec later move in the opposite leftward direction. One possible explanation is that we are seeing a consequence of the biphasic temporal impulse response of the visual system (the negative lobe of the contrast response producing a "reverse-phi" effect). Another hypothesis is that this result is somehow artifactual, perhaps resulting from the saccade-cutting procedure. To help discriminate between these possibilities, and better understand the correlogram analysis, we have constructed a computational model of oculomotor tracking. The model has two inputs (sensed position and velocity) and outputs a smooth velocity and, depending on the parameter settings, saccades. In its simplest form, pursuit is a delayed and attenuated version of the stimulus velocity, and saccades are made when the position error exceeds a threshold. (A more sophisticated pursuit model will eventually be substituted, but is unlikely to influence the effect of saccade cutting.) A large variety of behaviors can be simulated, none of which result in a biphasic correlogram. We therefore conclude that the biphasic correlograms are not an artifact of the analysis but may reflect the inner workings of visual motion processing.

supported by NASA RTOP 711-51-12.

Abstract 578 10:45 AM

Cancellation of gaze stabilizing mechanisms during human smooth pursuit: Indications for the involvement of an extra-retinal reference

Axel Lindner & Uwe J. Ilg U. of Tuebingen, Germany, U. of Tuebingen, Germany

When our eyes are tracking a target that is moving in front of a structured background, background image motion is induced in the opposite direction. Usually, such global image motion is an appropriate stimulus to drive gaze stabilizing mechanisms, which in turn would counteract the voluntary eye movement. We have previously demonstrated, that during human smooth pursuit eye movements (SPEM) the sensitivity for full-field motion is reduced strongly - but only in the direction opposite to the eye movement (Vision Res. 2001; 41:1685-94). Although these results provided an explanation for the accuracy of SPEM despite self-induced motion the mechanisms underlying this asymmetry in global motion processing remained unclear.
To come up with an answer we employed brief and unexpected background motion (20 /s) during horizontal SPEM (10 /s). Background motion could be either 'in-phase' or 'counter-phase' with respect to the direction of SPEM. In exp. 1 the SOA of background motion was varied between 0, 100 and 200ms with respect to target motion onset (thereby varying relative motion between target and background during SPEM initiation). As in our previous experiments a background induced perturbation in SPEM velocity occurred in 'in-phase' conditions, only. Therefore this asymmetry significantly depended on the phase relation between background motion and SPEM direction ($p<0.001$) but not on the SOAs and related relative motion ($p>0.5$; ANOVA2). In exp. 2 the pursuit target was briefly extinguished during background motion. Although now any relative motion between target and background was absent the effect of 'phase' was still present ($p<0.001$) and did not significantly differ from trials without target extinction ($p>0.5$; ANOVA2).
The asymmetry in global motion processing cannot solely be attributed to a visual mechanism, i.e. relative motion. This implies that the cancellation of gaze stabilizing mechanisms critically depends on extra-retinal information on SPEM direction.
Supported by DFG (GK Neurobiologie to AL; Heisenberg to UJI)

Abstract 579 11:00 AM

A neuronal correlate of trajectory prediction in the supplementary eye fields

Stephen J. Heinen, & Yong G. Kim Smith Kettlewell Eye Res. Inst., USA, Sejong Uni., South Korea

Neural systems employ predictive strategies to reduce behavioral response times. The supplementary eye fields (SEF) have been implicated in predictive oculomotor behavior based on remembered target motion from a previous trial. We asked whether SEF neurons could predict ongoing target motion, the trajectory of which was relevant for upcoming oculomotor behavior. To do this, we used an "ocular baseball task" previously employed to explore movement preparation activity (Kim and Heinen, 2001). The task involved having a monkey fixate and view an illuminated spot target that began to move on a screen in the peripheral visual field. If the trajectory of the spot crossed an illuminated "strike" zone that surrounded the fixation point, the monkey had to use a pursuit eye movement to follow it. If the target bypassed this zone, the monkey had to suppress pursuit and maintain fixation. Eye movements and single-unit activity in the SEF were recorded from two rhesus monkeys that performed the task. It was found that the monkeys could extract trajectory information from the approaching target as evidenced by short-latency ocular behavior. Some SEF neurons were recorded with activity related to pursuit movement preparation and suppression, as reported in the past. However, the activity of other neurons appeared to predict the trajectory of the target, but did not consistently predict the animal's behavior. The results suggest that the predictive role of the SEF is to provide high-level visual signals that can be used to guide oculomotor behavior.

Supported by: NIH(EY11720-05)

Abstract 580 11:15 AM

The role of cortical inhibitory circuits in target selection with saccadic eye movements

Peter H. Schiller & Edward J. Tehovnik MIT, USA, MIT, USA

In work reported last year at this meeting we had shown that subthreshold microstimulation in V1, V2, LIP, FEF and MEF of monkeys can variously produce facilitation, interference, and delays in saccade initiation, thereby identifying some of the essential neural computations carried out in the process of target selection with saccadic eye movements. We now report the effects of local administration of the GABA antagonist bicuculline and the GABA agonist muscimol on this process. Following fixation, monkeys had the free choice of selecting one of two identical targets presented with various temporal asynchronies, with one placed into the receptive or motor field of the neurons treated with the pharmacological agents. Also tested were the brightness, color and shape discrimination abilities at intact and affected sites. Bicuculline produced a high level of facilitation in the choice of the target appearing in the receptive and motor fields of the neurons in the FEF but yielded major interference in V1. Bicuculline also produced deficits in brightness, color and shape discrimination at the injected sites in V1 but not in LIP and the FEF. Muscimol in V1 produced dramatic interference in target selection as well as in visual discrimination whereas in the FEF it produced only moderate interference. Our results suggest that (1) GABAergic inhibitory circuits in V1 play a central role in the analysis of visual stimuli, (2) Signals for the generation of eye movements in V1 appear to be produced not by disinhibition but predominantly by excitation, (3) in the FEF disinhibition is a central process for initiating eye movements and (4) inhibitory circuits in the FEF do not appear to be central for visual analysis.

Supported by the National Eye Institute under grant EY008502.

Abstract 581 11:30 AM

Neural correlates for preparatory set associated with pro-saccades and anti-saccades in humans investigated with event-related fMRI.
Joseph F.X DeSouza & Stefan Everling Department of Physiology, University of Western Ontario, London, Ontario, Canada, N6A 5C1.

We sought to discover exactly when does the fMRI signal differ as subjects are planning to execute a pro-saccade or an anti-saccade. Thus as subjects waited prolonged instruction periods (6, 10 or 14-seconds) prior to the onset of a peripheral visual cue to execute either the pro- or anti-saccade, we examined the fMRI signal in various areas along the saccade network. The cortical regions examined were visual cortex (V1/V2), intraparietal sulcus (IPS), frontal eye fields (FEF), supplementary eye fields (SEF), and dorsolateral prefrontal cortex (DLPFC). The instruction to plan either a pro- or anti-saccade was conveyed by changing the color of the fixation cross from white to green (pro) or red (anti). A simultaneous peripheral cue and offset of the central fixation cross cued the subject to execute the appropriate eye movement. The cortical areas were functionally mapped using the general linear model comparing pro- and anti-saccade blocks to fixation blocks ($p(\text{corrected}) < 0.001$). We used these maps to define the brain areas and then examined the single trial event-related signal from each subject's scans. When the single eye movements were aligned to the onset of the instruction cue, the signal for visual areas showed no differences during the instruction period across subjects. More importantly, bilateral FEF, SEF and right hemisphere DLPFC & IPS showed an increased signal during the instruction period planning an anti-saccade as compared to a pro-saccade ($p < 0.05$). When data was aligned to the movement cue and the instruction period activity was removed, there were only signal differences between anti- and pro-saccades in bilateral SEF and left hemisphere FEF & V1/V2. This suggests that the larger signal for the preparatory set we have shown during anti-saccades preparation may have contributed to a larger baseline signals and thus greater activation patterns during the anti-saccade block designs that were found in many previous imaging studies. Supported by Canadian Institutes of Health Research & National Alliance for Research on Schizophrenia and Depression.

Abstract 582 11:45 AM

No oculomotor final comon path
Joel M Miller & Christopher J Bockisch Smith Kettlewell Institute, USA, Neurol Universitaetsklinik, Switzerland

For a given position of the eye in the orbit, most abducens motoneurons (LRMNs) fire at higher rates in converged gaze than when convergence is relaxed (Gamlin et al 1989; Mays and Porter 1984; Zhou and King 1998), implying that lateral rectus (LR) muscle force will be higher for a given eye position in convergence. If medial rectus (MR) muscle force balances LR force, it too would be higher in convergence, that is, LRMN recording studies predict horizontal rectus co-contraction in convergence. Three trained rhesus monkeys with binocular eye coils and custom muscle force transducers (MFTs) on LR and MR of one eye alternately fixated near (~7 cm) and far (200 cm) targets with vergence movements of 20-30 . Tonic muscle forces were also measured during conjugate fixation of far targets over a 30 x 30 field. MFT characteristics and effects on oculomotility were assessed. Contrary to predictions, we found small (< 1 g) decreases in both LR and MR forces in convergence, for those gaze positions that were used in the brainstem recording studies. This missing LR force paradox (higher LRMN firing rates in convergence but lower LR forces) suggests that motoneurons or muscle fibers contribute differently to oculorotary forces in converged and unconverged states, violating the final common path hypothesis. The absence of MR co-contraction is consistent with, and supports, the missing LR force finding. Resolution of the missing LR force paradox might involve nonlinear interactions among muscle fibers (Goldberg et al 1997), mechanical specialization of muscle fibers and other articulations of the peripheral oculomotor apparatus (Demer et al 2000; Miller 1989), or extranuclear contributions to muscle innervation (Büttner-Ennever et al 1998).

Supported by the Smith-Kettlewell Eye Research Institute, National Eye Institute consortium grant EY-08313 to Joseph L Demer and Joel M Miller, and National Eye Institute grant EY-13443 to Joel M Miller.

Tuesday AM Talks (South Hall)
Cortical Interactions

Moderators: A.B. Bonds & Anna Wang Roe

Abst #	Time	Authors
583	8:30	Godwin, Kurukulasuriya
584	8:45	Hoffmann, Morland, Moore, Tolhurst
585	9:00	Brown, Allison, Samonds, Bonds
586	9:15	Hung, Ramsden, Wang
587	9:30	Smith, Williams, Singh
588	9:45	Lappin,Borghuis, Tadin, Lankheet, van de Grind

Abstract 583 8:30 AM

A new spin on the brainstem: NO redirects the data stream in the LGN
Dwayne W. Godwin, Nuwan C. Kurukulasuriya, W. Breckinridge Carden and Jian Mu Wake Forest University School of Medicine, USA

An important determinant of information flow through the lateral geniculate nucleus of the thalamus (LGN) is the cholinergic/nitrergic projection from the parabrachial brain stem (PBR). The PBR has a well-characterized cholinergic influence on information transmission, mainly through depolarization of the LGN membrane and inactivation of the low threshold calcium current (T current). A unique gaseous transmitter, nitric oxide (NO), is also released by the PBR, but its function in vision is unclear. PBR terminals are associated with glutamatergic synapses in the LGN, thus we hypothesized

that NO may influence excitatory neurotransmission as well as the intrinsic membrane properties of LGN cells. Using intracellular recordings in LGN brain slices, we have studied excitatory postsynaptic potentials and currents (EPSPs/EPSCs) elicited either from the retinogeniculate (RG) or the corticothalamic (CG) pathway. Both RG and CG EPSPs are mediated by an early, non-n-methyl-d-aspartate (NMDA) component, and a later component that is sensitive to APV and mediated by NMDA receptors. NO generation within the LGN affects synaptic transmission in a unique way: RG synaptic inputs are reduced, while CG inputs are enhanced. At the same time, the T current is inhibited in a voltage-independent manner. Our findings suggest a new role for the reticular activating system in the control of visual information through the LGN. Activation of bNOS and resultant NO generation during visual processing may dynamically change the balance of information processing from a peripherally driven stream, to one that is more receptive to information carried by corticothalamic feedback loops - at a time when the relay cell membrane is in a more linear processing mode. Supported by EY11695.

Abstract 584 8:45 AM

Retinotopic organization of the visual cortex in human albinism

M.B. Hoffmann, A.B. Morland, A.T. Moore, & D.J. Tolhurst
Royal Holloway Univ. London, Royal Holloway Univ. London, Addenbrooke's Hospital Cambridge, Univ. Cambridge UK

Purpose: The albino visual cortex receives an unduly large input from the ipsilateral visual field (Guillery, 1986; Morland et al. 2002). To investigate how the visual cortex of humans albinos organizes this abnormal input we applied retinotopic mapping fMRI procedures. Methods: Two subjects with albinism and only small nystagmus and two control subjects underwent T2* MRI scanning of the occipital lobe during visual stimulation. In separate experiments we stimulated monocularly the nasal and temporal retina with a 'wedge' or 'annulus' of a phase reversing (6Hz) chequerboard pattern that stepped through polar angles or eccentricities respectively (Engel et al., 1997). Seven 36 s cycles of the stimulus were presented. Eight 128 x 128 voxel images (voxel size: 1.8 x 1.8 x 4 mm) perpendicular or parallel to the calcarine sulcus were acquired every 3 s. fMRI signals were projected to the flattened representation of T1 weighted images, Fourier analysed and correlated with the stimulus fundamental frequency. Results: Retinotopic mapping yielded phase maps that allowed the identification of V1 and other early visual areas in both controls and albino subjects. In the controls V1 comprised a representation of the contralateral visual field, while it comprised a representation of both the contralateral and the ipsilateral visual field in the albino subjects. Here the normal contralateral and the abnormal ipsilateral representations are, at the resolution of fMRI, arranged as overlaid maps. We obtained evidence for a similar arrangement in other early visual areas (V2 dorsal/ventral, VP). Conclusions: These results provide evidence for the presence of the "true" albino-pattern in human subjects with albinism. This pattern has previously been described in albino cats and one albino monkey.
Guillery RW (1986) TINS 9:364-367; Engel AS et al. (1997) Cerebral Cortex 7:181-92; Morland et al. (2002) JNNP (in press)

Abstract 585 9:00 AM

Area 18 contribution to spatial integration of receptive fields of area 17 cells in the cat.

HA Brown, JD Allison, JM Samonds, & AB Bonds Vanderbilt University, USA, Vanderbilt University, USA, Vanderbilt University, USA, Vanderbilt University, USA,

A stimulus placed outside the classic receptive field (CRF) of an Area 17 cell does not evoke an excitatory response. However if the CRF is stimulated to excite the cell, a second stimulus placed in the periphery can modulate this baseline activity. Does the integration of modulating influences arise in Area 17 alone? In cats paralyzed and anesthetized with Propofol and N2O, we investigated whether modulation of the response of Area 17 cells by peripheral stimulation originated from Area 18. We inserted a tungsten electrode in Area 17 ("central") and a multi-barrel injection and recording pipette in Area 18 ("peripheral") and identified sites with non-overlapping RFs. Optimal stimulus parameters for the Area 17 cell were determined and a control orientation tuning (OT) curve was measured. We then optimized stimulation parameters for the Area 18 site and verified that iontophoretic administration of GABA (0.5 M) silenced the response to that stimulus. To determine the influence of the peripheral site on the response of the Area 17 cell, both sites were stimulated simultaneously and the OT curve was remeasured. In 6/12 cases, peripheral stimulation suppressed the central response and GABA was administered to block the Area 18 activity. If the suppression were originating from Area 18, the blockade would eliminate the peripheral influence and the response of the Area 17 cell would return to control levels. In 4/6 cells, the OT curve returned to control levels during the Area 18 blockade indicating that Area 18 activity was responsible for most, if not all of the peripheral influence of Area 17 cells. The response of each cell returned to suppressed levels after GABA reuptake and returned to control values when the peripheral stimulus was removed. This result supports our hypothesis that Area 18 makes a major contribution to the widespread integration of information by Area 17 receptive fields.

Supported by NIH EYR0103778, NIH Training Grant EY07135

Abstract 586 9:15 AM

Seeing with prejudice: Inherent biases in connectivity between oriented and luxotonic cells

Chou P. Hung, Benjamin M. Ramsden, & Anna Wang Roe
Yale University

Recent evidence has demonstrated that the cortex can exhibit the same patterns of oriented activity during presentation of a blank screen (spontaneous 'ongoing' activity) as during presentation of a grating stimulus (c.f. Tsodyks et al. Science 1999). Here, we have made paired electrode recordings between oriented cells and luxotonic cells (cells responsive to large full-field flashes) in Area 17 and 18 of cats.

We present evidence that spontaneous 'ongoing' activity is not a flat baseline of activity, but an inherently biased network of interactions. We find such biased interactions between oriented and luxotonic cells in Areas 17 and 18. Luxotonic cells, which have been suggested to encode luminance, illuminance, and lightness constancy, tend to fire 5 to 10 milliseconds before nearby (< 5 deg in V1) oriented cells. This bias is present during spontaneous activity as well as during surface brightness modulation (oriented cell on contrast border, luxotonic cell at center of surface; cf. Hung et al. Vision Res 2001). This suggests that local brightness information tends to be calculated prior to edge extraction, perhaps for the purpose of enhancing or building border response.
We also show evidence of biased spontaneous interactions between pairs of Area 17 and 18 luxotonic cells. The direction of these biases is dependent on their receptive field separation, being 17-to-18 for adjacent pairs (< 5 deg separation) and 18-to-17 for distant pairs (5 to 35 deg separation). These biased interactions also persist with visual stimulation. This suggests that 'surround' interactions occur mostly as feedback from higher areas, whereas 'center' interactions tend to be feedforward.
Thus we find inherent biases in neuronal interaction during spontaneous conditions that persist during stimulated conditions. We posit that these inherent biases of information flow relate to existing functional organizations in the brain and may predict visual function at low contrasts.

Support: Packard Foundation, NIH

Abstract 587 9:30 AM

Receptive field construction in human area V2: iteration or integration?
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What is the nature of the information transformation that occurs between V1 and V2? Receptive fields (RFs) are larger in V2, in humans (Smith et al. Cereb. Cort. 2001, 11, 1182) as in other primates. Is there simply a biased projection from V1 to V2 that favours neurons sensitive to low spatial frequencies, as has been suggested? Or does the increase in RF size in V2 reflect integration of information across space? These alternatives have quite different implications for the function of V2. Human observers were presented with a stimulus consisting of a slowly expanding, centrally fixated ring of band-pass spatially filtered 2D dynamic noise. This was intended to isolate a subset of neurons with a particular spatial frequency sensitivity. Functional MRI (1.5T GE LX/Nvi) was used to estimate the average RF size of this neuron subset in human V1 and V2, based on the duration of the response elicited as the stimulus passes through the receptive fields of the neurons in each voxel (Smith et al. op. cit.). If information is passed from V1 to V2 with no major change in RF properties (i.e. V2 just contains a higher proportion of low-spatial-frequency neurons), then a given band-pass filtered stimulus should activate neurons with the same RF size in both areas. The size difference we have previously observed with broadband stimuli should therefore disappear. Results: In both V1 and V2, mean estimated RF size decreased as the stimulus spatial frequency was increased, confirming that neurons in both areas are tuned for spatial frequency. Receptive fields were larger in V2 than V1, even with band-pass filtered stimuli. This suggests that receptive fields in human V2 are generated by integrating the outputs of a group of V1 neurons that have a common spatial frequency sensitivity but slightly different RF locations.
Supported by The Wellcome Trust

Abstract 588 9:45 AM

Human motion discrimination is constrained by the temporal structure of spike trains early in the visual system
Joseph S. Lappin, Bart. G. Borghuis, Duje Tadin, Martin. J.M. Lankheet, & Wim A. van de Grind Vanderbilt Vision Research Center, USA, Helmholtz Institute & Neuro-Ethology Dept., Utrecht Univ., The Netherlands, same as Lappin, same as Borghuis, same as Borghuis

The responses of retinal ganglion and LGN cells to drifting gratings were analyzed as inputs to a motion detector. A cortical motion-detector that correlates spike trains from cells at separate locations must integrate these input signals over time in order to detect their similarity. An algorithm was developed to compute optimal integration times for extracting temporal information from the obtained spike trains. Optimal integration times ranged from 5 to 100 msec, decreasing as the temporal frequency of a drifting grating increased. As expected, firing rates increased with contrast, but optimal integration times generally were independent of both contrast and firing rate.

The temporal structure of these retinal and LGN spike trains constrains the motion sensitivity of cortical cells receiving this input. Thus, the temporal limitations of these input signals should also constrain human motion discrimination.

We examined this hypothesis psychophysically by measuring minimum stimulus durations required for human observers to discriminate motion directions. The stimuli were foveal Gabor patches containing a drifting grating (sigma = 10arcmin, SF = 3c/deg, TF = 0.5-20Hz, contrast = 4.6-92%, vertically oriented, random starting phase). Observers discriminated left vs. right motions. Duration thresholds ranged from 4 to 80 msec, decreasing with increases in temporal frequency and independent of contrast. These psychophysical thresholds behaved the same way as the optimal integration times computed from the neural spike trains. Evidently, the temporal thresholds for motion discrimination follow the limits imposed by the temporal structure of spike trains early in the visual system.

Tuesday AM Talks (South Hall)
Attention and Task

Moderators: Frank Tong & Steven Yantis

Abst #	Time	Authors
589	10:30	Sumner, Adamjee, Mollon
590	10:45	Liu, Slotnick, Yantis
591	11:00	Saenz, Buracas, Boynton
592	11:15	Parkhurst, Niebur
593	11:30	Franconeri, Simons
594	11:45	Yeshurun, Levy, Marom

Abstract 589 10:30 AM

Signals invisible to the collicular and magnocellular pathways can capture visual attention but do not produce an oculomotor distractor effect.

Petroc Sumner[1,2], Thofique Adamjee[2] and J. D. Mollon[1] [1] Cambridge, UK [2], *Imperial College, UK* Correspondence and requests for materials should be addressed to P. Sumner (e-mail: p.sumner@ic.ac.uk)

The retinal projection to the superior colliculus is thought to be important both for stimulus-driven eye movements and for the involuntary capture of attention. It has further been argued that eye-movement planning and attentional orienting share common neural mechanisms. The superior colliculus is thought to receive no direct projections from short-wave sensitive cones (S cones), and consistent with this, we show that irrelevant peripheral stimuli visible only to S cones do not produce the saccadic distractor effect produced by luminance stimuli. However, we show that the same S-cone stimuli do have normal involuntary attentional effects on responses to subsequent targets. We conclude that involuntary attentional shifts do not require signals in the direct collicular pathway, or indeed the magnocellular pathway as our S cone stimuli were invisible to this channel also, and that while some attentional effects may share mechanisms with eye-movement control, others do not. A third experiment, in which the previously irrelevant stimuli became targets for pro-saccades and anti-saccades, indicated that the luminance stimuli were much harder to detect than the S cone stimuli. This double dissociation with the results of experiment 1 suggests that perceptual awareness and saccade distraction are mediated by different pathways.

Abstract 590 10:45 AM

Neural basis of feature-based attentional control

Taosheng Liu, Scott D. Slotnick, & Steven Yantis Johns Hopkins University, USA

Visual attention can select relevant visual input on the basis of its location, its status as a segmented object, or its features (e.g., motion, color) by modulating the strength of sensory representations in early visual areas. We investigated the source of feature-based attentional control using rapid event-related fMRI. An aperture was presented containing random dots moving in one of six directions with one of six colors. Direction of motion and color changed randomly and independently once per second. Observers attended to either motion or color at any given time. Two directions of motion and two colors were targets: one direction and one color target instructed them to maintain attention on the currently attended feature; the other direction and color instructed them to shift from the attended feature to the other feature (e.g., motion to color). Previous experiments from our laboratory investigating shifts of attention between locations and between superimposed objects revealed that superior parietal lobule (SPL) emits a transient attentional switch signal that appears to change the attentive state of the observer. The present experiment revealed transient increases in activity in SPL time-locked to shifts of attention between features. These results extend our finding that SPL mediates the control of both spatial and non-spatial shifts of visual attention by issuing a transient attentional switch signal. Funded by NIDA R01-DA13165.

Abstract 591 11:00 AM

Global effects of eature-based attention to direction of motion and color

Melissa Saenz, Giedrius Buracas, & Geoffrey Boynton The Salk Institutue & UCSD, USA, The Salk Institute, USA, The Salk Institute, USA

We used a divided attention psychophysical task to test the hypothesis that visual attention to a stimulus feature facilitates the processing of other stimuli sharing the same feature. Human observers viewed two separate stimuli presented to the left and right of a central fixation point. Stimuli were circular patches of transparently overlapping fields of upward and downward limited-lifetime moving dots. Subjects performed a dual-task by simultaneously and independently performing a 2IFC speed discrimination task on one field of dots from each side. Thus, without changing the stimulus presentation, subjects could either divide attention across two fields of dots moving in the same direction (both up or both down) or in different directions (one up and one down). Baseline speeds were randomized so subjects could not benefit from comparing speeds across sides. Subjects performed better when dividing attention between fields of dots moving in the same compared to different directions (mean performance across 3 subjects: 78.7% vs. 70.8% correct; $p<0.01$). In a second analogous experiment, we showed that this attentional effect extends to the feature of color as well. Each stimulus was composed of transparently overlapping fields of stationary limited-lifetime red and green dots. Subjects simultaneously performed a color discrimination task on one field of dots from each side. Subjects performed better when dividing attention between two fields of dots of the same color (both red or both green) than of different colors (one red and one green) (mean performance across 3 subjects: 77.2% vs. 66.4% correct; $p<0.01$). Together, these results indicate that observers are better able to divide attention across multiple stimuli with common features compared to opposing features. These findings are consistent with an attentional mechanism in which attention to a stimulus feature globally enhances neuronal responses to stimuli throughout the visual field that share that feature.

Abstract 592 11:15 AM

Modeling the ability of motion to guide visual selective attention in dynamic natural scenes
Derrick Parkhurst & Ernst Niebur The Zanvyl Krieger Mind/Brain Institute, The Johns Hopkins University

The mechanisms of visual attention have been well studied in controlled experimental paradigms with simple stimuli. Experimental evidence suggests that both goal-directed and stimulus-driven mechanisms can guide attention. However, the way in which attention is guided by observers when viewing complex and dynamic natural scenes has only recently begun experimental evaluation. In previous research, we have shown that attention, as evidenced by eye movements, is stimulus-driven when observers freeview static natural scenes (Parkhurst, Law & Niebur, Vis Res 2002). Furthermore, using a computational model of attention, the stimulus-dependence of attention was found to be greatest just after stimulus onset. This work left open the question of the degree to which motion guides attention in dynamic natural scenes. To address this question, we implemented a computational model of visual selective attention that calculates stimulus salience based on color, intensity, orientation, and motion. To accomplish this in a biologically realistic way, neural mechanisms of visual processing thought to occur in the primate visual system were incorporated into the model. Each feature is processed at a series of spatial scales using realistic temporal parameters derived from neurophysiological data. The color and intensity feature pathways use temporal properties derived from the parvocellular and magnocellular pathways, respectively. Center-surround receptive field representation and scale normalization are implemented
through divisive inhibition. Given a dynamic natural scene, the model produces a dynamic saliency map that indicates the most salient spatial locations in the scene over time. By quantitatively comparing the ability of the model to predict eye movements made by human observers with and without motion processing enabled, the degree to which attention is guided by motion in dynamic natural scenes can be determined.
Support: an NIMH NRSA predoctoral fellowship to DP and an NSF CAREER grant to EN

Abstract 593 11:30 AM

No inducement needed: Attention capture occurs without task-induced attention sets
Steven L. Franconeri & Daniel J. Simons Harvard University, USA

Many dynamic events (e.g., onsets, looming) capture attention even when they are irrelevant to the primary task. Although this result suggests the automatic capture of attention, the demands of the task might actually induce an attention set for dynamic events that underlies capture. Because subjects must wait for the appearance of a display in order to start searching, they might form an attentional set for object appearances or for dynamic events in general. If so, then capture might not be stimulus-driven. In one experiment supporting this conclusion, an irrelevant red pre-cue captured attention only when the search display happened to be red, even though the color of the search display was also irrelevant (Gibson & Kelsey, 1998). The red pre-cue presumably captured because observers were waiting for a red search display. All prior evidence for attention capture by dynamic events is subject to the critique that the task induced an attentional set. We eliminate the possibility of such task-induced attention sets and show that abrupt onsets still capture attention.

Method
Two experiments used auditory rather than visual events to signal the start of a search for a target among 2, 4, or 6 distractors. In Experiment 1, subjects closed their eyes after finishing each search. The display changed, and a tone signaled them to open their eyes and begin searching. An onset occurred shortly after their eyes opened. In Experiment 2, the display was present prior to the search, and search began following auditory identification of the target.

Results & Conclusion
Both experiments found attention capture, with shallower search slopes when the onset validly cued the target position. Task-induced attentional sets cannot explain these results, suggesting that onsets can capture attention in a stimulus-driven manner.

D.S. was supported by NIH/NIMH Grant #R01 MH63773-01 and a fellowship from the Alfred P. Sloan Foundation. S.F. was supported by an NDSEG Fellowship.

Abstract 594 11:45 AM

Spatial attention and visual temporal processes
Yaffa Yeshurun, Liat Levy, & Golan Marom University of Haifa

Visual processing involves spatial and temporal components, yet the investigation of visual processing has primarily focused on the spatial domain. The goal of this research is to contribute to our understanding of the temporal domain by studying its possible relationship to spatial attention. We have previously shown that spatial attention can sharpen spatial resolution (e.g., Yeshurun & Carrasco, 1998). Here we investigated whether this attentional mechanism can also affect temporal processes. Specifically, we explored the effects of spatial attention on: a) temporal resolution --the ability to resolve rapid intensity changes over time; b) estimation of temporal length --the ability to correctly estimate the length of a stimulus duration; and c) temporal integration --the ability to integrate information through time. In all three, classic paradigms for studying these temporal processes –such as measurements of two flash fusion threshold or visible persistence-- were combined with the classic paradigm to manipulate transient spatial attention: A peripheral cue indicated the location of the target prior to its appearance, allowing observers to direct their attention in advance to the target location.

The central questions raised were whether spatial attention can alter temporal processing as it alters spatial processing, and whether its effects on temporal processes depend on its effects on spatial processes. Results indicate that attending the target location lowered observers' temporal resolution, lengthened their estimation of stimulus duration and prolonged the time period over which information was integrated. An attentional mechanism that can account for both the attentional effects on spatial resolution as well as its effects on temporal processes will be suggested, and the relationships between these findings

and other recent studies of attentional effects on temporal processes (e.g., visual masking, visible persistence) will be discussed.

This research was supported by THE ISRAEL SCIENCE FOUNDATION Grant (No. 925/01-1) to Y. Yeshurun

Tuesday Poster Session: Face and expression; face perception; locomotion; motion; multi-sensory; object perception; reaching

Abstract 595 B5.01

Perceptual categorisation of anti- expressions

Tamara L. Watson, & Colin W.G. Clifford University College London, UK. & Macquarie University, AUS., U. Sydney, AUS.

This study aimed to investigate the structure underlying the perceptual mechanisms of facial expression perception. Ekman's (1992) categorical theory of facial action perception and The Circumplex Model (Russell, 1980) of emotion recognition provide two different approaches to the representation of facial expression. It was hypothesised that morphing the six universal facial expressions (Ekman, 1992) into 'anti expressions' would clarify which aspects of these models best relate to the process of expression perception. Anti-expressions were produced by manipulating the configuration of an expressive face (+1) along an axis toward a neutral expression (0) as a mid point, and continuing along the axis into negative values until an anti-expression was achieved (-1). The configuration of this anti-expression was thus as different from a neutral expression as was the original expression, but the difference was in the diametrically opposite direction. Subjects were asked to categorise the resultant facial expressions. Anti-happy and anti-surprise were both found to be categorised as sad. Anti-sad and anti-fear were categorised as anger. Anti-disgust was categorised as surprise. Anti-anger tended to be seen as neutral or sad. The consistent categorisation of anti-expressions suggests that expression perception is not based on the two dimensions, pleasantness/unpleasantness and alertness/sleep. Rather the results are suggested as adding a perceptual structure to the categorical theory of facial expression recognition.

Ekman, P. (1992). An argument for basic emotions. Cognition and Emotion 6: 169-200.
Russell, J.A. (1980). A circumplex model of affect. Journal of Personality and Social Psychology 39: 1161-1178

Abstract 596 B5.02

Viewing portraits by rembrandt; fMRI reveals cerebellar and prefrontal cortical involvement

James Schirillo, Tina Susi, Jonathan Burdette & Paul Laurienti, 1Department of Psychology, Wake Forest University, Winston-Salem, NC 27109; 2Department of Radiology, Wake Forest University School of Medicine, Winston-Salem, NC, 27151

As in much of Western art, the left cheek of 74% of Rembrandt's female portraits faces the viewer, while the right cheek faces outward in 74% of male portraits. Schirillo1 proposed this asymmetry reflected lateralized hemispheric activity involved in approach/avoidance behavior. Here, participants ranked their desire to approach or avoid 20 Rembrandt portraits on a Likert scale (10 of each gender, half right cheek exposed, half left cheek exposed), while in an MRI scanner prior to a scanning session, followed by 4 fMRI scans. Stimulation consisted of viewing portraits for 30 sec alternating with 30 sec rest periods, 3 stimulation periods/scan. During the scan participants contemplated, but did not actively rate, their desire to approach or avoid each portrait. Portraits were presented multiple times at 2 sec intervals. Data were analyzed using SPM99 software.

As expected, while viewing faces regardless of sex or orientation, activation was noted in right superior temporal sulcus (STS). In addition, activation was present in visual, frontal, and parietal cortices. Interestingly, a region of the right middle frontal gryus consistently activated while the homologous region on the left did not. Moreover, the right cerebellum showed significantly greater activation when viewing right-facing compared to left-facing males. In addition, comparing all right-facing to all left-facing portraits yielded similar cerebellar activation. This may be consistent with reports that the cerebellum receives input from STS and that the cerebellum specifically evaluates and responds to danger rapidly.

1. Schirillo J. Neuropsychologia, 2000, 38:1593-1606.

Abstract 597 B5.03

Identification performance of brief dynamic emotional expressions as a function of orientation and position in the visual periphery

Michael D. Anes, Holly K. Sprunger, and Mark P. Heilala Albion College, Albion College, Albion College

Recent work indicates that negative emotional expressions are perceived outside the current locus of attention in visual search displays (Eastwood et al., 2001). Other research has found powerful behavioral and physiological effects of viewing brief, masked anger and fear expressions. We try here to tie together this work with recent facial motion research: motion is an independent information source in facial identification, and humans are quite sensitive to the normal temporal characteristics of emotional expressions.
Participants identified the displayed emotional expression of brief (330 ms) 6-frame movies of three Emotions (anger, surprise, happiness) and of static versions of the same stimuli. Stimuli were displayed in windows subtending 1.4 , either in the center of the screen, or offset 2.1 or 4.2 to the left and right of center, in upright and inverted orientations. Expected negative effects of Inversion ($F[1,15]=12.91$, $p<.01$) were found, as were effects of Emotion (identification accuracy for happiness and surprise were > 90%, anger displays ~84%, $F[2,30]=13.89$, $p<.001$) and Position (with expressions recognized more accurately in the center and near periphery

than more peripherally, F[2,30]=9.41, p<.01). Significant two- and three-way interactions occurred in the context of a significant four-way interaction of the factors, (F[4,60]=3.86, p<.01). There was no indication that anger was identified in the periphery better than other emotions, either with or without motion; however upright and inverted dynamic anger displays showed the greatest benefit in central compared to peripheral positions. In contrast, static, upright happiness displays showed an identification accuracy decrease centrally, due to a speed-accuracy tradeoff. An additional experiment is underway with a 200-ms display duration coupled with the ability to eliminate trials in which eye movements occurred, and in which we explicitly investigate sex differences in performance.

Sponsor: Foundation for Undergraduate Research, Scholarship and Creative Activity (FURSCA), Albion College

Abstract 598 B5.04

Putting the brain back together: Mechanisms of interhemispheric integration in face perception
Galit Yovel, Ken Paller & Jerre Levy Northwestern University, Northwestern University, University of Chicago

The fact that the two hemispheres use different strategies to process information is well established. It is still unclear, however, how they integrate their representations. The current study used a face matching task to test two hypotheses: First, whether the benefit of interhemispheric integration is greater when the two hemispheres process visual information differently (upright faces) than similarly (inverted faces). Second, whether interhemispheric integration is interrupted when the visual input is bilaterally inconsistent. Four types of facial stimuli were presented centrally in an upright or inverted orientation: Bisymmetric faces, which project consistent facial information to the two hemispheres; chimeric faces, which project inconsistent facial information to the two hemispheres and right and left hemifaces, which, respectively, project relevant facial information to the left and right hemisphere. The union of the accuracy levels of left and right hemifaces was used to estimate the performance for bisymmetric and chimeric faces of two independent hemispheres. Performance for bisymmetric faces surpassed the predicted performance of independent hemispheres and to a greater extent for uptight than inverted faces. This finding confirms the hypothesis that interhemispheric integration is beneficial to a greater extent when the two hemispheres process information differently than similarly. Performance for chimeric faces revealed interference relative to the predicted performance of two independent hemispheres. The magnitude of interference for chimeric faces was smaller than the magnitude of facilitation for bisymmetric faces, which suggests that regulatory mechanisms interrupt integration when the two hemispheres are presented with inconsistent information. Overall, our findings suggest that interhemispheric integration is adaptively regulated and is advantageous, in particular when the two hemispheres make different contributions to information processing.

Abstract 599 B5.05

Role of color in face recognition
Andrew Yip & Pawan Sinha Massachusetts Institute of Technology, USA, Massachusetts Institute of Technology, USA

One of the key challenges in face perception lies in determining the contribution of different cues to face identification. Here we focus on the role of color cues. Although color appears to be a salient attribute of faces, past research has suggested that it confers little recognition advantage for identifying people. A possible reason for the observed lack of a contribution of color to face recognition in these studies is that in situations where strong shape cues are available (as in high-resolution face images), performance may already be at ceiling and the contribution of color may not be evident. An interesting condition to examine, therefore, is one wherein shape cues are progressively degraded. The contribution of color to face recognition, if any, would be more evident under such conditions. To this end, we tested subjects' recognition performance with a set of famous faces that had been low-pass filtered at different thresholds. The faces were presented either in full-color or in grayscale. As in previous studies, we found no difference in performance for the color and grayscale conditions at high resolution; however, performance with color was significantly better than performance with grayscale images at lower resolutions. Our next experiment was designed to determine whether color contributes to face-recognition by providing diagnostic cues to identity or by facilitating low-level image analysis, such as segmentation. We tested subjects' performance with pseudo-color images that, we reasoned, would disrupt diagnostic cues but not low-level ones. We found performance with such images to be on par with true-color images. Taken together, our experimental results suggest that color does contribute to face recognition, and it does so by aiding low-level image analysis.

Abstract 600 B5.06

Spatio-temporal use of information in face recognition
Céline Vinette & Frederic Gosselin Université de Montréal, Canada, Université de Montréal, Canada

Most researchers now believe that human observers use a default coarse-to-fine strategy (i.e., from low to high spatial frequencies) to extract face information (e.g., Morrisson & Schyns, in press). Schyns, Bonnar & Gosselin (in press) recently discovered an analoguous differential use of face information along the spatial location and spatial frequency dimensions (see also Gosselin & Schyns, 2001). In sum, we know how time and frequency, as well as how frequency and location interact in face recognition; however, we do not know how location and time interact (neither do we know how spatial location, spatial frequency, and time interact, but this is another story). Here, we explore the spatio-temporal use of information in face recognition. Our stimuli set comprised 30 faces (i.e., [5 males + 5 females] * 3 expressions). The stimuli subtended 5.72 x 5.72 deg of visual angle and were presented for 320 ms. We utilized a novel technique called Bubbles (Gosselin & Schyns, 2001) to reveal directly the effective use of visual information. In a nutshell, we sampled space and time with small Gaussian windows (standard deviation = .22 deg in space and 43 ms in time), and adjusted their number on-line to maintain performance at 75% correct. We ran 10 subjects. A proportion-correct-when-available statistics was computed for each pixel (i.e., first order statistics); higher-order statistics were also computed. We obtained clear spatio-temporal modulations of effective use of information.

Abstract 601 B5.07

Men are from Mars, women are from Venus: Behavioral and neural correlates of face sexing using color

Michael J. Tarr, Bruno Rossion, & Katja Doerschner Brown University

Last year we reported that the color information alone is sufficient to determine the sex of a human face and that observers rely on this information in sex judgments when shape information is degraded. Here we build on these findings by addressing two new questions. First, when shape information in a face is ambiguous with regards to sex can we manipulate sex judgments by altering the ratio of red to green? This was investigated by crossing several morphs between male and female faces (I. Bülthoff - MPIK Tübingen) with a continuum of different red to green ratios. This two-dimensional shape-color space is bounded by male-shaped, reddish faces and female-shaped, greenish faces. Subjects judged the sex of faces at many points in this space. At the boundaries of the space, shape information determines sex classification regardless of the red to green ratio. However, at intermediate points where shape information is ambiguous, observers appear to rely on color information in judging sex. This effect is enhanced by forcing observers to judge sex very quickly or by removing the most extreme male and female faces along the shape dimension (i.e., when shape is less diagnostic overall, observers weight it less).

Second, how early in the visual processing of information does color influence sex decisions? Using a go-no-go sex judgment task with Event Related Potentials (ERPs) as the dependent measure we explored whether a "visual decision marker" (Thorpe et al., 1996) would be modulated depending on whether color was present or not in faces. We found that the ERP signal difference between go and no-go trials occurring approximately 200 ms post stimulus was both larger and earlier for color faces as compared to grayscale faces. Critically, there was no difference between the color and grayscale conditions independent of the sex judgment. We conclude that early decisions about the sex of a face are facilitated by the presence of color.

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Abstract 602 B5.08

Effect of band-pass filtered noise on cortical face responses

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Psychophysical studies have shown that the human face recognition system utilizes only a limited band of the spatial frequencies (sfs) present in facial images. To find cortical responses that would show a similar tuning, we recorded whole-scalp neuromagnetic responses to facial images that contained narrow-band spatial noise (10 noise bands with central sfs from 2 to 45 c/image). The signal-to-noise ratio was 0.74 across all sfs and made recognition impossible around the 16 c/image condition, but easy in the low and high sf conditions. The stimuli (7x7 deg2, mean luminance 130 cd/m2, RMS contrast 0.174) appeared abruptly on an average gray background for 0.5 s once every 2.5 s, and stimuli with different noise sfs were presented in random order. The subject had to respond to an image of a target person. In the six subjects, the strongest modulation by noise sf occurred in the 150–200 ms temporo-occipital responses: The largest signals were elicited by the noiseless and lowest-sf noise stimuli. The signals decreased as a function of increasing noise sf until they disappeared at the medium sfs, and increased again at the highest frequencies. For different subjects, the U-shaped tuning curve had a minimum at 5.6–23 c/image, and a bandwidth of 2–3 octaves. The sustained 250–650 ms response in the same cortical area was modulated less. The 80–110 ms midoccipital responses showed a different pattern, being weak for the lowest noise sfs, then increasing as a function of sf, and attenuating at the highest noise sfs. In conclusion, these results show that the 150–200 ms temporo-occipital response resembles behavioral face recognition in its sensitivity to noise sf. Thus it could reflect processes that are critical for the recognition of faces.

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Abstract 603 B5.09

Memory for moving faces: Effects of rigid and non-rigid motion

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Recent studies indicate that memory for familiar/famous faces can be improved when the faces are viewed in motion. For relatively unfamiliar faces, however, the role of motion in face memory is less clear. Several studies have yielded inconsistent results, suggesting the possibility that different types of motion may affect recognition accuracy in different ways. We examined the effects of non-rigid facial speech movements (Exp. 1) and rigid face rotation movements (Exp. 2) on recognition accuracy.

In Experiment 1, faces were presented and tested as either moving video clips or as still frontal images. The moving video clips were non-audible frontal faces talking directly to the viewer. Both the video and static presentations were matched for exposure time. The results indicated that face recognition was less accurate for the moving faces than for the static faces.

In Experiment 2, recognition accuracy was assessed in four conditions. In the first condition, participants viewed video clips of individuals rotating their head, from left to right profile, through nine equally spaced viewpoints. In the second condition, participants viewed still frontal images of faces. To control for the additional view information available in the motion clips, a third and fourth group of participants learned faces from the nine static images taken from viewpoints used in the video. These were presented in sequential or random order. Although recognition memory for moving faces was better than memory for the static frontal images, the availability of additional view information accounted for this advantage.

In conclusion, not all facial motions have similar effects on recognition. A plausible interpretation of the recognition disadvantage found with facial speech is that processing socially relevant facial motions may distract people from paying attention to the identity of a face.

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Abstrat 604 B5.10

Detecting faces in impoverished images

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The ability to detect faces in images has high ecological significance. It is a pre-requisite for important tasks such as person identification, gender and affect analysis. However, systematic experimental studies for characterizing the limits of human face detection performance have so far not been undertaken. We address this problem through a combination of techniques from psychophysics and computational vision. Our data provide lower bounds on image resolution needed for discriminating face from non-face patterns and help characterize the nature of facial representations used by the visual system. Specifically, our experiments allow us to derive the following inferences:
1. The lower bounds on image resolution needed for a particular level of face-detection performance: Faces can be reliably distinguished from non-faces even at just 2 cycles eye to eye using only the internal facial information. We have also analyzed how performance varies across different kinds of non-face distractors.
2. The role of local context in face-detection: The inclusion of facial bounding contours substantially improves face detection performance, suggesting that the internal facial representations encode this information.
3. The role of luminance contrast polarity: Contrast polarity appears to be encoded in the representation since polarity reversals have significant detrimental effects on detection performance, particularly with inner features. The visual system is more tolerant to contrast negation in the presence of bounding contours perhaps by encoding these contours in a contrast invariant manner.
4. The role of image orientation: Changes in image orientation away from the upright decrease face detection performance. Our data additionally suggest that vertical bilateral symmetry per se may not be a significant determinant of face detection performance.
Current efforts focus on computationally modeling this body of experimental data.

Abstract 605 B5.11

Role and interaction of featural and configural processing in face recognition

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In order to reliably recognize faces in everyday life it is necessary to detect subtle featural and configural differences. In three experiments we investigated the role and interaction of featural and configural processing in face recognition. In Experiment 1a we showed that previously learnt faces could be recognized when they were scrambled into constituent parts, which were previously determined in a free listing experiment (eyes, nose, mouth, chin, forehead, eye-brows, cheeks). This result clearly indicates a role of featural information at a certain level of face processing. In Experiment 1b we determined the blur level that made the scrambled part versions impossible to recognize. This blur level was then applied to whole faces in order to create configural versions that by definition did not contain local featural information. In Experiment 1c we showed that configural versions of previously learned faces could be recognized reliably. In Experiment 2 we replicated these results for familiar face recognition. All experiments provided converging evidence in favor of the view that recognition of familiar and unfamiliar faces relies on both featural and configural information. In Experiment 3 we investigated whether featural and configural processing provide independent routes of recognition or whether they converge to the same recognition units. Repetition priming for celebrity faces was found from scrambled to blurred recognition and vice versa thus favoring the convergent processing hypothesis. All results are explained in terms of an integrative model of recognition of unfamiliar and familiar faces.

Abstract 606 B5.12

The effects of limited attention on the identification of faces

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We focused on the early stage of face processing, particularly on the attention mechanisms. We investigated the effect of limited eye movements and attention on the identification of faces. Subjects were asked to memorize each of 30 faces under different viewing conditions: free viewing, limited peripheral viewing, and limited central viewing of a face. They were required to fixate alphanumeric characters successively displayed on various parts of a face image. On detecting a change of the numeric to alphabetic character, subjects had to immediately press the key. In order to manipulate the extent of attention, the color and /or kind of characters was changed. After this task, subjects were tested on their recognition of the faces shown in the first session of the experiment. Reaction times and error rates were measured. We also recorded eye movements by the method of corneal reflection to monitor saccades made by the subject. The results of the recognition task show that hit rates dropped significantly more for the condition of peripheral viewing of a face than for the free viewing and central viewing conditions, and that reaction times were longer. Furthermore, the extent of attention had effects on the performances under each viewing condition. We conclude that narrowing the spatial extent of attention could lead to impairment of configural encoding.

Abstract 607 B5.13

Recognizing moving faces: A psychological and neural synthesis

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Facial movements enhance the quality of our everyday social interactions. A raised eyebrow, sidelong glance, or nodding head can add meaningful content to a spoken message and may enrich our perception of the structure of a face. The effect of facial movement on memory for faces, however, is unclear. Recent studies have employed a variety of methods and facial motions, but have yielded inconsistent findings. We propose a model that synthesizes and consolidates these divergent psychological findings into the neural framework outlined by Haxby et al. (2000).

In combination, the psychological data we review suggests that: 1) dynamic information contributes more to recognition under non-optimal viewing conditions (e.g., poor illumination or recognition from a distance); 2) dynamic information contributes more as a viewer's familiarity with a face increases; and 3) facial motion can contribute to a perceptual structure-from-motion analysis by bootstrapping the encoding of the invariant facial structure. Poor viewing conditions may increase the contribution of the structure-from-motion analysis, but familiarity with the face is probably not a factor.

Haxby et al.'s (2000) "distributed" model of the neural substrates of face processing can accommodate these findings with minor modifications. In this model, the identification information available from static features is processed in the lateral fusiform gyrus/inferotemporal (IT) cortex, whereas socially-relevant facial movements (e.g., gaze, expression) are processed in superior temporal sulcus (STS). We hypothesize that dynamic face recognition is mediated by processes in both the dorsal and ventral visual streams. The dorsal stream processes social communication signals and person-specific "dynamic facial signatures". Dorsal processing of structure-from-motion information may contribute subsequently to the quality of a static face representation in the ventrally-based IT (Sary et al, 1993).

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Abstract 608 B5.14

Evidence from visual search for holistic processing of inverted faces

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The influence of facial organization on discrimination of a local facial feature was investigated using a visual search task. Subjects searched for a down-turned mouth in an array of one to six faces. Faces differed only in the presence (down-turned mouth) or absence (up-turned mouth) of the target feature, with target-present faces appearing unusual when viewed upright. In Experiment 1, subjects searched for the target mouth in upright normal faces, inverted normal faces, and faces in which the internal features were scrambled. Search was faster in the upright normal condition compared to the scrambled and inverted normal conditions. This suggests that the configural processing associated with upright faces facilitates local feature discrimination when an emergent feature such as facial expression can distinguish the target from distractors, and further, that the configural information giving rise to perception of facial expression is lost in the inverted face. However, a comparison of scrambled and inverted normal faces revealing faster search rates for scrambled faces suggests that some form of configural information remains in inverted faces and impedes the discrimination of local features. In Experiment 2 this result was confirmed and extended with a demonstration that external features contribute to configural processing of the face. Faster search rates were found for inverted scrambled faces in comparison with upright scrambled faces which in turn were searched faster than inverted normal faces. The overall pattern of results suggests that inverted faces, as well as upright faces, are first processed holistically. This obligatory holistic processing prevents immediate access to local feature information even when such constituent information is required by the task.

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Abstract 609 B5.15

Configural processing is not global processing: Insights from prosopagnosia

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Prosopagnosia is a selective loss of the ability to recognize faces as a result of brain damage. A well-accepted explanation for this disability is the loss of a mechanism involved in visual configural processing. A seemingly related visual process is the ability to allocate attention to the global aspect of an object. The relationship between these two processes was tested with an individual with prosopagnosia. It was predicted that if these two processes are one and the same then a prosopagnosic should be impaired at global processing. Normal control participants were also tested. Navon-type figures were presented in an undirected attention task in which a 2 or a 5 occurred at either the global or local level. The task was to identify which of these numbers was present during a trial. Size of the figures was also varied (3, 6, 9 and 12 deg. of visual angle). Contrary to the prediction, the prosopagnosic demonstrated superior global processing relative to local processing at all stimulus sizes. More interesting was the fact that as the stimuli increased in size, local processing worsened. In contrast, normal control participants demonstrated a well known interaction under these conditions; global processing was superior when stimuli were small in size and local processing was superior when stimuli were large in size. These results fail to support the notion that configural processing is global processing and introduce some new notions of the deficit underlying prosopagnosia.

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Abstract 610 B5.16
Withdrawn

Abstract 611 B5.17

Size constancy in face discrimination: synthetic faces & principal componentss
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'There is some evidence that faces are harder to recognize across a range of sizes using face photographs (Kolers et al., 1985). This may be because the face photographs would have provided more detailed information at larger sizes. We investigate whether thresholds for face discrimination exhibit size constancy using synthetic faces which all have the same information content for face identification. Thresholds for face discrimination were measured using 4-D synthetic face cubes (Wilson et al., ARVO, 2001). The experiment consisted of a 110 ms presentation of one face followed by a noise mask for 110 ms. Then two comparison faces appeared on the screen and a subject selected the face matched to the flashed face in a 2 AFC paradigm. We varied the linear size ratio (1:1, 2:1, or 4:1) between the target face and the comparison faces. When constructing regular face cubes, thresholds for face discrimination tended to remain constant across the size changes between target and comparison faces for both front and 20 deg side views of faces. When constructing face cubes based on principal components of our entire face population, thresholds for face discrimination tended to be unaffected by the size change between the flashed face and the comparison faces over a considerable range of the principal components. Only when the small face was flashed, the thresholds in higher and lower order principal components were affected by the size change. A control experiment in which small faces were flashed for 250 ms restored size constancy. These findings indicate that thresholds for face discrimination exhibit size constancy over a 4:1 size range for most principal components and that size constancy breaks down only when a small face defined by high spatial frequencies is briefly flashed. A longer processing time for small high frequency faces restores size constancy.

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Abstract 612 B5.18

Words and faces: eccentricity distinguishes crowding from context
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Introduction: Features of faces and words (e.g. eyes and letters) are more easily identified when they are presented in their familiar context as opposed to being presented alone or in an unfamiliar arrangement . In the fovea, this is known as the word and face superiority effect, and is evidence that words and faces are special (Reicher, 1969 Journal of Experimental Psychology 81 275– 280; Tanaka and Farah, 1993 Quarterly Journal of Experimental Psychology 46 225 - 245). However, in the periphery, the same feature and face stimuli reveal a face inferiority effect (Martelli et al., ECVP 2001). Here we ask what is the nature of the difference in face and word recognition between central and peripheral locations. Specifically we assess the role of crowding, whereby letters in the periphery are harder to identify when other letters are nearby.
Method: We measured contrast thresholds for identifying a mouth or a letter in a context that is familiar, unfamiliar, or absent, at various locations in the visual field. We also independently varied the spacing between the features and their size.
Results and conclusions: 1. The familiarity effect is independent of eccentricity (unlike crowding). 2. The context inferiority effect has a critical spacing proportional to eccentricity, showing that it is crowding. Thus faces are special at all visual field locations but, as eccentricity increases, crowding limits the observer's ability to distinguish a smile from a frown.

Abstract 613 B5.19

Prosopagnosics have Low Internal Noise?
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Subjects performed a forced-choice, match-to-sample task in which one face image was identical to the sample and the other face differed on a dimension of expression (happy-unhappy), gender, or individuation (two androgynous appearing faces of different individuals each with neutral expressions). The separation of the matching and nonmatching faces was varied by staircase method to yield a 75% threshold. Normal observers were most sensitive to expression changes, followed by gender changes, and least sensitive to identity changes. The threshold stimulus energy for a prosopagnosic, MJH, performing this task was within the range of normal controls when the faces differed along the expression dimension, was at the upper end of the normals when the faces differed in gender, and required much greater stimulus differences when the faces differed in individuation. Adding noise markedly increased the energy requirements of MJH on all tasks, so that he required much greater stimulus differences, relative to the controls, to achieve threshold accuracy, even when the faces differed in expression. According to linear amplifier models, this hypersensitivity to noise for MJH leads to the paradoxical inference that MJH, surprisingly, has very low internal noise compared to controls. Although the data can be fit with the model by assuming MJH is a highly inefficient observer (e.g., he uses a poor template), previous results using reverse correlation techniques suggest this is not the case for his gender and expression discriminations. We explore a model of representation based on the covariance between face images, which captures the population statistics of our sample. Internal noise in the covariance matrix may explain both the sensitivity differences across the three categorizations for normals and MJH, as well as the differences in performance between normal observers and MJH.

Abstract 614 B5.20

Face recognition is robust against incongruent image resolution

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Due to the poor image quality provided by conventional security systems, the identification of a person captured on video must largely rely on information carried by low spatial frequencies. However, matching stimuli for such video images are often made from high quality photographs with facial information carried by both low and high spatial frequencies. We examined whether a large discrepancy between the qualities of video image and photographic image affect identification performance, given prior evidence that face recognition is strongly influenced by spatial filtering and by the amount of overlapping spatial frequency between learned and test images. In two conditions, the quality of video clips and the photographic image was made to be either discrepant or equalized. In the equal-quality condition, photographs were reduced to the level of video image. A standard recognition task and a simultaneous matching task were used. Each person on the video was either presented as a short movie or as four static snapshots taken from the same clip.

The results of the recognition task with or without dynamic information showed no difference between discrepant and equal-quality conditions. However, in a matching task containing only dynamic information, the discrepant-quality condition produced a slight (6%) but significant advantage over the equal-quality condition. Motion and static images in both recognition and matching tasks produced comparable results.

Our results show that face recognition is tolerant to a large discrepancy between image qualities of matching stimuli. This finding is surprising given that recognition of unfamiliar faces is known to rely on image similarities between learned and test stimuli. Our study shows that image similarity in terms of resolution and spatial frequency may interact with other similarity parameters such as lighting, pose, and distinct external features of faces.

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Abstract 615 B5.21

The M100: Face categorization begins within 100 ms of stimulus presentation

Jia Liu, Alison Harris, & Nancy Kanwisher MIT, USA

Human visual object recognition is thought to begin within 150-170 ms of stimulus onset. Here we used magnetoencephalography (MEG) to show that recognition begins substantially earlier: by 100 ms after stimulus onset MEG responses over occipitotemporal sensors are significantly higher to faces than to nonface control stimuli. The amplitude of this "M100" response is higher when a degraded face stimulus is correctly categorized as a face than when the same stimulus is incorrectly categorized, showing that the M100 reflects not simply the low-level visual features present in the stimulus, but the perceptual experience of the subject. Furthermore, the magnitude of the M100 is not correlated with correct identification of a specific face, although the magnitude of the later face-selective M170 is. Thus, categorizing a stimulus as a face apparently begins substantially earlier than identifying a specific face. More generally, by sharply reducing current estimates of the earliest latency of stimulus categorization, our findings place powerful new empirical constraints on theories of human visual recognition.

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Abstract 616 B5.22

Facial motion and the perception of facial attractiveness

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Facial attractiveness has been extensively studied within many disciplines, such as art, anthropology and sociology. Within psychology it has usually been explored via static line drawings, photographs or computer generated pictures of faces. The faces that we see in everyday life, however, are continuously moving as we talk or laugh, for instance. Thus faces are dynamic rather than static objects varying along both spatial and temporal dimensions. While it has been well established that facial motion conveys information about gender, age, emotion and even identity, it is not clear whether it also contributes to the perception of facial attractiveness. Previously we made use of computer animation and motion capture techniques to investigate the relative contribution of facial form and facial motion to the perception of identity.Here, we use the same method to explore whether facial motion contributes to the perception of facialattractiveness. For this purpose we captured complex facial motion patterns from different human actors and applied them to an average face. Preliminary data suggests that facial motion, in the absence of individual facial form cues, can be used as a basis for attractiveness judgements. We are currently investigating the relative contribution of both cues, facial form and facial motion, to the overall impression of facial attractiveness.

Abstract 617 B5.23

Attentional requirements of face discrimination

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Face recognition is one of the most important types of visual discriminations that people make, and accordingly, there is evidence of specialized face processing in the brain. Does such specialized processing imply that faces may be perceived without attention? A recent study demonstrated that face processing was resistant to dual-task interference, suggesting that attention was not needed (Awh et al., 2001). Here, we present contrary evidence that indicates attention is indeed necessary to perceive faces. This experiment uses the attentional blink paradigm: subjects were shown a series of rapidly presented letters and were instructed to attend to a red letter (T1) occurring in the series and then to a face (T2) that appeared in the same location after a brief, variable interval. Subjects were then asked to identify the red letter and the face. Accuracy on the face task was significantly impaired when it

appeared within 500 ms of the primary letter task, demonstrating a classic attentional blink. Thus, face recognition requires attention.

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Abstract 618 B5.24

Low spatial frequency information preference in self recognition

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Six naïve subjects were presented a weighted 24-step morph sequence of themselves and Marilyn Monroe under three conditions: normal, low-band pass filtered, and high-band pass filtered. Five subjects show a strong preference for perceiving the low-band pass filtered stimuli as representative of "themselves" and the high-band pass filtered stimuli as representative of "Marilyn." The sixth subject was very strongly reversed, and data, when analyzed in terms of differences in PSE of the two conditions showed an outlier effect with respect to the other five subjects. Data excluding the outlier was shown to be significant with respect to PSEs ($p<0.003$). On average, the normal condition PSE fell right at the midpoint between high and low-band pass filtered conditions. Data is consistent with the hypothesis that self-recognition requires more low-band than high-band spatial information, and is likely lateralized to the right hemisphere because of this. Data also provides preliminary support for the more significant hypothesis that familiarity may fall along a continuum where familiar objects always require more low-band spatial frequency information or less high-band spatial frequency information than unfamiliar objects.

Abstract 619 B5.25

ERP evidence of task modulations on early perceptual processing of faces at different spatial scales

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Does the early perceptual processing of faces flexibly adapt to the requirements of the categorization task at hand, or alternatively does it operate independently of this cognitive context? Behavioral studies have shown that visual information such as the fine and coarse scales of a face are differentially processed depending on the categorization task performed, thus suggesting that the latter can influence stimulus perception. Here, we investigated the early vs. late influence of task effects on perceptual processing by examining visual event-related potentials (ERPs P100 and N170) reflecting the activity of early vision, while observers categorized faces for their gender and familiarity. Stimuli were full spectrum, or filtered versions of the faces that preserved either their coarse or fine scale information. Behavioral results replicated previous findings of a differential processing of coarse and fine spatial scales across tasks. In addition, ERPs revealed a modulation of the P100, which was enlarged for the familiarity task, suggesting an increased visual analysis subtending this more stringent categorization. Familiarity also decreased the amplitude of the N170, but only for coarse scale faces. These results suggest that the task of categorizing an identical face according to its familiarity or gender modulates the early visual processing of spatial scales.

Abstract 620 B5.26

Configural and holistic face processing: The Whole story

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Gauthier and Tarr recently distinguished between holistic-inclusive (the use of even the parts of an object that one is told to ignore) and holistic-configural (the use of the relationship between parts) and found that both increase with object expertise. With faces, these effects have often been confounded and all the baselines necessary to understand their nature have often not been used. In two experiments, we consider both holistic-configural and holistic-inclusive in a face part matching task. Our subjects performed sequential matching judgments on parts of face composites made out of the top and bottom halves of 12 unfamiliar faces. The face parts were shown in isolation or together; aligned or misaligned and the to-be-ignored part was either consistent or inconsistent with the correct response. Conditions where the second stimuli was an isolated part provided baselines revealing whether the effects on part matching were due to interference from transformed and inconsistent parts, or from facilitation from original parts. The sensitivity (d') results indicate that the holistic-configural effect is due to the test face configuration and does not depend on the studied face configuration. This effect resulted from interference from an unusual configuration, rather than from a within-trial configural change. In addition, we find that the holistic-inclusive effect (consistency effect of the to-be-ignored parts) is present both with aligned and misaligned face composites. This effect was mediated by interference from inconsistent parts in all conditions except when the faces compared were identical and had aligned parts: then we also find facilitation from a consistent part. The results provide a more complete description of holistic-inclusive and holistic-configural processing and suggest that most of the effects obtained here with faces and previously with novel objects in experts are better conceptualized as interference effects.

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Abstract 621 B5.27

Face-contingent motion aftereffect

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The demonstration of many types of contingent visual aftereffects suggests the existence of interactions between the two contingent properties somewhere in the visual processing stream. For example, the McCollough effect, or the orientation-contingent color aftereffect, implies that interaction between color and orientation. One view holds that contingent aftereffects are due to adaptation of neurons that are sensitive

to the particular combination of the two visual features; another view maintains that contingent aftereffects are the result of associative learning. Although the exact neural mechanism of contingent visual aftereffects remains elusive, it is nevertheless informative to know what pairs of visual properties can induce contingent aftereffects. Here we examined whether motion aftereffect can be made contingent on human faces. Subjects (the two authors and two naïve observers) viewed alternating expanding faces and contracting scrambled faces for 5 minutes. After various amount of delay, static test images were presented to the observers. A weak, but reliable, face-contingent motion aftereffect was reported by both the authors as well as the two naïve observers. An static face was seen briefly moving in the opposite direction to the adapting face motion, whereas a static scrambled face was seen briefly moving in the opposite direction to the adapting scrambled face. Similar face-contingent motion aftereffect was seen with rotating motion. These contingent aftereffects were very weak immediately after the adaptation, but gained strength after minutes of delay, a signature of contingent visual aftereffects. This result suggests that, somehow and somewhere in the brain, motion of faces is represented differently than motion of non-faces.

Abstract 622 B5.28
Withdrawn

Abstract 623 B5.29

Face detection dissociates from face recognition: evidence from ERPs and the naso-temporal asymmetry
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Neuropsychological data indicate that face processing could be distributed among two functionally and anatomically distinct mechanisms, one specialised for detection and the other aimed at recognition (de Gelder & Rouw, 2000; 2001). These two mechanisms may be implemented in different interacting regions of the human brain with sub-cortical structures (SC) dedicated to face detection and cortical structures (FFA and LOC) dedicated to face recognition. This model is consistent with recent data from developmental studies showing that the temporal hemifield of the retinotectal system may be involved in face preference in neo-natal observers. The present study used electrophysiological measurements (high density EEG) to test the hypothesis that neuro-anatomical correlates of a primitive face detection mechanism could be found. Participants were 10 normal adults and two developmental prosopagnosics. They were shown B/W photo-realistic or schematic images of faces and objects presented for 30, 50 or 100 ms. Monocular stimulus presentations were used with the stimulus presented in the periphery in order to stimulate either the temporal or nasal hemifield. We focussed on early extrastriate activities (occipital P1 and occipito-temporal negativities). Our results provide evidence for a temporal-nasal asymmetry for faces at around 150 ms. The same pattern obtains in normal adults and in developmental prosopagnosics but only for shorter durations.

Abstract 624 B5.30

The information about age, gender, and genetic relatedness contained in ratings of facial similarity
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Suppose that you are told that two children -- whom you have never seen -- are very similar in appearance. Do you now imagine that they are more likely to be siblings? More likely to be close in age? More likely to be the same gender?
What objective information about age, gender, and genetic relatedness is conveyed by a rating of similarity?
We asked observers to rate the facial similarity of pairs of children depicted in photographs. Observers were not instructed to consider the ages, genders, or possible relatedness of the children: they were told only to rate facial similarity. We estimated the Shannon information ("bits") about relatedness, age difference, and gender difference contained in these ratings of facial similarity.
The stimuli were 48 pairs of color photographs of children (3 to 12 years of age) from two provinces of northern Italy. Each photograph depicted the child from the shoulders to the top of the head with his or her face clearly visible. Half of the 96 children were male, and half female. In half of the pairs, the children were siblings, in the other half, the children were not related. Age difference, gender difference, and relatedness were counterbalanced across the pairs. Thirty observers rated the similarity of the 48 pairs on a scale of 0 to 10.
The maximum possible Shannon information that can be conveyed concerning a binary choice is 1 bit. The estimated Shannon information conveyed by a similarity rating was 0.171 bits (relatedness), 0.091 (gender difference), and 0.015 (age difference). The first two values are significantly greater than 0 ($p < 0.0001$ for each), while the third is not ($p > 0.05$). We conclude that the observers incorporate information about relatedness and gender difference into their ratings, but include little information relevant to age difference. In particular, the observers discounted the large physical changes in appearance that occur as children grow in forming a judgment of facial similarity.

Supported by NIH/NEI grant EY08266 and HFSP grant RG0109/1999-B.

Abstract 625 B5.31

No categorical perception of face gender found with different discrimination tasks
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Faces are easily categorized as male or female. But is this categorization done at the perceptual level? In previous studies (ECVP 2001), we found no categorical perception of gender for face stimuli using two discrimination tasks: either simultaneous same-different task or delayed matching-to-sample. This conflicts with results of another study using a different task (Campanella et al, Visual Cognition, 2001). Here we tested whether categorical perception of gender might become apparent if we used a discrimination task (sequential same-different task) more similar to that used by Campanella et al. We employed the same type of stimuli as in our previous

experiments. The face stimuli were created by generating series of morphs between pairs of male and female 3D faces (gender continua). We also generated a gender continuum based on an average face. While gender–related information was present in this latter continuum, the stimuli lacked individual characteristic facial features that might induce identity-related categorical perception. If male and female faces belong to perceptually distinct gender categories, we would expect that two faces that straddle the gender boundary are more easily discriminated than two faces that belonged to the same gender category. In our previous experiments we never found any evidence of categorical perception for unfamiliar faces. Our present results confirm these findings. We found no evidence that participants could discriminate more easily between faces that straddle the gender category. Thus no categorical effect for face gender was revealed when sequential same-different discrimination task was used. The conflicting results obtained by both studies do not appear to be due to the different discrimination tasks employed.

Abstract 626 B5.32

Stimulus configurations supporting the perception of faces
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Face-like images often appear easy to visualize within random patterns or natural scenes, suggesting that the perception of faces can be invoked by relatively simple configurations. We have examined some of the minimal configural requirements for stimuli to support face perception. In one set of experiments, we used reverse correlation to identify the configurations that led to recognizing images as a face. Frontal-view pictures of faces were presented in high levels of white noise, and observers judged on each trial whether or not a face was visible. The image elements leading to face perception were estimated from the differences between the visible vs. invisible patterns averaged over several hundred trials. Feature locations corresponding to the eyes, nose, and mouth all emerged, suggesting that they may each form a salient part of facial configurations. In a second set of experiments, observers were shown arrangements of 3 or more Gabor patches. These were chosen so that different configurations could be defined by varying the locations of identical features (e.g. all horizontal), or identical configurations could be shown with varying features (e.g. different orientations). The relative distances, positions, and symmetry of the patches, as well as the patch orientations, were systematically varied while observers rated how face-like each configuration appeared. The results of these studies serve to define the range of spatial configurations that can induce an impression of a face, and thus may point to the basic configural dimensions underlying the encoding of faces.

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Abstract 627 B5.33

Perceptual learning of spatial frequency information in faces
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Two experiments investigated the perceptual learning of spatial frequency content in grey-scale images of human faces. In Experiment 1, facial stimuli were filtered by either low- or high-pass ideal filters to create two conditions: Low (4-15 cycles/image) and High (16-63 cycles/image). Stimulus contrast was varied to measure identification thresholds in a 10-AFC matching task. Perceptual learning was found to be frequency-specific: observers trained to identify faces in the Low condition did not show improved performance when tested in the High condition, and vice versa. This result is consistent with studies that show that a certain degree of spatial frequency overlap is required for accurate matching of filtered faces (Liu et al., 2000). To investigate the effects of spatial frequency overlap more directly, observers in Experiment 2 were required to match filtered facial stimuli to All-Pass facial images. Faces were filtered to create 3 conditions, each with a 2-octave bandwidth: Low (2-7 cycles/image), Medium (8-31 cycles/image), and High (32-127 cycles/image). In a 4-AFC matching task, observers were able to accurately match the Medium faces to the correct All-Pass counterparts, but performed much worse in the Low and High conditions. An ideal observer analysis showed that the results could not be explained by differential amounts of information within different spatial frequency bands, and additional control experiments showed that the pattern of human performance was not due to the shape of the contrast sensitivity function. These results support the idea that observers can learn to identify faces when there is some overlap in spatial frequency content, but that the degree of overlap does not constrain performance per se. Instead, the middle band of frequencies plays a special role in face identification.

Abstract 628 B5.34

FFA activation correlates with sensitivity of perceptual decision processes
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Previous work in our lab used a backward masking paradigm to demonstrate that activation of the fusiform face area (FFA) reflects not only the contents of the visual image, but also the subject's perception of the image (i.e., with identical masking parameters, FFA activation is significantly greater when a face is detected than when it is not). In the present study, we used a rapid-presentation event-related fMRI design and methods of signal detection theory to examine the role of FFA while subjects made perceptual decisions requiring the discrimination of face from non-face images. Grayscale stimuli were constructed from photographs of human faces and scrambled versions of the same, with contrast adjusted in a staircase manner so that subjects were able to detect the images with an accuracy of approximately 79%. Subjects were then required to discriminate between these stimuli, when presented briefly (40 ms) in a 2-alternative forced choice paradigm. fMR images of FFA in the right hemisphere were acquired at 4T (3x3x5 mm, 1.5 s TR, 10 parasagittal slices) using a 12 cm single-loop surface coil. For all subjects, activation of the FFA during trials in which faces were correctly reported as faces (i.e., hits) was found to be significantly greater ($p < 0.05$) than during trials in which these same images were incorrectly reported as being

scrambled (i.e., misses). Furthermore, the subjects' sensitivity (d') in the discrimination task was directly correlated (r = 0.893) with the difference in the levels of FFA activation for the intact face and scrambled images. This provides evidence that the activation of the FFA reflects decision processes critical to perceptual discrimination.

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Abstract 629 B5.35

Comparing top-down influences in perceiving faces and scenesi

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Purpose. The hollow-mask illusion, i.e., obtaining the percept of a regular convex face when viewing a hollow mask, is weaker when the mask is inverted [Hill & Bruce, Perception, 1993]. The difference in performance can be attributed to global, top-down influences, since bottom-up cues, such as disparity range, foreshortening, texture gradient, motion parallax and perspective, are essentially the same for upright and inverted stimuli. Can this inversion effect also be obtained with natural non-face stimuli?
Methods. To compare the role of top-down processes in face and non-face stimuli, we used a hollow mask and a Patrick Hughes reverspective portraying a scene, respectively. Reverspectives, like hollow masks, are perceived in reverse (illusory) depth [Wade & Hughes, Perception, 1999; Papathomas, VSS 2001]. Each of the two stimuli was presented upright and inverted, and viewed both monocularly and binocularly. The strength of the illusions was quantified by three measures: 1) The critical distance at which the percept changes from illusory to veridical; both “approach” and “retreat” conditions were used here. 2) The relative “residence time” of the illusory percept as a percentage of the total viewing time. 3) The initial percept obtained immediately after the observer views the stimulus.
Results. The pattern of results is similar for all three measures. Hysteresis was observed between the “approach” and “retreat” conditions [Hill & Bruce, Perception, 1993; Papathomas, VSS 2001]. The critical distance was smaller, hence the illusion was stronger, for the reverspective than the mask. The strength of both, facial and non-facial, illusions is reduced significantly when the stimuli are inverted. However, the reduction is larger in the case of the facial than the scene stimuli.
Conclusion. The results seem to indicate that top-down influences are stronger for facial than for non-facial stimuli. Further work is needed to characterize these top-down influences.

Abstract 630 B5.36

Judgments of object location behind an obstacle depend on the particular information selected

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The ground surface can be used as a reference frame for coding object location (Gibson, 1950; Sedgwick, 1986). But at times in the real world scene, we do not see the full expanse of the ground surface from the feet to the target object. The direct path could be obstructed by another object (obstacle) such as a sofa or an opaque fence. While the obstacle does not in itself occlude the view of the target, we wonder if the partial occlusion of the ground surface leads to errors in judging the target location. To test this, observers performed four different distance judgment tasks on the ground from a viewing distance of 5, 6 and 7 m. In the occlusion condition, a box (51 x 165 x 54 cm) was placed on the ground in between the target and observer. The distance between the box and the observer was fixed at 2 m. Compared to baseline (no occluding box), observers significantly underestimated target locations in tasks that required them to judge the target location along a direct path through the occluding box. These include the perceptual matching, throwing, and blindfolded walking tasks, which were performed after removing the box. Performance, however, was accurate in a fourth task - a “triangulation” blindfolded walking task (Philbeck et al, 1997) - that required observers to perceptually bypass the occluding box by looking to the side of the box and then to the unobstructed view of the target. Altogether, our results show that accurate distance computation is achieved when the entire ground surface is sampled, even if having to use a roundabout strategy. Further, this raises the possibility that a single target may not always be judged at a unitary location, but depends perhaps, on how the visual system picks the information.

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Abstract 631 B5.37

Looking to your future path: is heading off on a tangent?

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There has been an assumption that the perception of ‘heading’ when passively observing linear motion tells us something about the information we use when steering ourselves along curved paths through the world. There are, however, two broad ways of categorising the information that can be derived from retinal flow in order to guide steering: ‘heading’ or ‘path’. ‘Heading’ refers to the instantaneous rectilinear direction of motion of the observer, but this is constantly changing when travelling on a curved path. In contrast, ‘path’ encompasses the future curvilinear course through the world. It has been hard to dissociate these two representations since in principle both could be derived from retinal flow information. Here we investigate our ability to judge both ‘heading’ and ‘path’ during motion on a curved path over a computer generated tarmac ground plane. We asked observers to look at their ‘path’ or instantaneous ‘heading’, and recorded point of gaze (PoG) during each trial. The results showed that observers where significantly more accurate at looking at their ‘path’ (~3º) than their ‘heading’ (~8º). This suggests that an accurate representation of instantaneous ‘heading’ is not available to an observer of curvilinear flow, whereas instantaneous ‘path’ information is present. The implication for models of steering are discussed.

Abstract 632 B5.38

Visual attention and processing in the elderly driver
Matthew I. Tofield, & John P. Wann University of Reading

The UK along with many European countries lacks a standardised test of visual attentional deficits in drivers, particularly with respect to subtle deficits. We used a semi-immersive virtual reality paradigm to identify deficits in peripheral processing and extend the concept of useful field of view (UFOV). The displays focussed upon peripheral attention, particularly with brief (90ms) episodes of relative motion, changing size, luminosity and colour. Participants were presented with different sets of stimuli on a large video screen at 10 , 20 and 30 eccentricities and used a natural gaze response to look to the cued location. Gaze response was monitored using an ASL 5000 eye movement tracking system. Three groups were tested: Young (N=21, mean age =25.29), Middle-age (N=20, mean age =50.25), and Older drivers (N=20, mean age =70.50). We found a systematic decrease in performance with increasing age ($p<.001$). This was amplified for the older drivers. Of particular note was that older drivers had more difficult detecting objects that were moving on a potential collision course with their future path. The results highlight deficits in processing basic components for visual control in driving that go beyond the current UFOV tests. .The paradigms are now being piloted with individuals who have experienced a stroke (CVA) and may wish to a return to driving in order to remain mobile and independent.
Research supported by the UK ESRC.

Abstract 633 B5.39

Reduction of perceived visual speed during walking: Effect dependent upon stimulus similarity to the visual consequences of locomotion
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PURPOSE We reported previously that perceived optic flow speed is reduced linearly with walking speed (Thurrell et al. 1998 Perception 27 pp 147-148), a mechanism we postulate would preserve world constancy during normal self-motion. We consider here whether the reduction also occurs with visual scenes that are progressively less characteristic of upright locomotion.
METHODS Subjects viewed an optic flow reference stimulus comprising either an expanding tunnel of concentric rectangles, horizontally or vertically translating gratings, a rotating spoked wheel or, as a control condition, flashing stationary rectangles, for 15 s while walking at an instructed rate (i.e. very slow, slow... very fast). Subjects then ceased walking and attempted to match the reference optical velocity (or frequency for flashing stimulus) by adjusting a similar visual scene with a hand-held knob. Notionally, human walking corresponds principally to expanding flow, with the translating grating providing a lesser degree of correspondence and the rotating wheel still less.
RESULTS Confirming previous findings, subjects made speed settings that indicated a perceived underestimation of optic flow during walking. A weaker reduction also occurred for the gratings and one weaker still, but not significant, occurred for the rotating wheel. There was no effect of walking velocity on the perceived flashing frequency of the stationary tunnel.
CONCLUSIONS The presence of a weaker effect for the translating grating than for the expanding tunnel (and the absence of one for the rotating wheel) suggests that the influence of walking on the perception of optic flow may depend on the degree of similarity of the visual scene to that experienced during everyday, upright locomotion. The lack of an effect for the flashing tunnel suggests the mechanism acts on velocity perception per se rather than being a time-distance construct.

Abstract 634 B5.40

Estimation of traveled distance in a virtual environment
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We investigated the role of optic flow information in the estimation of distance travelled and its relative importance in the presence of other sensory and non-sensory information (e.g., proprioceptive cues and elapsed time). Subjects wore a head-mounted display and rode a stationary bicycle along a straight path in a seemingly infinite hallway with random surface texture and without any distinctive features. The distance that subjects were required to travel varied randomly (equivalent to 8 to 64 meters) with the end of the path signalled auditorily. A percentage estimation of relative distance was required following a reference distance subjects initially travelled. The rate of pedalling motion was converted to optic flow velocity in the display. Such a proportional factor could be either held constant or varied across trials (much like changing the gears of a bicycle, but without changing required pedaling force). When a constant proportional factor was maintained over trials, subjects were able to make reliable distance estimations. The proportion of variance in distance estimations accounted for by distance was on average 86%. When the proportional factor was varied randomly between trials, the distance information based on visual input was often incongruent with that based on pedalling movement and/or elapsed time. Subjects' distance estimations in this condition were found to rely more heavily upon the visual source as opposed to relying on the information provided by pedalling motion. On average, the proportion of variance accounted for by distance information derived from visual input was 59%, while the amount of variance accounted for by distance information predicted using pedalling motion was 10%. By introducing a sensory conflict paradigm, the current study convincingly supported the notion that travelled distance estimation depends primarily on optic flow even in the presence of additional sensory and cognitive cues.
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Abstract 635 B5.41

Reduction of perceived visual speed during walking: Evidence against the involvement of attentional or vestibular mechanisms

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PURPOSE We reported previously that perceived optic flow speed is reduced linearly with walking speed (Thurrell et al. 1998 Perception 27 pp 147-148), a mechanism we postulate would preserve world constancy during normal self-motion. We consider here whether this reduction occurs as a consequence of attentional load or vestibular stimulation during walking.
METHODS Subjects viewed an optic flow reference stimulus for 15 s while walking on a treadmill at an instructed rate (i.e. very slow, slow... very fast). During this period, subjects were either a) given an auditory/verbal numerical summing task, b) rested their heads firmly using a bite-bar rigidly attached to the treadmill frame, or c) neither of the above conditions (i.e. control). Subjects then ceased walking and attempted to match the reference speed just perceived by adjusting the optic flow of the same pattern with a hand-held knob.
RESULTS Confirming previous findings, subjects made speed settings that indicated a perceived underestimation of optic flow during walking. The strength of the influence of walking velocity on perceived optic flow speed was slightly reduced compared with the control for both conditions a) and b), although neither reduction was significant statistically.
CONCLUSIONS The reduction in perceived speed of optic flow with walking velocity is not due primarily to the vestibular apparatus or to the modulation of attentional load. Indeed, in contrast to the results, an increased effect would be predicted in the case of the attentional task.

Abstract 636 B5.42

Perceived Speed and Driving Behavior in Foggy Conditions

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Control of speed and heading is the primary task for motor vehicle operators. While cognitive information is available from the speedometer, motorists probably rely more heavily upon extra-vehicle visual information. How is this accomplished in poor visibility conditions? Consistent with evidence that perceived speed decreases with reduced contrast, Snowden et al. (Nature, 1998) found that drivers underestimate their speed when operating a simulator in foggy conditions. The present study investigated whether this hazardous misperception and unintentional increase in speed also occur when driving an automobile on a rural public road. With the speedometer obstructed from view, 14 participants (mean age 35.79 yrs) drove around a closed road circuit three times under each of three randomly ordered visual conditions: clear view and two levels of reduced contrast (created by diffusing plastic filters on the windscreen and side windows). Dependent measures, collected on separate laps at 7 locations along the circuit, were: Verbal Estimates of speed; Adjustment of Speed to instructed levels (25 to 70 km/h); and Judgments of Minimum Stopping Distance (before colliding with a model wallaby). Actual speed was recorded at each judgment. All measures of perceived speed decreased significantly with reduced visibility: Travel Speed (58 to 49 km/h, $F(2,13)=24.3$; $p<.0001$); Verbal Estimates (50 to 44 km/h, $F(2,13=7.95$; $p<.02$); Minimum Stopping Distance (17.9m to 129.5m, $F(2,88)$ 13.84 $p<.0001$). Linear regressions showed that speed adjustments were highly correlated with the target instructions ($r2=0.95$ to 0.96), with slopes declining from 0.91 to 0.80 with reduced contrast. These findings demonstrate that drivers travel more slowly in fog, and they estimate their speed with equal reliability, under clear and foggy conditions. Moreover, unlike laboratory findings, speed adjustment data revealed a tendency to overestimate speed in the fog.

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Abstract 637 B5.43

The effects of distraction and age on reaction time in a driving simulator

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The objective of this study was to investigate the effects of cognitive and visual driver distraction on reaction time to unexpected road hazards. Participants operated a driving simulator while intermittently answering prerecorded questions of varying difficulty (simulating a conversation) or dialing specific numbers into a cellular telephone. Two different road hazards were each presented at unpredictable times and locations, including red brake lights and a red pedestrian-shape of approximately the same area as the brake lights. Stimuli were presented in one of two different locations: directly in front of the driver at the bottom of the screen, or off to the side of the road. The results showed a significant overall increase in reaction time for older subjects, as well as a strong interaction with the dialing task condition. There were no significant differences from the control for either of the verbal response conditions. In addition, participants took significantly longer to respond to stimuli on the side of the road, especially when they were presented in conjunction with the dialing task. These data suggest a strong link between age, visual task load, stimulus location, and increased reaction time to unexpected stimuli.

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Abstract 638 B5.44

Self-motion sensation in virtual reality improves spatial updating for mobile observer

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Human performance of detecting layout change is view-dependent if observer's viewpoint remained constant, but view-independent if the observer walked to a new viewing position (Simons & Wang, 1998, Psych.Sci.) or its motion was visually

simulated in virtual reality (not for accuracy but reaction time, Christou & Bulthoff, 1999, Max-Planck-Institut Tech.Rep.). We assumed self-motion sensation in virtual reality could improve this view-independent performance. So, we used a large visual display with rich motion information. [Methods] Expt1: We simulated 5 objects on a table (2x2m top) centered in a simple room (9x9x9m) with texture-mapped (16x16 checkers) floor and walls. This scene was projected on a screen (2.3x2m) and observed from a distance 2.7m. Viewpoint was simulated to move by rotating the room (47deg) around center vertical axis or remained constant. Retinal projection of objects was manipulated independently: the objects and the table rotated together around the vertical axis (different retinal view) or remained constant (same retinal view). Subjects (n=10) observed the entire scene for 3s, then the viewpoint and/or the table moved for 7s while objects were occluded and one of those moved to a new position. They again saw the entire scene for 3s and identified the moved object. Expt2: We conducted a similar experiment using 3500 spheres randomly positioned in a space around the table instead of the room (n=10). [Results] ANOVA showed a main effect of retinal view (Expt1. $p<.003$, Expt2. $p<.008$) and an interaction of viewpoint change and retinal view (Expt1. $p<.04$, Expt2. $p<.004$). These indicated that the performance to detect layout change was view-dependent for stationary observer, but view-independent when observer's self motion was visually/virtually simulated on a large display with rich motion information. Subjects also reported self-motion sensation in Expt2. These suggesting that visually-induced self-motion sensation improves spatial updating.
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Abstract 639 B5.45

Walking a straight line without vision
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PURPOSE: Vision is routinely used to walk from one nearby location to another, e.g. crossing at intersections. Motivated by the mobility problems of visually impaired people, we asked: 1) How accurately can people walk a straight line without vision? 2) Is this capacity affected by long-term vision loss? 3) Is such ability related to sensitivity in detecting curved paths?

METHODS: Five blindfolded sighted subjects and 5 blind subjects repeatedly attempted to walk along a straight 30'(foot) path. Deviations from the straight line were scored on a floor grid. In a 2nd experiment, the same subjects were guided along circular arcs of radii ranging from 30' to 120', and judged the direction of curvature (left or right). Threshold was defined as the curvature yielding 90% correct.

RESULTS: There were no clear differences between the blind and sighted groups. The mean absolute veer of straight-line walks calculated at 30' ranged from 1.4 to 5.7' across subjects. Analysis of the trajectories showed that in many trials, there were statistically significant linear and quadratic contributions to the veer. But these separate contributions were uncorrelated in both magnitude and direction (left vs. right). Mean threshold in the curvature discrimination task was a radius of ~ 60'. We found no significant correlation between thresholds and any measure of veer in the straight-line walking task.

CONCLUSIONS: Extensive experience with visual impairment does not influence the ability to walk a straight line or discriminate left from right-curving paths. The decoupling of linear and quadratic components in straight-line walking excludes simple random walk models for veering error. Surprisingly, accuracy in producing a straight-line walking path without vision is not related to perceiving the direction of curvature of a walking path.

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Abstract 640 B4.46

Gait algorithms and natural walking patterns: An observational study
Michelle M. Jacobs and P. Jonathon Phillips RAND, USA; National Institutes of Science and Technology, USA

There are very few studies that examine gait outside of the laboratory setting. The majority of gait studies are set up to observe gait in a very patterned style, so that subjects primarily follow a straight path on the treadmill or outdoors, and employ little to no head movement. The lack of information about “natural” gait patterns and the impact of other variables such as dress, shoes, and carrying items, question the validity of current gait recognition rates. Likewise, the continued concentration on artificial or overly constrained data adds to the potential of developing algorithms that do not generalize to real-life scenarios. We observed the gait patterns of 98 subjects walking to and from a variety of public transportation entrances. Among subjects observed for the study, less than half walked a straight line for more than 6 strides and almost 80% of all subjects moved their heads while walking. This study offers important information about natural gait tendencies in humans and the importance of gathering gait data outside of the traditional laboratory setting.

Abstract 641 B5.47

Ordinal structure in route navigation
Marianne C. Harrison, William H. Warren, & Michael J. Tarr Brown University

What geometric properties of the environment do humans depend upon for navigation? Last year (VSS 01), we reported that participants relied on ordinal structure rather than metric distances and angles, when they walked to learned locations in a virtual hedge maze. By ordinal structure, we mean the sequence of places, junctions and landmarks along a route. Previously, we stretched or sheared the maze to manipulate metric structure. In the present experiment, we add or delete paths to manipulate ordinal structure, and test whether subjects rely on the number of junctions along a known route. Participants walked in an immersive virtual environment (12 m x 12 m), while wearing a head mounted display (60 x 40 deg, 50 ms latency). The environment consisted of a virtual hedge maze containing eleven occluded places (statue, bird bath, etc.). During training, participants learned the layout of places by freely exploring the environment for 8 min. During testing, they were asked to walk to specified locations, starting from the

same home position on each trial. On probe trials, a side path was either added to or deleted from the maze. If participants rely on the number of junctions from home, this would lead them to take an early or late turn to a different location. On the other hand, if they rely on the ordering of paths from another reference point (e.g. a unique junction, the far end of the path), or on metric structure, they would turn onto the correct path. The results indicate that participants rely on junction number on a significant percentage of trials, demonstrating an influence of ordinal sequence along a known route. However, other structural properties of the environment, such as distinctive junctions, path endpoints, or landmarks, may also provide reference points for an ordinal navigation strategy.

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Abstract 642 B5.48

Visual illusion from walking
Laura Fox, & Frank H. Durgin Swarthmore College

The normal coupling of action and perception can be re-calibrated by unusual contexts. After running on a treadmill, subjects experience an illusion of increased optic flow rate when walking on solid ground (Pelah & Barlow, 1996). Despite the importance of this finding, prior techniques for quantifying the illusion were not very precise. In the present study, we sought to quantify the illusion using virtual reality. We found that adaptation to walking on a treadmill in a static virtual environment is sufficient for producing a measurable illusion.

Eleven subjects walked continuously on a treadmill while wearing a stereo HMD depicting a fully textured moving corridor. Subjects made FC judgments about whether the speed of the corridor was too fast or too slow relative to their own speed on the treadmill. A multiple-staircase procedure was used to determine the point at which the visual corridor speed was perceived as corresponding to walking speed (PSE). Each subject then walked on the treadmill for a 2-minute adaptation period during which the virtual corridor was stationary. Again, a staircase method was used to determine PSE, but with a brief period of re-adaptation to the stationary corridor before each trial.

As expected, following adaptation to the stationary corridor the average gain at PSE was reliably less than the average gain before adaptation (by about 10%, $p < .01$). Although inter-subject variability was high, all but 1 of the 11 subjects showed a decreased PSE following adaptation.

The results show that walking on a treadmill in a static world is sufficient to produce an illusion of increased optic flow during subsequent locomotion. Moreover, we have developed a new technique for measuring changes in a subject's perceived matching point between locomotor activity and optic flow. Further studies of changes in expected gain using this technique may be very useful to understanding the visual variables involved in the recalibration process.

Swarthmore College Faculty Research Grant

Abstract 643 B5.49

Travel distance estimation from optic flow
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Can optic flow be used to estimate travel distance? In principle this is impossible because optic flow speeds scale with the dimensions of the environment. Distance estimation from optic flow therefore needs calibration from other sources of depth information. Previously we have shown, however, that discrimination of the distances of simulated self-motions of different speed and duration is reliably possible from optic flow if the visual environment is the same for both motions. In this case, independent scaling information is not necessary. Here we ask whether a distance estimate obtained from optic flow can be transformed into a spatial interval in the same visual environment.

Subjects viewed a simulated self-motion sequence on a large (90 by 90 deg) projection screen. The sequence depicted self-motion over a textured ground plane. Simulated distances ranged from 1.5 to 9 meters with variable speed and duration of the movement. After the movement stopped, the screen depicted a stationary view of the scene and two horizontal lines appeared on the ground in front of the observer. The subject had to adjust one of these lines such that the spatial interval between the lines matched the distance traveled during the movement simulation.

Adjusted interval size was linearly related to simulated travel distance, suggesting that observers were able to obtain a measure of distance from the optic flow. The slope of the regression was 0.7. Thus subjects underestimated distance by 30%. We conclude that optic flow can be used to derive an estimate of travel distance, but this estimate is subject to scaling when compared to static intervals in the environment.

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Abstract 644 B5.50

Prospective control of lane changing and tau-dot
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Many manual and locomotor tasks require the actor to reach a certain position in space, while reducing movement velocity close to zero. The 'tau-dot' variable, the first temporal derivative of the current time-to-contact, was suggested to play a critical role in the prospective control of deceleration (e.g. Lee, 1976; Yilmaz & Warren, 1995). Lane changing can be considered as a biphasic task, where in a first phase a lateral velocity is produced (pull-out), which then has to be minimized in a second phase (approach to the envisaged lane). This second alignment phase necessarily requires prospective control of the lateral deceleration. Here we asked, whether lane changing might be guided by tau-dot, resulting in a lateral approach to the new lane with tau-dot values kept constant at or regulated around -0.5. In a driving simulation using a large cylindrical projection screen (7m diameter), 46 participants were asked to drive in a 3.5 m wide straight lane and to perform consecutive lane changes to an adjacent lane. The deceleration of 1460 trajectories of the second phase were analyzed, computing fit and slope of a linear regression of time-to-contact with respect to time. We found that two-thirds

of the lane changes can be described by a single tau-dot value (criterion r > 0.6, mean r = 0.94). These trials yield a mean tau-dot of -0.499 (sd = 0.132), which is in suprising agreement with the theoretical value of -0.5. Futhermore, we observed also a positive correlation (r = 0.68) between the time required for the completion of the lane change and the tau-dot values. Our results complement previous studies showing evidence for the use of the tau-dot variable, even when the point of termination of the approach was largely self-defined, as it was true for our task. Drivers prefered a path with a constant lateral deceleration, despite the non-linear relationship between lateral deceleration and steering-wheel amplitude.

Abstract 645 B5.51

Perception of motion with orientation-defined missing fundamental gratings

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Purpose: It has been known that for luminance-defined missing fundamental (MF) with 1/4 cycle shifts is perceived in the direction opposite to physical shift. Similar phenomenon was reported for disparity- (Smith & Scott-Sammuel, 1998) and motion-defined (Maruya & Sato, 2001) MF patterns. In these stimuli, modulated features were derived from magno-pathway. In our study, we examined orientation-modulated MF patterns whose feature was derived from parvo-pathway and investigated higher-order motion perception based on first-order-like detectors. Our stimuli were made of orientation filtered random noise where no first-order artifact existed since source noise was replaced dynamically.
Method: The stimuli were 3.2 (V) x 9.7 (H) deg orientation-defined 0.15 cpd MF patterns generated by filtering random noise with Gabor filters (f=2.6cpd, sigma=0.21deg). Orientation of the Gabor filter was varied along horizontal axis following MF waveform between 0 to 90 deg. Stimuli were consisted of 5 motion frames. MF patterns were shifted 1/4 cycle between frames. Each frame was consisted of 8 temporal subframes (20ms) they were generated from different random noise with the identical orientation-modulation filter. ISI between motion frames was varied from 0 to 320ms. Subjects were asked to report the motion direction by 2AFC.
Results: Motion in the direction of shift was perceived for sinusoidal orientation-defined-motion patterns. For MF patterns, however, motion in the direction opposite to shift was dominant.
Conclusions: These results suggest that visual system detects higher-order motion in a similar way to that of regular first-order motion detectors in orientation-defined motion patterns. The present results suggested that higher-order motion system based on Fourier component like first-order detector is independent on modulated feature, even when original signal is derived from parvo-pathway.
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Abstract 646 B5.52

Motion facilitation across space and the role of attention

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Purpose: Much work has shown attention to modulate motion perception. Raymond et al. (1998, Vision Res., 38, 2863-67), have demonstrated that a first RDK (prime) affected motion sensitivity to subsequently presented RDKs (probe), when both were in the same spatial location. Using a similar task, we assessed whether attention modulates motion sensitivity for sequentially presented RDKs in two different spatial locations, and for both central and peripheral visual fields.
Methods: RDKs with limited-lifetime dots (1 jump) were used. Dots appeared for 26.7 msec and inter-frame interval was 26.7 msec. For central visual field measures, RDKs were presented in one of two adjacent circular 10 regions on either side of fixation, and for peripheral measures, in one of two 20 regions separated by 60 . Two different primes were used: 1- single: half the dots were stationary and half the dots moved in one of four directions (left, right, up, down); 2- dual: half the dots moved in one direction along the horizontal plane and half along the vertical plane. The probe RDK moved in one of the four aforementioned directions. Task: a cue word (horizontal or vertical) appeared for 653 msec indicating the motion plane to attend to. The prime then appeared for 533 msec, followed by a 200 msec interval, and finally the probe for 107 msecs. Two responses were required: 1- the direction of the prime, and 2- the direction of the probe. The method of constant stimuli was used, and only trials in which the first response was correct were used for threshold calculation.
Results: Thresholds were lower when prime and probe moved in the same direction than in orthogonal (baseline) or opposite directions. Attention did not enhance this facilitation, and even diminished it slightly.
Conclusion: Motion in the same direction leads to facilitation across space. Attention for one region may inhibit facilitation in another, unlike what is found when both prime and probe are in the same spatial location.
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Abstract 647 B5.53

Modulating motion-induced-blindness with depth ordering

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Purpose: Motion-induced blindness is a striking phenomenon where salient static visual stimuli "disappear" for seconds at a time in the presence of specific moving patterns. The present study investigates whether the phenomenon is due to surface completion in the presentation. Stereo-depth information was added to the motion stimulus to create depth ordering between the static and moving components of the display and dot disappearance was measured.
Methods: A 6ºx6 º field composed of 49 equally spaced blue cross elements was rotated about its center-point at 30 º/s. Superimposed on the grid were three yellow dots, equally spaced on an imaginary circle with radius 1.75º. Stimulus presentation was dichoptic, using a modified Wheatstone stereoscope. During each 30 second trial subjects viewed a fixation cross in the center of the display and indicated dot disappearance by pressing and holding any of three keys (one per dot) then releasing the key when the dot reappeared. Three conditions were tested: 1) Grid presented stereoscopically in front of the dots, 2) Grid presented at same depth, 3) Grid presented behind the dots.

Results: Results for all subjects indicate an effect of depth ordering. When the grid was presented in front of the yellow dots, the amount of disappearance was greater than when the two were presented on the same depth plane, which was greater than when the grid was presented behind the yellow dots. The monocular information was the same for the non-zero depth conditions. A second experiment showed that an induced Kanizsa surface (four "pac-man" elements) yielded similar results to the grid experiment, while the same elements rotated 180 degrees (no induced surface) did not.
Conclusions: Our data indicate that motion-induced blindness results from surface completion of the moving components of the display. A surface resulting from these moving elements acts as a perceptual occluder, masking the static dots.

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Abstract 648 B5.54

A natural constraint for motion-in-depth
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Purpose: When the image of an object changes in size, the change may be due to either a change in object size, or the motion of an object in depth. This ambiguity may be resolved by making assumptions about the nature of motion in the world. Although many such assumptions have been suggested, consistent psychophysical support has been scarce. Methods: We present an experiment aimed at establishing the assumptions made by observers in the interpretation of object motion. Observers were presented with a simulation of an object moving around an orbit in depth. The path of this orbit was specified only by changes in image size and lateral position. We varied the extent of the orbit in depth and the function describing the change in image size in time. Three functions were used to describe the change in image size. These were analogous to a constant rate of change of image size, a constant speed along the path of the orbit, and an interpolated function halfway between the two other functions. Observers were asked whether the orbit was greater in depth or width. Results: Psychometric functions were obtained by varying the depth extent of the orbit. Three such functions were obtained for each of the size change functions. Effects of varying the size change function were examined by comparing the PSEs for each curve. The perceived extent of the orbit was most veridical when the change in image size corresponded to a constant speed along the orbit. When the rate of change of image size was constant, the orbit was perceived to be flatter. Conclusion: Our results are consistent with a mechanism biased toward minimal acceleration. That is, the visual system may assume minimal acceleration in the object and interpret changes in image size in line with this assumption. We discuss the results of this experiment with regard to Bayesian models of perception and previously reported motion constraints.

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Abstract 649 B5.55

A nystagmus-induced motion aftereffect
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Large moving patterns give rise to nystagmus eye movements. We find that following a prolonged period of nystagmus a pronounced motion aftereffect (MAE) is experienced. Naive observers viewed two vertically translating striped patterns (16.5x25 deg) separated horizontally by 10 deg. Stripes consisted of dimly illuminated dots shown on a black background in a completely darkened room. Six conditions were investigated. In two eye-movement conditions, observers maintained gaze on a central blank area. Stimuli moved upward or downward at 10 deg/s. Following 60s stimulation the adapting pattern was replaced by a small spot, which observers fixated and then indicated when the MAE ceased. The duration was recorded. To investigate whether the MAE was based on adaptation of retinal motion sensors, four eye-stationary conditions were presented containing similar adapting motion but viewed with a static fixation point. Upward and downward conditions were combined with translation speeds of 2 and 4 deg/s, thus approximating the retinal motion experienced in the eye-movement conditions if slow-phase gains of nystagmus were 0.8 and 0.6, respectively. No observer reported any MAE in the eye-stationary conditions. Conversely, all reported strong MAE opposite to the adapting motion in the eye-movement conditions. This was confirmed by the recorded durations (eye moving upward, mean duration = 25.5s; downward, mean = 9.1s; eye-stationary, mean = 3.5s). The marked asymmetry between the eye-movement conditions may be the result of greater slow-phase gains found during the upward adaptation phase. The results suggest the MAE is extra-retinal in origin because the stationary test stimulus was displayed in a region of the retina previously unstimulated and also keeping the eyes stationary during adaptation produced no MAE. The MAE probably results from an extra-retinal signal created by the need to suppress afternystagmus when fixating the stationary test.

Abstract 650 B5.56

Internal noise and sampling efficiency for motion detection, discrimination and summation
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In an ideal observer framework, human performance is limited by suboptimal sampling efficiency and by additive internal noise. We developed ideal observer models for the detection of drifting gratings, for direction discrimination of oppositely drifting gratings, and for detection of the sum of two oppositely drifting gratings. Human contrast energy thresholds for performing these tasks were measured as a function of the external Gaussian dynamic noise level. We find that the three tasks share a common source of internal noise. The sampling efficiency for discriminating motion direction is much lower than that for the other tasks. One possible explanation of the low efficiency for direction discrimination is that the internal representations of the two drifting gratings are overly similar. An ideal observer cross-correlates the received stimulus with representations of each of the two signals (drifting in opposite directions). If the human observer misrepresents the signals as being highly similar, discrimination performance will be quite inefficient (as we find).

Abstract 651 B5.57

Motion detection and velocity discrimination are still immature in 5-year-olds

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We compared motion detection and velocity discrimination in 5-year-olds and adults (n = 18/grp). With a 10 deg Gabor and the method of limits, we measured the minimum velocity required to detect movement. With 10 x 10 deg sine-wave gratings and a 2 interval forced-choice procedure, we measured velocities that were just noticeably faster than 1.5 and 6 deg/sec.

Results. A t-test revealed that 5-year-olds needed a significantly greater velocity than adults in order to detect movement (2 times faster than adults; $p < 0.001$). An ANOVA on the velocity discrimination thresholds revealed an interaction between age and velocity ($p < 0.001$). Five-year-olds were significantly worse than adults for both velocities (ps < 0.01), with significantly worse discrimination thresholds at the slower (1.5 deg/sec) than at the faster velocity (6 deg/sec) ($p < 0.001$). Five-year-olds were about 7 times worse than adults at 1.5 deg/sec and 3 times worse than adults at 6 deg/sec.

Conclusions. The mechanisms underlying motion detection and speed discrimination are less sensitive in 5-year-olds than in adults. Further, in 5-year-olds, the velocity discrimination mechanisms are even less sensitive at the slower than at the faster velocities. These results complement the findings that the direction of motion for slower velocities matures less rapidly than that for faster velocities (Aslin & Shea, Vision Research 1990; Ellemberg et al, ARVO 2000). This suggests that the mechanisms underlying sensitivity to the direction of motion and sensitivity to differences in velocity operate under similar principles.

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Abstract 652 B5.58

Temporally offset motion-induced spatial misalignment

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We investigated the effect of visual motion on apparent spatial location [1]. A rotating (40 rpm) black bar (2.7) on a white background was flanked by two smaller horizontal bars (10.8 min arc) that flashed in synchrony with the bar. We measured the apparent vertical misalignment of the flanking bars as a function of the angular position of the rotating bar using a binary choice psychophysical procedure. The vertical offset of the flashed bars was varied systematically over trials and subjects reported which was the higher of the two bars. Surprisingly, the greatest effect (perceived misalignment ~20 min arc) was found when the bar was around 30 of rotation before the horizontal rather than when the bar was closest to the flashed bars. The effect was replicated in a subsequent experiment using a number of naïve subjects. We found a significant misalignment 30 before the horizontal and no misalignment 30 before the vertical. This induced effect demonstrates that spatial position information is maximally affected by motion information present 125 msec before the rotating bar reaches the flash position. This critical angle before the horizontal is consistent with previous flash-lag measurements showing a similar sized lag between the rotating bar and flash[2]. Thus the flanker misalignment is maximal when bar and flash are perceived to be aligned rather than when they are truly aligned. We believe that this spatial misalignment may result from a cortical feedback mechanism [1,3] that updates position information during motion.

1. Whitney, D. and P. Cavanagh (2000) Motion distorts visual space: shifting the perceived position of remote stationary objects. Nature Neuroscience 3(9): 954-959.

2. Nijhawan, R. (1994) Motion extrapolation in catching. Nature 370(6487): 256-257.

3. Pascual-Leone, A. and Walsh, V. (2001) Fast backprojections from the motion to the primary visual area necessary for visual awareness. Science, 292, 510-512.

Abstract 653 B5.59

Spatial integration in structure from motion

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Recent investigations have shown that the perceived slant of the orthographic projection of a rotating random-dot planar surface is (1) an increasing function of deformation and (2) a decreasing function of tilt of the velocity field (e.g. Domini and Caudek, 1999). Deformation is defined as the sum of the squared horizontal and vertical gradients of the velocity field and tilt as the ratio between the vertical and horizontal gradients. Further findings have also indicated that perceived slant is (3) a decreasing function of the average velocity of the first-order optic flow (e.g. Todd and Perotti, 1999).
If the perceptual interpretation of a linear velocity field is affected by the three factors listed above, then some form of spatial integration must also take place. In fact, observers report perceiving a planar rotating surface when viewing a linear velocity field regardless of the fact that, for each local patch of the velocity field, factors 1 and 2 are the same, but factor 3 can largely vary. According to the above hypothesis, we should then expect that perceived orientation of different patches of a rotating random-dot planar surface should be (i) different when they are viewed in isolation, and (ii) equal when they are viewed as part of the same surface.
In our investigation, we asked human observers to judge the perceived slant and tilt of local patches of a rotating random-dot planar surface. Surprisingly, we found that the local patches were perceived as having different slants even if the surface was entirely visible. These differences, however, were significantly smaller than those found when the local patches were perceived in isolation, therefore indicating that spatial integration does in fact take place. Perceived tilt was also found to depend on the local mean velocity. Also this effect, however, was significantly reduced when the whole surface was visible.

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Abstract 654 B5.60

The effects of selective attention to first- and second-order motion stimuli on motion aftereffect duration
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Motion aftereffect (MAE) duration is longer for a selectively attended plaid component than for the non-attended component. We have previously shown that this holds whether adaptation is to either: 1) a homogenous plaid made of two first-order gratings, or two second-order gratings, or 2) a heterogeneous plaid made of a mixture of first-order and second-order gratings. Here, the effects of selective attention during adaptation on MAE duration were investigated further with a dynamic test stimulus oriented either like the attended component, the unattended component, or perpendicular to the coherent motion direction. The plaids were composed of two spatially superimposed, but temporally alternating square-wave or sine-wave gratings differing by 140 degrees in motion direction. Results replicate previous findings and further suggest that MAE duration is longer when attending equally to both components than when attending to only one component when test orientation is perpendicular to the coherent motion direction. In a second experiment, MAE was measured for 20 and 40 sec adaptation times. First order: MAE duration was much shorter when attention was alternated between 1st and 2nd order components for 40 sec than when restricted to the 1st order component for 20 sec (same overall attention times). Thus attention operates both via facilitation and suppression. Second order: A similar but reduced effect was present for one observer, but not for the other. The longer MAE in experiment 1, produced when attention was directed to only one component, as opposed to when alternating between the two components, was thus not due to the longer attention time, but to the presence of attentive suppression.

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Abstract 655 B5.61

Motion pop-out in young human infants
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Motion pop-out occurs when there is a single moving target among multiple static distractors. Motion pop-out occurs in human infants, but the extent of pop-out is modulated by the characteristics and spatial distribution of the static elements in the visual field (Dannemiller, 2000). When equal numbers of low and high contrast static elements are distributed unevenly across the visual field, infants are less likely to orient toward the moving target when it appears contralaterally to the hemifield with more of the high contrast static elements. The static elements compete with the moving target to determine the likelihood of motion pop-out. A signal detection model with a maximum-response decision rule captures these results with infants reasonably well. This model predicts a set-size effect as the number of static elements in the visual field increases unlike the case with adults in which no set size effects are predicted when the moving singleton is well above detection threshold. In two separate samples (n = 97 and n = 98) with infants from 2 to 5 months using Teller's (1979) Forced-Choice Preferential Looking procedure, the predicted set size effect did not occur with a range from 1 to 14 distractors. Instead, infants oriented toward the moving target at levels above chance but below 100%, and set size had no effect. We now show with two additional experiments (N = 64) that both the competition effect with heterogeneous distractors and the lack of a set size effect with homogeneous distractors are explained by a high-threshold-like model in which motion pop-out occurs on some percentage of trials. On the complementary percentage of trials pop-out fails to occur but orienting is not completely random; instead, it is determined by the properties of the static elements. This is analogous to a less-than-ideal observer whose orienting decision is based on the target on some percentage of the trials and on the distractors on the remaining trials.
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Abstract 656 B5.62

Are transparent motions represented simultaneously.
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Background. Locally-paired stimuli have been used to demonstrate that transparent motions are not represented at the same point in space. Most studies of motion-defined transparency assume that transparent motions are represented at the same point in time. With the exception of one study (de Bruyn & Orban 1993) this assumption has gone untested. The purpose of this research is to test the above assumption using stimuli made up of simple, translating motions. Methods. Observers were presented with stimuli containing either a) two sets of translating dots moving approximately orthogonal to each other, b) two spatially segregated sets of dots moving in approximately orthogonal directions, or c) one set of translating dots superimposed on a background of randomly moving dots. In the first two conditions observers judged whether dot surface directions differed by more or less than 90o; in the third condition observers judged the direction of translating dots relative to the nearest cardinal direction. Stimulus duration was progressively decreased. Results. Performance in the superimposed motions tasks (a and c) differed, with observers needing more time to reliably make judgements requiring the detection of two motions. Performance in the segregated motions task, however, was comparable with performance in the single motion task. Conclusions. At first glance the data suggest that transparent motions are not represented simultaneously, yet segregated motions are. Alternatively, poorer performance in the transparent-motions orthogonal task at shorter stimulus duration may be a consequence of random local pairing of dots, which would result in degraded transparency, rather than an inability to represent two transparent motions simultaneously. Early results of on-going experiments support the latter explanation.

Abstract 657 B5.63

Modeling 1D and 2D non-Fourier motion
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A luminance-gradient mechanism can detect high-order 1D motion (Benton et al., 2001, J Opt Soc Am A, 18, 2204). I examine the response to 1D and 2D motion of a Bayesian gradient-based model whose output is an activation pattern in velocity space (Weiss & Adelson, 1998, AI Memo 1624/CBCL Paper 158, MIT; Cobo-Lewis & Smallwood, in press, Spatial Vision). Using traditional luminance-modulated and contrast-modulated noise carriers, as well as nth-order stimuli (Taub et al., 1997, Vision Res, 37, 1459), I confirm that no front-end nonlinearity is required to detect high-order motion—as long as the model's spatial and temporal resolutions are finer than the carrier's sampling periods. However, because the model is susceptible to static noise, it underestimates the ambiguity in a non-Fourier grating's velocity, fallaciously "solving" the aperture problem. This issue worsens as the carrier's sampling period approaches the model's resolution. The model does correctly account for the velocity ambiguity of second-order gratings—if an appropriate front-end nonlinearity is introduced. Using Fourier and non-Fourier (including high-order) Type 2 plaids, I examine the consequences for 2D motion. The model detects high-order non-Fourier plaid motion, but with large biases toward the vector-sum direction, even when aperture size and stimulus duration are large. This yields a psychophysical prediction that detectable Type 2 plaids of order >2 would be perceived to move close to the vector-sum direction. The large biases can be eliminated for the second-order plaids if an appropriate front-end nonlinearity is introduced. Because contrast-modulated Type 2 plaids behave like luminance-modulated Type 2 plaids (Cropper et al., 1994, Vision Res, 34, 2609), this could suggest that a front-end nonlinearity does participate in the analysis of second-order 2D motion. Alternatively, the model could be rendered more robust to static noise (Johnston et al., 1999, Proc R Soc Lond B, 266, 509). Supported by NIH R15 EY 13362.

Abstract 658 B5.64

Effects of orientation adaptation on motion perception
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Purpose. In a previous investigation, we found that attention directed to a stationary Gabor patch in the center of the visual field can bias the perceived direction of plaid motion in the periphery (Caudek & Domini 2001). Consistently with the interpretation that has been provided to those previous results, here we tested the following related hypothesis: Adaptation to a stationary Gabor patch affects differently subsequent motion sensitivity in the parallel or orthogonal directions relative to the Gabor's orientation. Methods. In each trial, observers underwent adaptation (4 s) to a 0 , 45 or 315 oriented Gabor patch. Immediately after adaptation, a stochastic motion stimulus (Williams & Sekuler, 1984) was presented for 140 ms. In half of the trials a proportion of dots (i.e., 'signal' dots) moved in a coherent direction whereas each of the remaining ('noise') dots moved in a random direction. In the other half of the trials all dots were noise dots. Coherent motion was simulated in the 45 , 135 , 225 , 315 directions. The task was to discriminate between noise and signal-plus-noise trials. Results. Consistently with our hypothesis, motion sensitivity differed in the orthogonal and parallel directions relative to the Gabor orientation. In particular, we found a lower motion sensitivity in the direction parallel to the Gabor orientation. Conclusions. The present results indicate that adaptation to a stationary stimulus can subsequently affect motion perception, and are consistent with the feature similarity model of Treue and Trujillo (1999).

Abstract 659 B5.65

Evidence for the existence of multiple encoding of pattern motion direction
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Purpose: two-component moving plaids may contain two pattern direction solutions, (Bowns 1996), however, they are perceived to move in a single direction. We asked the following question: if a subject adapts to the perceived direction will the plaid be perceived in the other direction? Method: subjects were first tested to check their perceived direction of a two-component plaid previously reported to move in either the vector sum direction or the Intersection of Constraints direction (IOC). Subjects then adapted to their perceived direction using either a) a single grating moving in their perceived direction, or b) a plaid moving in their perceived direction. Plaids were used as a control to ensure that the orientation of each of the components in the adapting plaid was a minimum of 40 deg. orientation away from the components in the test plaid stimulus. Results: if subjects perceived a moving plaid in the IOC direction, after adaptation they perceived the plaid in the vector sum direction. If subjects perceived a moving plaid in the vector sum direction, after adaptation they perceived the plaid in the IOC direction. Conclusions: we believe that our results provide firm evidence for the existence of multiple solutions competing for perceived pattern direction, the balance of which can be shifted following brief adaptation. These results cannot be explained in terms of adaptation to individual components. It is interesting to note that pattern direction can be adapted using both single component direction as well as plaid component direction.

Abstract 660 B5.66

Integration of Moving Contours from Local Directional Signals
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Purpose:
The movement of spatial structure that extends over large areas of visual space is thought to be analysed by a battery of local directional analysers. However, little is known about how such local signals are integrated to represent the motion of individual objects. Here we examine the detection of moving spatial structure embedded in random moving noise.
Methods.
Stimuli were a field of pseudo-randomly positioned Difference of Gaussian elements. Background elements were randomly positioned and moved in random directions. Contour elements

were constrained to fall on a notional contour whose length, curvature, element spacing and motion were under experimental control. The contours were defined only by the relative motions of the elements forming them and were not visible on single movie frames.
Results.
The detectability of moving contours increased with the number and proximity of elements defining them, in agreement with studies of static images. Unlike static images, detectability was unaffected by the curvature of the contour. Contours that moved in directions orthogonal or parallel (open black arrows) to the mean contour orientation (broken line) were more detectable than those moving in intermediate directions (solid black arrows), but the most detectable were non-rigid contours, whose elements moved along the length of the contour (white arrows).
Conclusions.
The detectability of moving structure embedded in moving noise shares some of the spatial grouping principles that have been identified for static contours. However, a number of differences and the high visibility of non-rigid contours, suggest that the grouping of motion cues to object structure obey different principles and possibly different architecture.

Abstract 661 B5.67

Detection of second-order motion by a gradient-energy model
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Central to research into second-order motion is the assumption that standard luminance based motion analysis cannot adequately detect direction of motion in second-order stimuli (unless some pre-processing non-linearity is applied). However recent work demonstrates that the information specifying direction of motion and/or velocity of second-order motion can potentially be accessed directly by luminance based motion mechanisms [1]. In the current study, a gradient-energy equivalent computational model [2] was applied to translating contrast modulations of static and dynamic binary noise. Models of this type can be divided into two stages of processing with a directionally selective stage preceding contrast normalisation. Directional indexes were calculated from model output at both stages. Directional index was defined as (|F| - |R|) / (|F| + |R|) where F is the vector sum of model outputs indicating motion in the direction of envelope motion and R is the vector sum of model outputs indicating reversed motion. The model robustly indicates the correct direction of motion for modulations of static noise at the contrast normalisation stage. Results at the opponent energy stage were more complex with the model occasionally signalling reversed motion (an effect largely dependent upon noise element size). Results for modulations of dynamic noise followed a similar pattern although the amplitude of the bias was considerably reduced. These findings demonstrate that direction of second-order motion can be extracted by a simple luminance based mechanism without the application of a pre-processing non-linearity. The successful recovery of second-order motion may well require operations beyond simple directional selectivity.

1) Benton, C.P. & Johnston, A. (2001). Proceedings of the Royal Society of London B, 268, 2435-2443.

2) Adelson, E.H. & Bergen, J.R. Proceedings from the workshop on motion: representation and analysis (pp 151-155). Charleston, SC, May 7-9 (1986).

Abstract 662 B5.68

Discrimination of shifted centers-of-motion in a patient that cannot perceive radial motion
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Purpose. We use psychophysical data from a motion-impaired stroke patient, GZ (Vaina & Goldberg 2002), to challenge the generally accepted view that a precise computation of local and/or global motion information is necessary for recovering the 2D center-of-motion (COM) associated with translational direction in a 3D scene, (Reiger & Lawton 1985; Bruss & Horn 1983). Methods. Motion stimuli were represented as constant density random dot kinematograms presented within a 24 deg aperture (central 4 deg removed) for 440±40ms. In two perceptual tasks observers were presented with 30 deg/s radial (expansion/contraction) or circular (CW/CCW) motion-patterns and were required to discriminate (1) the shift in the COM, left or right, relative to a central fixation or (2) opposing motion-patterns (e.g. expansion vs. contraction) defined by a proportion of signal dots embedded in masking motion noise (Motion Pattern Coherence). Results. In normal observers (1) COM thresholds for circular motion-patterns were significantly higher than for radial motion-patterns ($p<0.005$; $t(19)=2.92$) while in (2) discrimination thresholds for radial and circular motion-patterns were comparable (~10%). GZ was only able to discriminate moderate shifts (~1 deg) in the COM for radial and circular motion-patterns. In contrast GZ totally failed to discriminate radial motion-patterns even at 100% coherence. However, she could discriminate CW from CCW motion and radial from circular motion-patterns. Conclusion. GZ's performance could be explained by a mechanism that computes a scalar norm from the motion-pattern for use as an error measure to localize the COM (Sundareswaran 1992). In this scheme a sparse sampling of scalar errors across the visual field provides a coarse spatial localization of the COM, independent of the type of radial motion-pattern. Discrimination with finer accuracy can be obtained through computations that use the direction information of the radial motion-patterns.
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Abstract 663 B5.69

Recurrent processing in the dorsal pathway underlies the robust integration and segregation of motion patterns
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It is an open question how different cortical areas interact to accomplish the robust analysis of moving visual patterns. Here, we present a model of recurrent interaction of V1, MT and MSTd utilizing a space-variant mapping of the retino-cortical pathway. We claim that a recently discovered motion illusion (Pinna & Brelstaff, Vis.Res. 40:2091-2096, 2000) unravels the

underlying mechanisms involved in processes of motion integration and segregation.

The (static) pattern that leads to a strong illusory motion effect consist of two rings of diamond-shaped items each outlined by light and dark lines such that coarse contrasts appear along the diagonal axes of individual items. While fixating the center of the rings an approaching viewer perceives the rings as rotating in two opposite directions. An essential part of our model is the transformation of the retinal input flow pattern to a log-polar V1 representation (Schwartz. Biol. Cybernetics 37:63-76, 1980) achieving a mapping of the peripheral true motion into a horizontally oriented uniform gauge pattern. Motion information from two successive frames of a movement simulation are integrated along the V1-MT-MSTd feedforward pathway utilizing direction selective cells of increasing spatial size (X:Y:Z ratio; Grossberg et al. Cerebral Cortex 9:878-895, 1999).

The illusion is shown to induce a motion pattern in the cortical MT and MST areas. MST-MT feedback achieves the necessary disambiguation of initial noisy estimates. This leads to segregated opponent motions along circular directions when perceptual splitting occurs, while homogeneous motion fields occur when no perceptual splitting is observed. The results provide evidence for the essential role of feedback from higher-order motion area MST.

Abstract 664 B5.70

Fine discrimination of angular velocity despite poor localization of center of rotation

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Purpose: We recently showed that humans extract precise information of angular velocity from rotational motions. The angular velocity at a given point is the ratio between the speed at that point and its distance from the center of rotation. Here, we investigate how precisely humans locate the center of rotation. Methods: Stimuli consisted of random-dot patterns undergoing rotations, viewed through an annular window. In a first experiment, we measured with a 4AFC task, how precisely a subject could estimate the position of the focus of rotation, parametric on the inner radius of the window. Next, we tested angular-velocity discrimination, with a single-stimulus paradigm. In this protocol, the distance between the center of rotation and the geometric center varied randomly between trials. Results: Subjects could not tell precisely in which of four quadrants of an 8º disk the center of the rotation was. We estimated that the localization error was about 1.5º. Interestingly, this error did not increase substantially when we substituted an annulus for the disk. We then wondered whether, in our original angular-velocity-estimation experiments, subjects overcame this large error by using the geometric center as a surrogate for the center of rotation. The second experiment tested whether such a substitution of centers occurred. Subjects had no problems discriminating between angular velocities despite random displacements of the center of rotation. Conclusions: Humans cannot locate the center of rotation precisely, but can discriminate well between angular velocities. Computational analysis suggests that the reason is that the center of rotation and the angular velocity are stable parameters of rotation models. In other words, an error in the estimate of one of these parameters does not affect the estimate of the other. Finally, we also conclude that the vanishing point of the rotational flow and its geometric center are not important estimators of the center of rotation.
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Abstract 665 B5.71

Increase of brain activity during the motion aftereffect investigated by magnetoencephalogram

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Purpose: Several neuroimaging studies have reported the enhancement of MT+ activity during the motion aftereffect (MAE). However, only physically standstill test stimuli were used in those studies. Therefore the detail study to investigate the relationship between brain activity during the MAE and the change in perceived velocity caused by adaptation should be conducted. In the present study, we used magnetoencephalogram (MEG) to examine brain activity when subjects observed physically moving test stimuli after adaptation. Method: We used concentric half rings (1.1 c/deg), that moved in either contracting or expanding direction. MEG responses were recorded in synchrony with the change in velocity of motion. In the first experiment, after the presentation of the adapting stimuli at –3 or –0.75 deg/s for 5 s (MAE condition) or 0.6 s (control condition), we presented the test stimuli at –6, –3, –1.5, 0.75, 0, 0.75, 1.5, 3, or 6 deg/s for 1s. Positive and negative values of velocities indicate expansion and contraction of the stimuli, respectively. In the second experiment, subjects adjusted velocities of the test stimuli to null the MAE (perceive no illusory motion). It was designed to investigate whether the enhancement of brain activity during the MAE was directly related to the perception of illusory motion. Results and Conclusion:(1) MEG peak latency showed no statistically significant change by adaptation. (2) Brain activity in area MT+ clearly increased by adaptation and the enhancement was common to all test stimuli irrelevant to the change in perceived velocities by adaptation. (3) MEG intensity was not simply related to perceived velocities of the test stimuli. Our results suggest two possibilities. First, it is possible that the direction selective cells that are sensitive to the opposite direction to the adapting stimuli increase in firing rates during the MAE. Second, each direction selective cells would fire with increasing synchronization by adaptation.

Abstract 666 B5.72

Induced effects in motion parallax

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Ogle's induced-size effect refers to the percept of slant elicited by a difference in vertical size between the left and right half images of a stereoscopic display. The effect is not readily predicted by the geometry of the situation and has been of considerable interest in the stereoscopic literature. Rogers and

Koenderink (Nature, 322: 62-63) demonstrated that modulation of the vertical size of a monocular image during lateral head motion produces the impression of a surface slanted in depth - a motion-parallax analogue of the induced-size effect. We investigated motion parallax analogues of the induced-size and induced-shear effects further and compared them with the corresponding stereoscopic versions. During lateral head motion or with binocular stereopsis, vertical-shear and vertical-size transformations produced 'induced effects' of apparent inclination and slant that are not predicted geometrically. With vertical head motion, horizontal-shear and horizontal-size transformations produced similar
analogues of the disparity induced effects. Typically, the induced effects were opposite in direction and slightly smaller than the geometric effects. For both stereopsis and motion parallax, relative slant and inclination were more pronounced when the stimulus contained discontinuities in disparity/velocity gradient than for continuous disparity/flow fields. The results have important implications for the processing of disparity and optic flow fields.

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Abstract 667 B5.73

KDE: Extrapolating a 3-D representation
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We reexamined and replicated the Wallach et al. (1953) finding of memory for the KDE establishing that a static projection of a 3-D wire figure, initially seen as 2-D, is seen as 3-D after observing an oscillating shadow projection of the figure which is seen as 3-D. In addition, we asked whether a static projection of the 3-D figure not included in the oscillation episode because it is was a projection from a viewing angle outside the range of simulated motion, also would be seen as 3-D. Both static and moving projections of the wire helix used by Wallach et al. (1953) were simulated on a computer screen. In one condition 12 Ss
described the appearance of a static projection of the figure included in the animation episode (in-movie) before and after 30 sec of viewing the figure oscillating through 42 deg. In the other condition before and after observing the same animation episode, 12 subjects described a static projection of the figure 22.5 deg. beyond its closest projection in the movie (out-movie). Following these judgments Ss in both conditions also described two control figures (a circle and rectangle containing horizontal bisecting lines). Every subject in both conditions saw the pre-animation views as 2-D. 11 Ss saw the in-movie view and 10 the out-movie view as 3-D post animation.
Almost all Ss saw the two control figures as 2-D (2 Ss each saw one of these figures as 3-D). These results suggest that the representation of a 3-D figure generated from limited exposure extends to an extrapolated projection.

Wallach, H., & O'Connell (1953). The kinetic depth effect. Journal of Experiemental Psychology, 45(4), 205-217.

Abstract 668 B5.74

The integration of auditory and visual motion is not direction selective
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There is evidence that visual and auditory signals are integrated at a perceptual level and in spatial attention tasks. In this study we investigated whether the subthreshold integration of visual and auditory motion signals depends on the direction of the motion signals in the two modalities.
The visual motion stimulus consisted of a random dot kinematogram (RDK) extending over 25 degrees of visual angle. A certain percentage of the dots moved in the same direction whereas the remaining dots moved in random directions. The RDK was presented for only 175 ms to minimise eye movements. The auditory stimulus consisted of two components, a noise pedestal which was different for each loudspeaker, and an incremental noise component that was cross-faded between the two loudspeakers, giving rise to a motion percept. The visual and the auditory motion had matched speeds of 10 degrees per second. The motion signals were either to the right or to the left. Auditory and visual motion directions could either be consistent (both to the left or both to the right), or inconsistent (one to the left, the other to the right). In each trial, two intervals were presented. One interval contained the noise stimulus (neither auditory nor visual motion); in the other interval the signal was present which was defined as either visual, auditory, or motion in both modalities. The task of the observer was to identify which interval contained motion.
Motion detection thresholds were defined as the coherence level at which the motion was detected with a probability of 0.81. For each of the two conditions (consistent and inconsistent motion) we fitted two-dimensional psychometric functions and estimated the motion thresholds. We find that the thresholds for inconsistent and consistent auditory and visual motions are very similar. This suggests that the integration of auditory and visual motion signals is not direction-selective.

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Abstract 669 B5.75

How do observers weight the otolith signal in a heading estimation task?
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When an observer moves through a scene, visual and non-visual cues can aid heading estimation. One cue, the optic flow field, strongly influences perceived heading. Another cue, otolith stimulation signaling linear acceleration, also affects perceived heading (Sibigtroth & Banks, 2001). It is not known how these two cues are combined to determine one's heading. Specifically, we wondered what cues determine the weight of the otolith signal. There are two hypotheses: 1) the otolith weight increases with the magnitude of the otolith signal, and 2) the otolith weight increases with the visually-specified speed. We presented optic flow displays simulating curvilinear translation (100-800 cm/s) across a ground plane. Gaze was

tangent to the path. We presented two path curvatures and these gave rise to rotation rates of 1–12 deg/s. To stimulate the otoliths, we exploited the fact that when an observer is on a curved path with centripetal acceleration x, the resultant gravito-inertial force is applied to the head at an angle whose sine is x. We simulated this force by rotating observers about the roll axis. To determine the relative influence of the flow field and the otolith signals, we independently manipulated the centripetal acceleration specified by the optic flow field, and that specified by the otolith signal (or equivalently, the roll angle). In particular, for a given path curvature and visually-specified speed, the visual stimulus did not vary with roll. Observers indicated their perceived path at the end of a 9-sec motion sequence. The majority of observers gave the otolith signal higher weight as visually-specified speed increased, consistent with hypothesis 2.

Abstract 670 B5.76

Recovery of visual perception from adaptation by sound: The cross-modal "beating-heart" effect

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In a variant of Troxler's filling-in, nearly equiluminant, chromatic flickering stimuli fade away quickly. We found that a series of sounds synchronized with such a stimulus aids its recovery, and delays its fading. Two red disks (2.5o dia.) centered 5.2o left and right of fixation were alternately flashed for 17 ms each (187 ms inter-stimulus interval, or ISI) on an equiluminant green background at 2.5 Hz for 3 min. The background filled in perceptually. On trials that followed, a 14.9 s re-adaptation phase was followed by a 6.4 s long pairing of one of the flickers with a 11 dB 2 ms long, spatially non-localized click. Subjects (Ss; n=5) had to pick the more visible or visually salient disk regardless of sound. They chose the one coincident with the sound on 81% (range: 73-90%) of trials. General arousal or eye movements cannot explain the data since they would make both stimuli equally visible. Randomly flickered stimuli (107-267 ms ISI) gave a similar result (n=3; 76%). Next, we asked whether sound can protect the visual stimulus from fading. From the trial's outset, one disk was paired with a coincident sound, and Ss (n=5) waited for one of the two disks to fade. On 73% of trials (60-100%), the stimulus not coincident with the sound faded first. The protection by sound was transient though: In the third experiment, the sound was turned off after 24 s, and the two stimuli alternated for 2.1 s thereafter; the stimulus paired earlier with the sound was judged more visible after the sound was turned off on 47% (6 Ss, 27-60%) of trials only. We speculate that attention to a stimulus at some location in visual space is enhanced by a sound synchronized with it. Our findings agree with past reports of audition affecting vision; we go beyond them in showing the role of synchronized sound in visual perception.

Abstract 671 B5.77

Visual capture of auditory motion

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We examined the capturing effect of visual motion on auditory motion created by manipulating interaural intensity difference (IID), interaural time difference (ITD), and both.
Method: Visual stimulus was a moving disk filled with random dots. The diameter of the disk was varied in 5 steps: 5, 10, 20, 40, and 80 deg. The random dots had a density of 12.5%. The disk was moved at 20 deg/sec. The auditory stimulus was random noise (100 - 4500Hz) of 65dB. In Exp. 1, IID was varied at a steady rate over time. The changing rate was varied in 5 steps: plus/minus 0, 1, 2 dB/sec. In Exp. 2, ITD was varied again at a steady rate taken from 5 values: plus/minus 0, 178, 345 micro s. In Exp. 3, auditory motion was generated by using both IID and ITD. The change rate for IID motion was varied in 5 steps: plus/minus 0, 0.5, 1 dB/s, and that for ITD motion was varied in 5 steps: plus/minus 0, 90, 178 micro s. The two parameters were combined in the order in the list. The visual and auditory stimuli were presented together for 1 sec and subjects determined, while fixating to a marker, which direction the auditory stimulus perceived to move.
Results: All IID, ITD, and IID+ITD auditory motions were captured by visual motion. Stationary auditory stimuli were perceived to move in the same direction as visual stimuli, and direction decision was biased for moving auditory stimuli. Effects of size of visual target were also found, the capture was strongest with 20 deg and attenuated for both smaller and larger targets. The effect was not observed for the largest target (80 deg).
Conclusion: These results indicate that visual capture from visual to auditory motion is observed as long as the visual target was reasonably small. This probably comes from that smaller stimuli were interpreted as a moving target to which auditory motion can be attributed, but larger targets were interpreted as an environment itself.

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Abstract 672 B5.78

Selective disruption of Audio-Visual interaction studied with Transcranial Magnetic Stimulation.

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Many studies have shown that the brain often combines in a single percept auditory and visual information provided the two sensory inputs are temporally and spatially contiguous, a phenomenon called multi-sensory integration. What is less well understood at present is whether the type of pairing as defined by the stimulus domain and by the type of association between auditory and visual stimuli also plays a role. Evidence from neuropsychology indicates that disruption of audio-visual interactions is often domain–specific in the sense that some audio-visual pairings are disrupted (for example audio-visual speech) while others are preserved (for example ventriloquism or multisensory perception of affect). The present study extends the available methods to understand multisensory processes by the use of Transcranial Magnetic Stimulation (TMS). We compared the impact of TMS on two types of pairs that have extensively been used in the literature (naturalistic voice-face pairs vs. arbitrary tone-shape pairs). Based on earlier findings we selected three sites of stimulation (pre-frontal, left and right posterior parietal sites). Participants were instructed to perform

a similar speeded categorisation task in all conditions. TMS applied over the left posterior parietal cortex at 150 ms post-stimulus onset and later disrupted integration as measured by the loss of the latency advantage for categorisation in the audiovisual condition. This effect was limited to the arbitrary pairs indicating a dissociation between Naturalistic and Arbitrary pairs for this stimulation site.

Abstract 673 B5.79

The effects of visual input on the separability of volume and mass

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The size-weight illusion refers to the commonly observed inverse relationship between physical volume and perceived heaviness. The present research proposed a new way of classifying the various types of models and examined the validity of each type through two experiments on haptic touch with and without vision. A feature-complete factorial design was used, whereby the stimuli varied factorially in levels of volume and mass, and participants gave perceptual reports on each dimension. The data were analyzed through tests of response proportions and multidimensional signal detection analyses. When visual input was eliminated, results indicated a lack of both perceptual and decisional separability of volume and mass, providing support for models suggesting that both the perception of weight and the decision criterion for perceived heaviness are functions of both physical volume and mass. When visual input was present, results indicated only a lack of decisional separability of volume and mass, providing support for models suggesting that the placement of one's decision criterion for perceived heaviness is dependent upon the level of physical volume. These findings imply that different models are needed to explain the size-weight illusion, depending upon the type of sensory input available.

Abstract 674 B5.80

The effect of auditory stimuli on the visual detaction task

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Recent works show that sound can alter the visual perception qualitatively on a large scale. However, it is not clear whether the interaction between two modalities, auditory and visual perception, occurs at the early stage of sensory processing or late stage of perceptual processing, perceptual organization. The purpose of this study was to investigate whether or not sound facilitate the detection of a visual target without auditory perceptual organization, the grouping of parts into larger units.

5 subjects took part in the experiment to detect a visual target in a rapidly changing sequence of visual distracters under three sound conditions (741Hz, 1000Hz, and 1259Hz). Sound was synchronized with visual stimuli involving a target and distracters. In the experimental condition, the visual target stimulus was synchronized with the salient sound of a frequency different from those of other sounds. In the control condition, the visual target was synchronized with the sound of the same frequency as the other sounds.

The mean reaction times were significantly shorter under the experimental condition than under the control condition. On the contrary, there were no significant differences in target detection rate between two conditions. These results suggest that sound does not exert any influence on the detection of the visual target without auditory perceptual organization. We conclude cross-modal interaction is related to the higher perceptual processing that may lead to perceptual organization.

Abstract 675 B5.81

Variance predicts visual-haptic adaptation in shape perception

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When people are exposed repeatedly to a conflict in visually and haptically specified shapes, they adapt and the apparent conflict is eventually eliminated. The inter-modal adaptation literature suggests that the conflict is resolved by adapting the haptic shape estimator. Another possibility is that both estimators adapt by amounts that depend on their relative variances. Thus, the visual estimator could adapt if its variance were high enough. Is relative reliability the better predictor of visual-haptic adaptation? We examined this by manipulating the variance of the visual signal during inter-modal adaptation and then measuring changes in the within-modal (vision-alone and haptics-alone) shape percepts. The stimulus was a 3D object with a rectangular front surface. It was specified visually by random-dot stereograms and haptically by PHANToM force-feedback devices. In pre- and post-tests, observers judged whether its front surface was taller or shorter than it was wide. For each modality, we found the aspect ratio that was perceptually a square. During adaptation, a conflict was created between the visually and haptically specified shapes by independently altering the visual and haptic aspect ratios of the front surface. The variance of the visual estimator (determined by dot number) was either low or high. We assessed the amount of visual and haptic adaptation by comparing pre- and post-test shape estimates. When the visual estimator's variance was low, essentially all of the adaptation occurred in the haptic estimator. When the visual estimator's variance was high, we observed visual and haptic adaptation. These results suggest that the relative reliability of visual and haptic estimators determines the relative amounts of visual and haptic adaptation.

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Abstract 676 B5.82

A common generalized perceptual strategy? The evidence from dyslexics

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Sensory information processing is considered modality specific with limited cross interactions. This is clear in the early input levels. However, for the performance of a task, which involves multi-sensory-modalities, is there a common generalized perceptual strategy, which governs the processing in each modality or, is the strategy modality specific with cross interactions?
Previously it was shown that the extent of visual letter-recognition is larger for dyslexics than for ordinary readers (OR). That is, OR demonstrate focal attention while dyslexics a wide spread attention (e.g. Geiger et al. 1992). This difference was also shown in the tactile domain (Grant et al. 1999).
To determine if childen who are dyslexic or OR have analogous differences in auditory perception we tested both groups in recognition of centrally located spoken stimuli. Our tests had five conditions: 1. recognizing the central stimuli alone, 2. recognizing it in the presence of conversation-background in the periphery, 3. in the presence of chopped-speech background, 4. in the presence of white noise background and 5. repeat of condition 2 while also counting the words perceived from the background.
The results show larger drop of stimuli recognition in the presence of conversation-background for dyslexics than for OR. However, dyslexics perceived more words from the background than OR did. This suggests a wide spread auditory attention for dyslexics and a focal one for OR. Additional testing with the same subjects have shown wide visual attention for dyslexics and narrow one for OR, similar to previous results and analogous to the results on auditory perception above. Overall, our data suggest a common perceptual strategy, which govern these sensory-modalities.

Abstract 677 B5.83

Visual, vestibular, and postural components in motion sickness

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Virtual motion environments often elicit ill effects common to many actual motion environments. Immersion in such an illusory moving surround involves substantial visual, as well as postural and vestibular activity. Most provocative motion environments cause three distinct, but possibly related, responses: reflexive eye movements (EM), sensory conflict (SC), and postural instability (PS). Three current theories, concerning the cause of motion sickness (MS), emphasize one of these responses, but deny the importance of the others. Such theoretical approaches preclude the possibility of a synergistic interaction of these factors. This experiment employed a three-factor experimental design wherein each factor was manipulated alone or in combination with the others. The independent variables involved two levels of: PS (induced by having the subject stand in a posturally neutral or challenging position); SC (with or without ego vection elicited visually by whole field motion stimulation); and EM (unrestricted or controlled with fixation). Measures of PS, SC, EM, and MS were recorded under the various conditions. Analysis of measures of PS, SC, and EM confirmed the effectiveness of these manipulations. Analysis of MS measures revealed a strong effect of conditions of SC, with the greatest MS found within conditions of illusory motion. The findings lend considerable support for the SC theory of MS, but do not convincingly rule out the PS, EM, or an interactive approach to MS. Results are discussed in terms of SC eliciting visual and postural activity, which may contribute to the intensity of MS experienced within a virtual motion environment.

Abstract 678 B5.84

Contribution of internal details in object recognition

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Object recognition becomes difficult when the main axis of the object is foreshortened. This foreshortened disadvantage was greater when the silhouette of the object was presented than when the line drawing of the object was presented (Lawson & Humphreys, 1999). The severe disadvantage in silhouette recognition indicates that the internal detail of the object, which lacks in silhouette, provides useful information, particularly when the main axis is foreshortened. One account is that internal detail contributes to the derivation of the main axis. The other account is that internal detail provides the distinctive features that are directly matched to the object represented in memory. The present study was conducted to test these two accounts. The object presented was either a line drawing or silhouette. The written name of the object was presented before the object. The task was word-object matching. There were two rotational angles of the object: foreshortened (frontal view) and less foreshortened (oblique view). To reduce the uncertainty regarding the axis orientation, in half of the trials, the 3-D arrow indicating the orientation of the main axis was presented as a cue, after the written name, and then the object was presented. The differential foreshortened disadvantage between silhouettes and line drawings was shown in the arrow absence condition. In contrast, the differential foreshortened disadvantage disappeared in the axis present condition. These results indicate that the severe foreshortened disadvantage in silhouette recognition was caused by a lack of axis information. In other words, the internal details provided the information necessary for axis derivation when the axis was foreshortened. These results support the structural description hypothesis, which holds that axis information plays an important role in object recognition.
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Abstract 679 B5.85

The awakening of Attneave's sleeping cat: Identification of everyday objects on the basis of straight-line versions

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In 1954, Attneave (Psychological Review, 61, 183-193) has demonstrated that a line drawing of a sleeping cat could still be identified when the curvature extrema (i.e., points along the contour where the curvature changes maximally) were connected by straight lines. This demonstration has often been

cited as evidence for the role of curvature extrema but it has not been examined thoroughly. Here, we do so by showing a large number of subjects (total N = 216) a large number of stimuli (N = 184). We started from outline versions of everyday objects and manipulated them in different ways, depending on the selection criterion for the points to be connected. In Experiment 1, we started from the mathematical curvature singularities. In one variant (Experiment 1a, N = 58), we allowed only one curvature extremum per lob (i.e., a segment of the shape with uniformly positive or uniformly negative curvature) and compared this to a condition with an equal number of inflection points (i.e., points along the contour where curvature changes from positive to negative): Identification was clearly better with extrema (46% correct) than with inflections (20%). In another variant (Experiment 1b, N = 50), the number of extrema and inflections was equated per picture to the number used in Experiment 2 (100% condition), and the same difference became even stronger (53% vs. 14%). In Experiment 2 (N = 108), we used points along the contour which an independent sample of observers had marked as most salient (see De Winter et al., VSS-2002, submitted) or around the points midway between two popular points, and connected either 75 or 100% of the points reaching a pre-defined threshold. In both cases, the straight-line versions connecting the popular points were clearly easier to identify (55 and 69% correct) than those connecting the midpoints (18 and 34%). Results will be discussed in relation to Attneave's original demonstration and other findings about useful information for object recognition.

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Abstract 680 B5.86

The null-contrast necker cube: A geometric depth stimulus invisible to known cortical mechanisms

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Purpose. An interesting type of probe stimulus is one that is designed to be null with respect to the responses of known classes of cortical neurons. If such a stimulus is visible, the perceptual processing must be carried by undiscovered types of neural processing. Methods. The classic Necker cube may be generated in the novel form of a null-contrast image, gray bars against a background of high-contrast random texture of the same mean luminance as the bars. Regions of zero contrast produce no response in all known cortical neurons, so the brain has no obvious mechanism to identify the gray regions in the image. In particular, there is no signal to be integrated along the length of the bars and support their unification into a perceptual whole. Plausible computational models of simple, complex and hypercomplex neurons were developed on the basis of established neural models. Simulations revealed that none of the neuronal types responded coherently to the presence of the gray bars, being activated only by the noise background. Results. Statistical evaluation of the simulated responses revealed no trace of the gray bars that could be detected by any signal operator (such as a peak detector) because the 'bars' only exist as an increased number of zeros among the background signals. Nevertheless, perceptual observation of the null-contrast stimulus revealed that it was subject to the well-known depth reversals of the standard Necker cube. These observations imply not only perceptual integration into a unitary figure, but one that can be interpreted three-dimensionally. Conclusion. This new class of null stimuli therefore represents a challenge for visual neuroscience, to explain the observed spatial integration of regions of no neural signal into coherent line structures supporting 3D percepts.

Abstract 681 B5.87

Transient size change detection

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We studied the monocular visual cues (as opposed to ttc, d theta or r dot) that the drivers of following vehicles may utilize to determine their relation to a lead vehicle. The purpose is to improve collision intervention signals. We focused on increases in lead vehicle width (horizontal size change), height (vertical change) and area (concurrent horizontal and vertical change). Six normal subjects were more sensitive to brief (0.1 sec) width and area increases than to height increases. The stimulus was a grey rectangle (~6.5 deg wide x 6.5 deg high) that increased symmetrically in the direction of the parameter being tested. Three different degrees of border increase, 0.6, 1.2 and 4.2 minutes of visual angle, were used (e.g. 0.6 min increase means a 1.2 min overall increase and a "rubbery" transformation of the stimulus). With a 0.6 min change, we observed a 27% advantage in detection performance (measured in terms of average % error of detection in the yes-no task) for width increases and 36% advantage for area increases over height ($p=0.086$ and 0.041 respectively). For 1.2 min change, the improvement was 175% (width) and 59% (area) ($p<0.0005$ and 0.058). There was no significant difference between the performance on the width and area tasks.
This result is not consistent with prior studies suggesting greater sensitivity to rigid (area) vs. rubbery (width and height) transformations. We plan to test other parameters such as texture and distance to a fixed landmark. These results imply that a warning system would only need to draw the attention of the following driver to the changing width or area of the lead vehicle, rather than to the height. If costs are a concern, focusing on just the width change would be sufficient.
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Abstract 682 B5.88

Brain areas involved in attentional control and perception of ambiguous figures

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To what extent are attention-related brain areas involved in monitoring versus controlling incoming perceptual information? Ambiguous figures such as the Necker cube provide an ideal stimulus to explore this question because observers report spontaneous reversals while viewing such stimuli yet appear to retain some degree of voluntary control

over perception. Here, we monitored fMRI activity while subjects maintained fixation and provided an online report of their perceptual interpretation of a Necker cube. Before each trial, subjects were visually instructed to either: 1) passively monitor the stimulus, 2) actively attempt to initiate a perceptual switch ('active' condition), or 3) attempt to sustain a single percept throughout the trial ('stay' condition). Behavioral data revealed that subjects could successfully control their perception to some extent, though not absolutely (mean switch times for active = 2.2 s, passive = 3.7 s, stay = 6.9 s, trial duration = 12 s). fMRI analyses across all three conditions revealed extensive activation in visual, parietal, and prefrontal and anterior cingulate cortex. Comparisons between voluntary control conditions (active and stay) and passive viewing revealed more restricted activation in parietal and frontal brain area previously implicated in visual attention. Some subjects also showed differential activity in the anterior cingulate and/or extrastriate visual areas. Importantly however, all brain areas showing greater activity during voluntary control also revealed highly robust responses during passive viewing (relative to fixation baseline) and only slightly, though significantly, enhanced responses during voluntary control conditions. Our findings indicate considerable overlap between the brain regions involved in controlling or biasing the perception of ambiguous figures and those involved in monitoring perception. These results are consistent with the notion that voluntary control of perception is imposed through the selective allocation of attention and the activation of stored perceptual representations. Moreover, the voluntary control of perception seems to rely on the very brain areas that serve to monitor perception from moment-to-moment.

Abstract 683 B5.89

Recognition affects the perception of apparent motion

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Purpose. Research indicates the perception of apparent motion can be influenced by viewers' knowledge of how objects move in the environment. Shiffrar and Freyd (1990) suggested "biological" apparent motion is unique when they reported the perception of apparent motion for human figures was different from inanimate objects. We investigated whether this effect is due to the biological nature of the stimuli or due to the stimuli being recognized as familiar objects.
Methods. In two experiments, ambiguous apparent motion displays were created by alternating between two pictures of an object on either side of a wall. Objects could be perceived to pass through or around the wall. Participants reported which path of motion they perceived. Degraded versions of the stimuli were also used to test whether recognition of the objects influenced the extent to which the physically possible, "around" path was seen.
Results. Participants reported seeing the physically possible path of motion for both objects capable of movement in the environment and objects not usually seen in motion. Participants did not report seeing the physically possible path with the degraded versions of the objects.
Conclusions. The apparent motion effect previously only found with human stimuli can be found with non-human stimuli, provided they depict familiar objects in the environment. The results suggest when stimuli are recognizable objects, observers use knowledge of how objects interact to interpret ambiguous apparent motion displays.

Shiffrar M. & Freyd, J. (1990). Apparent motion of the human body. Psychological Science, 1, 257-264.

Abstract 684 B5.90

A Perceptual Comparison of Image Similarity Metrics

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Purpose: Assessing how well one image matches another forms a critical component of many image analysis operations. Two norms commonly used for this purpose are L1 and L2, which are specific instances of the LP family, or Minkowski metric. These metrics are often used interchangeably, as there is typically not a principled reason for choosing one over the other. Given that the purpose of most image analysis operations is to maximize image quality for a human observer, it stands to reason that the human visual system is the "gold standard" of image similarity. The goal of these experiments is to determine whether the L1 or L2 metric produces results more congruent with human notions of image similarity.
Methods: In two experiments we sought to determine whether observers preferred image matches derived using either the L1 or L2 metric. Subjects were asked to decide which of two images more closely matched a third, where the two images were chosen from a reference set of images to be most similar to the third by the L1 and L2 metrics. The first experiment used images created by vector quantization (with L1 or L2 as the distortion function) that were matched for semantic content. The second experiment used images that were abstract, with no high level meaning.
Results: There was a small but very significant preference for the L1 metric in both experiments. In each experiment 54% of all responses indicated that the L1 match was more similar to the original image, and 11 of 12 subjects selected the L1 match on more than half the trials.
Conclusions: These results suggest that the L1 metric may better capture human notions of image similarity. This gives a principled reason for choosing the L1 metric rather than the L2 metric for use in applications related to the retrieval, manipulation, and compression of natural images. Further analysis of results provides preliminary clues about why the L1 metric may correspond better with human notions of similarity.

Abstract 685 B5.91

A modified search task investigates an alternative to the two-stage model of amodal completion

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When using disk and square patterns as distractors, search for a notched disk abutting a square is less efficient than search for the same notched disk standing separate from the square (Rensink and Enns, 1998). It is generally accepted that search is inefficient in the first case because amodal completion renders the notched disk target similar to the complete disk

distractors. In a recent study, one of us showed that search becomes efficient again if the displays are masked after a short duration (Rauschenberger and Yantis, 2001). This result is consistent with a pre-completion representation revealed by the early interruption of processing. However, other studies of amodal completion cast doubt on the generality of a two-stage model having an initial pre-completion, or "mosaic," representation (Bruno, Bertamini and Domini, 1997). As an alternative to the two-stage model we investigated the possibility that pictorial occlusions are inherently ambiguous and that the perceived organization of the target in Rauschenberger and Yantis was biased toward the completion interpretation by its context of complete disk distractors. On this view, masking the search display after a brief exposure eliminates the context effects. To test this context hypothesis, we attempted to bias the ambiguous target toward a "mosaic" interpretation by presenting it amongst notched disk and square distractors. We assessed the efficiency of search in both brief (100 ms) and long (250 ms) masked exposures. In contrast to the two stage model, the context hypothesis predicts that, under these conditions, search for the notched disk target should be relatively inefficient in the long exposure condition. Our results supported the context hypothesis.

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Abstract 686 B5.92

Amodal completion in passively viewed displays: A priming study

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Schulz et al. (OPAM, 2001) used priming to investigate the time course of grouping by color. Participants were shown ambiguous masked prime displays for a variable prime duration. A central column of elements in each prime appeared behind a transparent surface. The central column could group with elements on the right or the left depending on whether grouping was based on a pre- or a post-constancy representation of color. Participants reported the grouping of unambiguous target displays that matched either the pre- or the post-constancy representation of the prime. At short prime durations, responses were faster when the target matched a pre-constancy interpretation of the prime. At long prime durations, responses were faster when the target matched a post-constancy interpretation. Here we extend this line of inquiry by using priming to investigate the time course of amodal completion. Primes consisted of ambiguous displays in which a central column of half disks abutted a thick, opaque vertical stripe, giving rise – with unlimited viewing – to the percept of complete disks partially occluded by a stripe. The central column of half disks was flanked on one side by two columns of complete disks, and on the other side by two columns of half disks. This prime display was masked after various durations either long enough to permit amodal completion of the central half disks or not. Following the prime, we presented unambiguous target displays that were similar to the prime displays, with the exception that the central column contained either complete disks or half disks presented without 'occluder'. Participants reported the grouping of the unambiguous target displays. A reaction time advantage for targets that matched a post-completion interpretation increased with prime duration.

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Abstract 687 B5.93

Object recognition in pigeons: The effects of spatial frequencies

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We explored the effects of spatial frequency filtering on the visual recognition performance of pigeons. By comparing the effects of spatial frequency filtering across two very different species, we sought to determine the species-generality of prior human studies. In our experiments, pigeons were trained with either fully-shaded representations of three-dimensional objects or with line drawings of the same objects. Those pigeons that were trained with shaded images exhibited more control by the low spatial frequencies of the visual stimuli, whereas those pigeons that were trained with line drawings exhibited more control by the high spatial frequencies. This result suggests that pigeons may preferentially use low spatial frequencies when trained with more realistic objects, but they will use high spatial frequencies when required to do so. Continued research using pigeons and other species will determine what role spatial frequencies play in general recognition processes.

Abstract 688 B5.94

Identification of everyday objects on the basis of contour fragments: Salient points are less useful than midpoints

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At last year's VSS (Wagemans et al., VSS-2001, Abstract No. 97), we presented results on priming in picture identification on the basis of contour fragments with specific curvature properties. Contours were built up gradually in 20 steps (i.e, increasing fractions of the total contour), each presented for 500 ms. One of the surprising results then was that fragments around inflections (i.e., where curvature changes from positive to negative) yielded better identification rates than fragments around curvature extrema (i.e., where positive or negative curvature is locally maximal or minimal). In the present study, we used more stimuli (N = 188), more subjects (N = 200), and a different method in an attempt to replicate and further substantiate this finding. Fragments were now centered around points along the contour which an independent sample of observers had marked as most salient (see De Winter et al., VSS-2002, submitted) or around the points midway between two popular points. Four fragmentation levels were used (15, 20, 25, or 30% of the total contour) but only one fragmented version was shown per stimulus (for 5 s each), counterbalancing stimulus identity and condition across observers. Results showed that recognition was about 7% easier for fragments centered around the midpoints than for fragments

centered around the popular points, at each of the four tested percentages (45 vs. 52%, 52 vs. 59%, 57 vs. 64%, and 62 vs. 67%, respectively). This robust finding contrasts sharply with the results which we obtained in a related study, using connected straight-line versions, where the most popular points were clearly more useful than the midpoints (see Wagemans et al., VSS-2002, submitted). This suggests that identification on the basis of fragments is indeed special as suspected long time ago (see Kennedy & Domander, 1985, Perception, 14, 367-370 and a critique by Deregowski, 1986, Perception, 15, 217). More research is needed to explain this difference.

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Abstract 689 B5.95

Recognition with purely 3D information

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The role of 3D information in object recognition is a fundamental unresolved issue in high-level vision. Here we explore whether recognition can operate on exclusively 3D cues and how 3D cues interact with 2D information. Superficially, the first issue seems to admit a ready answer – given that we can recognize objects in random-dot stereograms, where the cues are putatively purely 3D, one may conclude that 3D information is sufficient for recognition. However, this conclusion can be challenged on the grounds that recognition in this situation may be based not on the perceived 3D information per se, but rather on the 2D distribution of depth discontinuities and iso-depth contours. In our first experiment, we examined whether there were any differences in recognition performance (accuracy and reaction time) when objects in random-dot stereograms had correct 3D structure versus incorrect 3D shape that precisely preserved the 2D distribution of the depth discontinuities and iso-depth contours. We found a significant difference between the two conditions. On a set comprising ten common objects such as faces, vehicles and animals, subjects' recognition accuracy with incorrect 3D information was significantly reduced relative to recognition accuracy with the correct 3D structures. Next, we examined the interaction between 3D and 2D cues by testing whether the inclusion of 3D cues could shift the threshold luminance contrast needed for recognition. Our data so far do not reveal any such shift, suggesting that the analysis of 2D and 3D cues for recognition may be relatively independent. Planned future experiments include the use of more sensitive methods, such as progressive deblurring, for detecting shifts in the onsets of object recognition across the correct and incorrect 3D conditions, and imaging studies for determining whether common cortical areas subserve object perception based on 2D versus purely 3D cues.

Abstract 690 B5.96

Object disappearance effect: Perceptual heuristics and destination capture in the 3D context

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When an object rapidly disappears from view, the event requires some cognitively consistent explanation. We report a new phenomenon, the Object Disappearance Effect (ODE), in which static, suddenly disappearing stimuli are seen to move backward in depth when they are in a stereoscopic context. The target was a row of disks switching off/on in a static background of similar rows of disks. In the context of the normal flat display, the target seemed to simply switch off/on. When the context was changed to a stereoscopic view of a 3D surface, the observers unexpectedly saw depth-motion despite the lack of disparity change in either the target or the surround. Thus, the 3D-context activated the heuristic of backward motion to explain the object disappearance. How will this phenomenon be affected (i) by the spatial target/surround configuration and/or (ii) by introducing stereomotion in the surround? Five configurations were studied in (i) a static and (ii) a stereomoving environment. The stereomotion was either with or against the direction of the illusory motion. The direction and speed of both target and surround were judged. The data indicate that the target was perceived to move backward as it switched off, forward when switched on again. It appeared to go to the same specific depth location, regardless of the disparity of the starting point. We propose the operation of a Destination-Capture Principle determining the perceived speed and trajectory. Introducing stereomotion in the surround did not significantly affect the illusory depth-motion in the target. Surprisingly, the illusory target motion reduced the disparity-defined surround motion, but only when the motions were in the same direction. Thus, the ODE reveals how the basic strategy of the visual system is to use heuristics in interpreting object behavior (events) in dynamic scenes. The new phenomenon reveals the dominance of cognitive factors in associating 3D motion perception and object-level processing.

Abstract 691 B5.97

Object coding: Multiple cues, multiple ways

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In a recent study by Tucker and Ellis (1998) participants saw photographs of familiar objects, and made a judgment about their (up/down) orientation. Each object had an affordance (e.g., handle) that was on the right or left. Responses were faster if the object's handle was on the same side as the response hand. Although Tucker and Ellis claim that it is the coding of the object as graspable that accounts for these findings, it is not clear what property of these asymmetrical stimuli was differentially affecting left or right responses. A simple shift in attention to one side will facilitate responses made on the corresponding side. Perhaps the affordances of objects, being salient properties, draw attention to one side of the image and produce stimulus-response compatibility. Using the stimulus-response compatibility paradigm, we investigated the coding of asymmetrical objects more closely. We began with simple, abstract shapes, larger on either the left or right side. Responses were faster when made on the same side as the larger side of the object ($p<.05$). In a second study, an arrow was added to the smaller side of the object. Responses were faster when made on the same side as the arrow ($p<.05$). Our results suggest that objects can be coded, or attention shifted, by various cues. These can be perceptual (center of

mass), cognitive (direction of arrow) and motor (affordances). In further studies, we investigated what properties of the task or the stimuli would cause these different cues to be employed.

Abstract 692 B5.98

Single inferior temporal neurons are tuned to metric shape dimensions as well as to nonaccidental differences
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Inferior Temporal (IT) neurons contribute to object recognition and categorization by coding for complex object features. Still, it is not clear how their responses can be related to similarities between complex objects. Op de Beeck et al. (2001, Nature Neurosci.) varied the amplitude of 2 radial frequency components of complex 2D-shapes and found a faithful representation of these variations in IT-neurons. This illustrates the importance of systematically varying the underlying dimensions of high-dimensional stimuli in order to find a consistent presentation of a low-dimensional subspace in individual neurons.
We recorded the responses of 80 IT-neurons to 3D instead of 2D-shapes, composed of 1 or 2 single volumes. We parametrically manipulated broadness, height, and curvature or asymmetry of each volume. Most cells were sensitive to at least 2 of these dimensions. Their responses could be accurately predicted by a quadratic regression using these dimensions as factors. (Median r2 = .83, average n of stimuli = 21, average n of dimensions = 3) We could restrict the number of dimensions in the 2-part stimuli from 6 to 4, by averaging broadness and length over the two parts.
The influence of broadness and length on the neuronal responses couldn't be explained by mere sensitivity to area changes. The same neurons were even more sensitive to nonaccidental shape changes and view changes (Kayaert et al. (2001, Soc Neurosci Abstr)). These results indicate that the coding of metric and nonaccidental properties is accomplished by a single population of neurons rather than different subsets of neurons responding to different kinds of variations in object shape.

Abstract 693 B5.99

Effects of occlusion on within-object shift of attention
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In accordance with object-based account of attention, one-object advantage has been shown in attentional shift of locations, even when the object was occluded (Moore, Yantis, & Vaughan, 1998). It is unknown, however, whether attention equally operates on occluded and non-occluded objects. The purpose of this study is to explore the substance of “object” on which attention operates. Experiment 1 compared attentional shift of locations on a single perceptual object between across and along an occluded region. Stimuli were generated by random-dot stereograms, in which a square was overridden by a bar having crossed or uncrossed disparity relative to the square, so that the square was perceived as two segmented rectangles or an occluded square. As a cue, a corner of the square was flashed. After 300 ms of the cue onset, participants detected the diminishment of dots at the cued (valid trial) or uncued location (invalid trial). RTs on valid trials were faster than those on invalid trials. In the segmented display, RTs on invalid trials were faster for cued rectangles than uncued ones, replicating one-object advantage of attentional shift. In the occluded display, however, RTs on invalid trials were slower for a cued region compared to an uncued region, suggesting faster attentional shift across than along an occluded region of a single object. Experiment 2 compared within-object shift of attention on occluding and occluded surfaces using a central arrow cue. The same two slanted surfaces were placed adjacently, so that one was perceived to occlude the other and the border between them was owned by the occluding surface. RTs on invalid cued-surface trials were faster for an occluding surface, showing that attentional shift along the border was facilitated for the surface having the border. Results of both experiments support an involuntary tracing operation of attention in direction of boundary and surface formation of 3D objects.

Abstract 694 B5.100

Bottom-up and top-down influences on the development of object perception
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Human observers, including infants, perceive unitary objects by analyzing both motion and static information (e.g., configuration). When aligned edges undergo common motion, infants tend to perceive them as unified, but when aligned edges are stationary, or misaligned edges move together, infants’ unity percepts are abolished. The best account of how motion and alignment interact in early object perception is in dispute. One possibility is that early perceptual organization follows a limited set of principles (e.g., edges moving in tandem are always interpreted as connected). On this "top-down" account, misalignment has an indirect impact on unity by reducing motion sensitivity. A second possibility is that object percepts arise from lower-order perceptual skills and experience. On this "bottom-up" account, motion and static information have direct, independent inputs to unity percepts. To address this controversy, 2-month-old infants viewed displays in which edges protruding from above and below an occluder underwent in-phase or out-of-phase motion. Edges were either aligned or misaligned when moving in-phase. Following habituation, the infants saw an identical display, alternating with the opposite-motion display, and looked longer at the novel motion regardless of edge orientation. In a companion experiment, 2-month-olds were probed for unity percepts in displays with aligned or misaligned edges; only infants in the former group perceived unity. These experiments lead to three conclusions. First, configuration has no bearing on motion sensitivity: Infants discriminated in-phase and out-of-phase motion regardless of edge alignment. Second, performance in the first experiment cannot be explained on the basis of responses to unity, because infants in the second experiment perceived unity only when edges were aligned. Third, infants' capacity to discriminate motion and

configuration exceeds their capacity to perceive unitary objects, in accord with a bottom-up view.

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Abstract 695 B5.101

Early target related processing in the discrimination of natural objects

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Human ERP studies have suggested that visual processing of natural scenes occurs rapidly, with differences between object categories under discrimination emerging by 150 ms after presentation. These early differences have been suggested to be related to the target status of a given image, which implies that they represent an upper limit for the time required to perform object recognition processes. Previous studies, however, leave open the possibilities that these differences could be the result of pre-object recognition visual processing or post-target decision motor processes. Target and nontarget images in previous studies have differed in spatial frequency content and background contextual cues which might affect pre-object recognition visual processing. To address this issue, we prepared a set of images consisting of cutout natural objects of widely varied categories placed against a pseudonatural background. We presented these images to volunteer subjects and asked them to perform a forced choice target/nontarget discrimination. A variable target cue before each image ensured that, across subjects, the images seen in target and nontarget conditions were identical. To address whether the differences might be due to motor processes, a separate set of subjects performed a go/no-go version of the task above, in one block pressing a button only for target images, in another pressing a button only for nontarget images. The results of these experiments demonstrate clear target-related differences. However, the differences arise later (~170 ms) and more gradually than those seen in previous experiments. These results confirm that the visual processing of natural objects occurs very rapidly but leave open the possibility that the earliest differences reported previously do not represent an upper limit on the time required for object recognition.
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Abstract 696 B5.102

Geometrical transformations in object categorization

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A previous speeded categorization experiment demonstrated that basic level categorization performance deteriorates with increasing amount of topological (warping) transformation between two successively presented category members (Graf, VSS 2001). If topological transformations are involved in basic level categorization, then performance in related tasks should also be influenced by the amount of shape deformation. In particular, the typicality (or representativeness) of category members should be determined by the transformational distance to the category representation. Also, shape similarity should decrease with increasing transformational distance between the objects.
These predictions were investigated for 2D outline shapes of objects from 25 common and familiar object categories. In the typicality task, subjects had to rate the typicality of different category members that were produced with a warping algorithm – i.e. had to judge how well the objects fit with their idea of the category. In the similarity task, the amount of topological transformation between two objects from the same basic level category was manipulated, and subjects had to rate the similarity of the objects.
The results confirmed the predictions: First, typicality ratings varied in a systematic way with topological shape transformation: A graded category structure was found, and typicality decreased with increasing distance to the most typical exemplar. Second, perceived similarity decreased in a highly significant way with increasing amount of topological transformation.
These findings indicate that basic level categorization performance and perceived shape similarity depend on the amount of topological transformation. The results can be accounted for by an alignment model of categorization and similarity which involves deforming transformations. The suggested model can be regarded as an image-based extension to the structural alignment account of similarity (e.g. Markman & Gentner, 1993).

Abstract 697 B5.103

White noise reveals properties of internal representations

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We have all seen a human face in a cloud, a pebble or in blots on a wall. Evidence of “superstitious” perceptions have been documented since classical antiquity (Gombrich, 1960; Janson, 1973) but have received little scientific attention. Here, we used superstitious perceptions in a new principled method to reveal the properties of unobservable object representations in memory. We presented 20,000 complete or partial white noise fields to our observers. Three observers saw an ‘S’ letter in a significant proportion of the noise fields in Experiment 1, and three observers saw a smile in Experiment 2. We extracted the first and second Wiener kernels (Wiener, 1958) subtending these perceptions. The first Wiener kernels were similar to an ‘S’ and a smile in Experiment 1 and 2, respectively. Moreover, they possessed spectral properties compatible with those reported in the psychophysical literature (e.g., Bayer, Schwartz & Pelli, 1998; Solomon & Pelli, 1994). These results suggest that purely top-down processes are responsible for our subjects perceptions. The possibility remains, however, that some bottom-up structure infiltrated our noise fields. In Experiment 3, the same sequence of 20,000 noise fields was presented to two observers: One saw a ‘Y’ letter and the other an ‘H’ letter, and, as expected, the corresponding first Wiener kernels were similar to a ‘Y’ letter and to an ‘H’ letter, respectively.

Abstract 698 B5.104

Spatial frequency and object categorization level
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Research on the contribution of different spatial bands to object recognition has been prolific, but there has been relatively little work examining how spatial factors and level of categorization task interact. In this study we examined the effects of spatial frequency filtering on object categorization at the Basic, Subordinate and Superordinate levels. In each trial, subjects were shown first a word at either the Basic level (e.g., Dog, Car, Boat, etc.), the Subordinate level (e.g., Collie, Limousine, Sailboat, etc.), or the Superordinate level (e.g., Animal, Vehicle) and then a picture of an object. Their task was to indicate if the pictured object matched the word. The picture could be either low-passed (50% cutoff at 8.0 cycles/image width), high-passed (50% cutoff at 16.0 cycles/image width) or full-bandwidth. The design was blocked along the spatial frequency and category level dimensions; trials were otherwise completely randomized. Reaction time and error rates were assessed. Our results show that while both superordinate and subordinate classifications are adversely affected by spatial filtering, basic-level categorization is robust to this manipulation. Subordinate classification proved especially vulnerable to low-passing. These findings are in agreement with previous studies suggesting that basic-level representations are robust to changes in image information (rotation, scrambling, etc.). These results also suggest that differences in the level of categorization task may explain in part differences in findings regarding which spatial bands are most effective for object recognition.

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Abstract 699 B5.105

Lack of benefit from information across spatial scales in an object recognition task
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PURPOSE. Information in an image can be represented in separate spatial-frequency bands, or spatial scales. If non-redundant information is available in different spatial scales, access to multiple scales should provide better recognition performance than access to a single scale. An image can also be divided into different spatial regions. If there is a capacity constraint on the amount of visual information that can be processed at one time, there will be a trade off in the resolution of the spatial scale and the size of the region analyzed. Such a capacity constraint can be simulated by using a restricted "window" which varies in size according to the spatial scale. We asked how effectively people would use multi-scale information when they can control the spatial scale and spatial location of such a window in an object recognition task.

METHOD. Three normally sighted subjects recognized grayscale images on a computer screen. The stimulus set consisted of images of four 3D objects (wedge, pyramid, cylinder and cone) in eight different views. Spatial scales used were 2, 4, 8 and 16 cycles/object. The square window had a linear size of about half a cycle at the scale used. Subjects used a mouse to control the spatial location of the window in discrete steps and four different keys on the keyboard to select the spatial scale. The subjects were instructed to maximize accuracy, not speed.

RESULTS. Averaged percent correct across subjects for the multi-scale condition was 54.17%. Averaged percent correct for the 2-, 4-, 8- and 16-single conditions were 42.71%, 55.21%, 64.58% and 62.50% respectively.

CONCLUSIONS. Recognition accuracy in the multi-scale condition was poorer than that in some of the single-scale conditions. Our findings indicate that human observers did not benefit from access to information in different spatial scales.

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Abstract 700 B5.106

Class specific representations of objects, faces, and places in the human brain
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Considerable effort has been put forth into identifying the nature of how different categories of objects are represented in the cortex. The debate is often summarized into two competing theories. The modular hypothesis proposes that specific modules dedicated to representing specific classes of objects. Conversely, the distributed hypothesis suggests that objects are represented diffusely in the cortex. fMRI can be an effective tool in determining the nature of representation over large scales in the human cortex. The current study sought to determine if unique spatio-temporal patterns of activation exist in the cortex that are class specific. Data from five subjects performing a passive viewing task on three classes of objects (faces, chairs, and houses) were obtained from FMRIDC database (Ishai et al). Linear discriminant analysis was used to identify patterns of activity specific to a class of objects relative to the two other classes and a stimulus control. The derived discriminant was able to reliably predict the subject's perception at individual time acquisitions (faces 73%, chairs 73%, objects 72%), well above chance levels (16.7%). Once identified, the patterns of activation specific to each class of objects were projected onto the cortex to evaluate its spatial representation independent of the shared processes. Results indicate that, for each stimulus category, the strongest contributions to the discriminant come from specific areas of the cortex; however, a modest contribution from distributed regions does exist.

Ishai, A., Ungerleider, L., Martin A., Haxby, J. (2000) The Representation of Objects in the Human Occipital and Temporal Cortex. Journal of Cognitive Neuroscience 12(2) 35-51

Abstract 701 B5.107

Category and contour of objects affect the letter 'B' Titchener illusion

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The Titchener illusion is an illusion where identical objects are perceived as unequal in size because they are surrounded by objects of a different size. Previous studies concluded that object perimeter and not category or similarity of the internal details between the inducers and the test target influences the Titchener illusion. We hypothesized that these results are the consequence of using arbitrary shapes and objects where the details of the objects are not very meaningful. In this study, we tested whether or not the category and details of objects affect the magnitude of the illusion when the details carry the identity of the objects. To do so, a classic Titchener configuration was used; a reference letter B was surrounded by 4 inducers that were 3 times larger than the reference, and a test letter B surrounded by 4 inducers that were 3 times smaller than the reference. Three categories of inducers were used: letters, numbers and shapes. Within each category, inducers had similar or different contours than the letter B. The size of the test letter B ranged from 5% larger to 7% smaller than the size of the reference, which stayed constant. Observers (N=82) indicated on each trial whether the test letter B was larger or smaller than the reference. The magnitude of the illusion was defined as the point of subjective equality where the size of the test letter B was perceived as identical to the reference. In general, the magnitude of the illusion varied depending on the category of the inducers (from largest to smallest: letters, numbers and shapes). Within each category, inducers that had different contours than the letter B yielded a larger illusion magnitude. Contrary to previous reports, our results suggest that both category and the details of the inducers play a role in inducing the Titchener illusion when meaningful objects are used and the details of the objects convey the identity of the objects.

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Abstract 702 B5.108

An object-superiority effect induced by a local luminance manipulation

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Previous research has shown that comparisons among object-properties are more efficient within a perceptual “object” than between distinct objects, a result referred to as the “object-superiority effect.” We tested this effect in a stimulus configuration in which the global organization into objects was induced by an isolated luminance change in a region remote from the locations of the critical properties. Observers were presented with a checkerboard pattern, including four grid squares (a), (b), (c) and (d) (see Figure at http://ruccs.rutgers.edu/~elanbz/checkerboard.html), on which two probes could appear. It also contained two variable squares (x) and (y) whose luminance was varied across conditions. Depending on the luminance of (x) and (y), squares (a) and (b) were perceived to be either separate squares in the checkerboard pattern or part of the same continuous object (a bar) in one of three different ways: in front of an occluder, behind an opaque occluder, or behind a transparent occluder. In the “separate squares” organization, the comparison between (a) and (b) and (a) and (c) is always between objects. However in the three “bar” organizations, the comparison between (a) and (b) is within-object, but (a) to (c) is between objects. Results showed a significant object-superiority effect just in those cases where the luminance manipulation induced a continuous object (bar) organization; subjects’ performance was better on within than between trials, but there was no difference on the “separate squares” case. These results demonstrate the potential influence of small local manipulations on the global perceptual organization of the image, and also highlight the importance of transparency in the determination of coherent surfaces.

Abstract 703 B5.109

The cortical network processing contextual, semantic and physical relationships between visual objects

Elissa Aminoff, Chloe Vaitsou, Daniel Schacter, & Moshe Bar NMR Center at MGH, Harvard Medical School and Psychology Department, Harvard University

Human imaging studies of visual representations have so far focused on objects that belong to the same category (e.g., flowers, chairs, etc.). However, objects can relate to each other along multiple dimensions. They may share physical features (e.g. a hairdryer and a drill), the same basic-level name (e.g. two different lamps), or the same context (e.g., an oven and a refrigerator). How are these different relationships represented in the brain? Using fMRI to address this question (12 subjects; 3T magnet; TR=2sec; 33 slices, 3mm each), we presented subjects with blocks of pictures, where each block contained objects that shared properties along a single dimension (i.e. appearance, basic-level name, or context). In addition, we included control blocks with pictures of meaningful objects that were unrelated to each other. We compared the cortical activation that was elicited by each of the experimental blocks with the cortical activation elicited by the control blocks. The results revealed a unique activation pattern in the temporal cortex, which was dependent on the relationship between the objects. Contextually related objects elicited activation that focused in the collateral sulcus and in the anterior tip of the fusiform gyrus. Different exemplars, on the other hand, showed primarily a decrease in activation compared with control objects. This activation concentrated in the mid-fusiform gyrus and in the lateral-occipital sulcus. Finally, perceptually related objects activated regions in the fusiform gyrus and in the posterior lateral-occipital sulcus. These findings indicate that the representation of objects and their intricate relations is subserved by a cortical network involving at least five distinct regions. The relative role of each component of this network in orchestrating our comprehensive perception of objects in the environment, ranging from physical features to conceptual properties, will be discussed.

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Abstract 704 B5.110

Object recognition by a donut

Denis Pelli, MoonHee Lee, Marialuisa Martelli, & Najib Majaj
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Olzak and Thomas posited "cigar" channels, which integrate across a wide range of frequency and a narrow range of orientation, and "donut" channels, which integrate across all orientations and a narrow range of frequency. Majaj et al. (Vision Research, in press) used critical band masking to measure the radial frequency tuning of the channel that observers use to identify letters, and always found the same one-or-so-octave bandwidth: no cigar. We did similar critical band masking experiments, but restricting orientation instead of radial frequency of the noise spectrum. With a grating signal, we reveal a channel tuned to the grating orientation, as expected. Witha letter signal, we reveal a channel that is equally sensitive to all orientations: a donut. It is a first-, not second-, order channel, as shown by the fact that the threshold energy elevation sums linearly across orientations. Thus, the letter identification channel is a donut.

Supported by NEI grant EY04432 to Denis Pelli.

Abstract 705 B5.111

Estimating depth and distance in reach space: the role of head motion parallax

Anna M. Plooy & John P. Wann University of Reading

The extent to which motion parallax can provide depth and distance information sufficient for manual interaction has not been clearly established. A series of experiments are presented which assess the contribution of motion parallax to judgements of reach distance and object depth under monocular, bi-ocular and stereo viewing conditions. A camera pair captured images of real objects, in a sparse environment, and relayed these to a modified Wheatstone stereoscope where they were viewed as virtual objects in front of the observer, which could be “grasped” without vision of the hand. The cameras and stereoscope formed a rigidly linked system which rested on a linear track, thus allowing the whole device to be slaved to lateral movement of the participant’s head over an equivalent distance to the observers inter-ocular separation. Reach distance and grasp aperture were recorded via a magnetic tracking device (miniBIRD). The results confirm the advantage of stereo information in specifying object depth (gain approx 1.2) but motion parallax did not enable equivalent performance when added to monocular or bi-ocular viewing conditions (gain approx 0.5 for both). Without the benefit of motion or stereo information, performance was poor (gain approx 0.2). Participants were more variable in judging reach distance and this diluted the effect of viewing conditions that was demonstrated for object depth. The stereo and motion parallax information do not seem to enable accurate judgements of egocentric distance in the absence of additional cues such as height in the scene (vertical gaze angle) and vertical disparity. In a further experiment where participants were presented with conflicting motion parallax and stereo information, distance estimation results supported a cue-averaging model where each cue carried equal weight. Some participants reported apparent object motion under these viewing conditions. Research supported by the UK EPSRC.

Abstract 706 B5.112

fMRI reveals a dissociation of visual and somatomotor responses in human AIP during delayed grasping

Jody C. Culham, Stacey L. Danckert, & Melvyn A. Goodale
U. of Western Ontario, CANADA

Purpose: We previously reported that the anterior intraparietal (AIP) region of humans shows a greater response to visually-guided grasping than reaching. If, as proposed, human AIP is the homologue of macaque AIP, it too should respond both to the visual presentation of an object to be grasped as well as to the grasping action. We used functional magnetic resonance imaging (fMRI) to dissociate the visual response and somatomotor responses during delayed grasping and reaching. Methods: We measured the fMRI response over a series of single trials (20 sec each). On each trial, the subject viewed the target object (250 msec) with no immediate motor response. After a 10 sec delay, the fixation point changed color (250 msec) to cue the subject to make either a reaching or grasping response, followed by a 10 sec interval before the next trial. Subjects either used a precision grip to grasp the objects or reached with the arm to touch the object without preshaping the hand. Results: The area at the junction of the intraparietal sulcus (IPS) and postcentral sulcus (PCS) that we previously found activated during immediate grasping (vs. reaching) may in fact contain two subregions. In the delayed tasks, an anterior subregion in the PCS showed a large somatomotor response but little visual response; whereas, a more posterior subregion just behind the PCS, in the anterior IPS, showed both visual and somatomotor responses. The posterior subregion showed a greater response to grasping than reaching for both the visual and somatomotor components. Conclusions: Only the more posterior subregion of grasping activation may correspond to AIP-proper. The greater visual response during grasping (than reaching) is likely related to the object processing required to preshape the hand. Given behavioural evidence that delayed grasping involves a different network than immediate grasping, further analyses will investigate activity in ventral stream areas such as the lateral occipital complex.

Acknowledgement: Supported by McDonnell-Pew Cognitive Neuroscience Program (JCC) and Canadian Institutes for Health Research (MAG).

Tuesday Afternoon Talks (North Hall) Perceptual Organization I

Moderators: Caspar Erkelens & Hany Farid

Abst #	Time	Authors
707	3:00	Palmer, Brooks
708	3:15	Farid, Adelson
709	3:30	Cunningham, Graf, Bülthoff
710	3:45	Erkelens
711	4:00	Howe, Purves
712	4:15	Macuda, Qiu, von der Heydt

Abstract 707 3:00 PM

Grouping occurs both before and after constancy
Stephen E. Palmer & Joseph L. Brooks University of California, Berkeley

Previous results from our laboratory have shown that perceptual grouping occurs after various kinds of constancy processing, because perceived grouping can be strongly influenced by depth, post-constancy lightness perception, amodal completion, and illusory contours. We now report results showing that grouping also occurs before constancy processing. The general logic is to demonstrate that grouping both affects constancy and is affected by constancy. In shape constancy, for example, we first demonstrate that pictorial depth cues influence whether observers see a central column of ambiguous ovals as grouping with circles in the frontal plane or with ovals in the frontal plane. We then also show that whether observers perceive an ambiguous oval as a circle slanted in depth or as an oval in the frontal plane is strongly influenced by whether it is grouped with a surrounding trapezoid (consistent with the circular interpretation) or with a surrounding square (consistent with the oval interpretation). Proximity, common fate, and color similarity all have strong effects in our displays. We have also demonstrated similar kinds of grouping effects on edge assignment in depth perception for textured surfaces: the edge is assigned to the region whose texture elements group with the edge according to factors such as common fate, proximity, color similarity, and orientational similarity. Analogous grouping effects also appear to occur in displays involving lightness constancy. These results are inconsistent with aspects of Palmer and Rock's (1994) theory of perceptual organization, but consistent with an alternative formulation in which grouping occurs throughout perceptual processing.

Abstract 708 3:15 PM

Energy versus synchrony in perceptual grouping
Hany Farid & Edward H. Adelson Dartmouth, USA, MIT, USA

It has been proposed that the human visual system can use temporal synchrony for perceptual grouping. In a compelling demonstration of this theory a stochastic motion display purportedly driven solely by temporal synchrony was shown to promote grouping. It was then argued that these effects point to the role of synchrony-based mechanisms and processes. We have previously argued that the displays contain a traditional form of contrast energy and thus the grouping phenomena might be attributed to traditional mechanisms.

To further study this topic we devised new stimuli rich in temporal synchrony but devoid of contrast energy. These stimuli allow aspects of synchrony and spatio-temporal energy to be independently manipulated. We find that the energy, and not the synchrony, predicts the results.

The stochastic displays consist of a sea of drifting elements. On each frame every element moves according to a random process. Different random processes drive all the elements in the central and surrounding regions. One might argue that the resulting form cue is defined solely by the fine-grained temporally synchronous motion reversals. We observe, however, that there are moments when all elements in one region repeatedly reverse directions, while in the other region all elements have a run with no reversals. We show that a classic spatio-temporal energy model consisting of a spatial lowpass filter and a temporal bandpass filter can convert these relatively large-scale temporal change differences into a contrast cue.

This simple model is consistent with the psychophysical results of Lee and Blake (Science, 1999), Kandil and Fahle (Euro. J. Neuro., 2001), Farid and Adelson (Nat. Neuro., 2001), and Morgan and Castet (Proc. Roy. Soc., 2002). A model based on temporal synchrony alone can not explain all of these results. We conclude that the proposed synchrony-based mechanisms and processes are neither necessary nor sufficient to explain the phenomena.

Abstract 709 3:30 PM

A relative encoding approach to modeling Spatiotemporal Boundary Formation
Douglas W. Cunningham, Arnulf B. A. Graf, & Heinrich H. Bülthoff Max Planck Institute for Biological Cybernetics

When a camouflaged animal sits in front of the appropriate background, the animal is effectively invisible. As soon as the animal moves, however, it is easily visible despite the fact that there is still no static shape information. Its shape is perceived solely by the pattern of changes over time. This process, referred to as Spatiotemporal Boundary Formation (SBF), can be initiated by a wide range of texture transformations, including changes in the visibility, shape, or color of individual texture elements. Shipley and colleagues have gathered a wealth of psychophysical data on SBF, and have presented a mathematical proof of how the orientation of local edge segments (LESs) can be recovered from as few as 3 element changes (Shipley and Kellman, 1997). Here, we extend this proof to the extraction of global form and motion. More specifically, we present a model that recovers the orientation of the LESs from a dataset consisting of the relative spatiotemporal location of the element changes. The recovered orientations of as few as 2 LESs can then be used to extract the global motion, which is then used to determine the relative

spatiotemporal location and minimal length of the LESs. Computational simulations show that the model captures the major psychophysical aspects of SBF, including a dependency on the spatiotemporal density of element changes, a sensitivity to spurious changes, an ability to extract more than one figure at a time, and a tolerance for a non-constant global motion. Unlike Shipley and Kellman's earlier proof, which required that pairs of element changes be represented as local motion vectors, the present model merely encodes the relative spatiotemporal locations of the changes. This usage of a relative encoding scheme yields several emergent properties that are strikingly similar to the perception of aperture viewed figures (Anorthoscopic perception). This offering the possibility of unifying the two phenomena within a single mathematical model.

Abstact 710 3:45 PM

The binding of motion to form is not direct but mediated by location signals

Casper J. Erkelens Helmholz Institute, Utrecht University, The Netherlands

Form and motion are processed along parallel neural streams. Unified visual perception of form and motion requires interaction between these streams of information. How this interaction occurs is an unsolved problem, known as the binding problem. Here we present a stimulus that demonstrates that motion is not directly bound to form. The stimulus consists of the sequential presentation of two patterns (53 X 67 deg). The two patterns contain identical distributions of easily visible random dots (0.5 deg). One pattern is displaced relative to the other by a few dots in a certain direction, except for an area in the shape of a square (12 X 12 deg) of which the dots are displaced in the opposite direction. When the patterns are generated on a CRT monitor running at 75 Hz, they are perceived as a single, static, random-dot pattern, containing white, black and grey dots, in which the square is not visible. The square becomes clearly visible if the presentation of each pair of patterns is interleaved with a grey field of uniform brightness. Furthermore, the texture inside the square is perceived to move in one direction and the texture of the pattern outside the square seems to move in the opposite direction. The motion is induced by the displacements of the dots of one pattern relative to those of the other pattern, whereas the perceived texture results from the stationary, mean, brightness distribution of the two patterns. Thus motion is perceived of textures that are not displaced. This finding suggests that motion is not directly bound to form, but that the binding is mediated by signals which indicate specific locations.

Abstact 711 4:00 PM

A probabilistic explanation of perceived line length and orientation

Catherine Q. Howe, & Dale Purves Duke University, USA

Human perception of the length and the orientation of a straight line is systematically biased as a function of the 2D orientation of the line in the retinal image. Motivated by recent evidence that the relationship between the retinal image and perception is a wholly probabilistic one, we have explored the idea that perceived length and orientation of a linear stimulus are determined by the probabilistic relationship between the linear projection in the image plane and its possible physical sources. To test this hypothesis, we collected a database of natural scenes that included the range and luminance of every pixel in the images. The database thus relates projections in the image plane to the arrangement of objects in the physical world. Accordingly, we could determine the 3-D orientations of the physical sources of all straight-line projections on the retina (the image plane), as well as the ratio of the physical length of the sources to the length of their projections. We found that the probability distributions of the tilt, slant and the physical-to-image length ratio of straight lines determined in this way change systematically as a function of the orientation of the projected line. These variations in the probability distributions predict the perception of line length and line orientation as a function of line orientation. Because the probability distributions of the possible sources of oblique projections show greater variance than those of the linear projections in the cardinal axes, these statistical relationships can also rationalize the oblique effect (i.e., the poorer and more variable performance of human observers confronted with oblique lines compared to performance with lines in the cardinal axes).

This work was supported by NIH grant # 28610.

Abstact 712 4:15 PM

The tilt aftereffect depends on border ownership

Todd J. Macuda, Fangtu T. Qiu, & Rüdiger von der Heydt Johns Hopkins University, USA, Johns Hopkins University, USA, Johns Hopkins University, USA

The visual system tends to assign contrast borders to one of the adjacent regions, as if the borders were occluding contours of objects in 3D space. Orientation selective neurons of V2 and V4 of the monkey visual cortex are often border ownership selective, responding more strongly to a contrast border when it belongs to a figure on one side of the receptive field than when it belongs to a figure on the other side (Zhou et al., J. Neuroscience 20, 6594-6611, 2000). Thus, each piece of border seems to be represented by two pools of neurons, one for each side of ownership. Here we demonstrate a tilt aftereffect that depends on the ownership of the adapting line.

The same retinal location (0.5 beside fixation) was adapted alternatingly with a right-tilted line that was the left side of a trapezoid, and a left-tilted line that was the right side of another trapezoid. The result was that a vertical test line appeared tilted to the left when it belonged to a square on the right, but appeared tilted to the right when it belonged to a square on the left. The size of the aftereffect was comparable to the classical tilt aftereffect. The small size of the “minimum response fields” of V2/V4 neurons predicts that the aftereffect should be localized. The relative size invariance of neural border ownership selectivity predicts that adaptation figures larger than the test figures should be similarly effective in producing ownership contingent aftereffects as adaptation figures of the same size. The results confirmed these predictions. Testing locations 1 left or right of the adapted position reduced the aftereffect by 60-80%. Same size and larger adaptation figures produced similar aftereffects.

These results shed new light on the neural basis of the tilt aftereffect and show that border ownership is coded at early stages of human visual cortex.

Supported by NIH EY02966.

Tuesday PM Talks (North Hall)
Perceptual Organization II

Moderators: Mary Bravo & Rudiger von der Heydt

Abst #	Time	Authors
713	5:00	Ren, Malik
714	5:15	Herzog, Fahle
715	5:30	Grabowecky, Suzuki
716	5:45	Bravo, Farid
717	6:00	von der Heydt, Qiu, Macuda
718	6:15	Brady, Kersten, Ziegenhagen

Abstract 713 5:00 PM

The ecological statistics of good continuation: multi-scale Markov models for contours

Xiaofeng Ren* & Jitendra Malik U.C. Berkeley, USA, U.C. Berkeley, USA
*VSS 2002 Student Award

Background
Previous models of good continuation [e.g., Williams & Jacobs 95] make the first-order Markov assumption, i.e., if we parametrize a curve by arc length t, the tangent direction of the contour at t+1 only depends on the tangent at t. The goal of this study is to use human-marked boundary contours in a large database of natural images to empirically determine the validity of this model.

Methods
Experiment 1: We measure the distribution of lengths of contours segmented at local curvature maxima. If the first-order Markov assumption holds, the lengths of the segments would have an exponential distribution.
Experiment 2: We evaluate higher-order Markov models, in which the tangent direction of a contour at t+1 depends on the tangent at t and the tangents at the same location t of this contour at coarser scales. This is done by empirically measuring the information gain when the order of our model increases, i.e., the mutual information between the tangent at t+1 and the tangent at t at scale s conditioned on all the tangents at t at scales finer than s.

Results
Experiment 1: We observe a power law, instead of an exponential law, in the distribution of the contour segment length. The probability is inversely proportional to the square of segment length. The power law justifies the intuition that contours are multi-scale in nature; the first-order Markov assumption is shown to be empirically invalid.
Experiment 2: The information gain shows that coarser scales contain a significant amount of information (17% of the base scale). We accordingly propose a multi-scale algorithm for contour completion, which uses higher-order Markov models. Completion is done in a coarse-to-fine manner.

Conclusion
Any algorithm for contour processing has to be intrinsically multi-scale. Higher-order Markov models exploit information across scales and lead to an efficient algorithm for multi-scale contour completion.

Abstract 714 5:15 PM

Grouping rather than orientation determines contextual modulation

Michael H. Herzog & Manfred Fahle University of Bremen

Physiological and psychophysical investigations have revealed that a context surrounding a target can strongly modulate neuronal as well as behavioral responses to that target. For high contrast targets iso-oriented contexts impair performance compared with orthogonal ones. Long or short range horizontal connections between orientation sensitive neurons are usually assumed to underly this contextual influence. However, using a recently discovered illusion, shine-through, we show psychophysically that the orientation of contextual elements does not allow predictions on contextual modulation. Hence, the effects are not based on simple interactions between orientation-sensitive horizontal connections. In the shine-through illusion, a vernier, presented for a short time, shines through a subsequently presented grating if this grating is homogeneous and extended. Otherwise the vernier remains invisible. Shine-through is also strongly diminished if single contextual lines are added above and below the grating. However, if more single lines are presented, forming a contextual grating, shine-through and good performance is regained. Therefore, the degree of contextual interference depends strongly on the overall spatial layout of the context and not on the orientation of the contextual elements per se. Grouping rather than orientation itself is the determining factor for contextual interference.

Supported by the SFB 517 "Neurocognition" of the German Research Council (DFG)

Abstract 715 5:30 PM

Evidence for perceptual "trapping" and high-level neural adaptation in multistable visual rivalry

Marcia Grabowecky & Satoru Suzuki Northwestern University, USA, Northwestern University, USA

The processes underlying bistable rivalry (e.g., binocular, depth, and figure-ground rivalry) have long been believed to be stochastic. In other words, the length of a particular dominance phase cannot be predicted from the dynamics of the preceding dominance alternations. Bistable rivalry, however, has limits for examining sequential effects in spontaneous visual rivalry

because transition probabilities are uninformative (transitions are always between two percepts). Using quadra-stable rivalry, we have demonstrated clear evidence of path dependence. Four psychophysical observers viewed a pair of overlapped shapes (diamond & hourglass, left & right-pointing chevrons, upright & inverted triangles, or left & right-skewed parallelograms) presented dichoptically. Each fused image was quadra-stable, perceptually alternating among two pairs of shapes which shared minimal contours and were "opponent" in that they produced opposite shape aftereffects (e.g., Suzuki & Cavanagh, 1998, JEPHPP; Suzuki, 2001, Vision Research). Observers viewed each fused image for 60-70 sec. while reporting changes in the dominant percept; the sequence and duration of the four dominant percepts were recorded for each image. We found evidence of "perceptual trapping" in that spontaneous shifting of percepts was substantially more likely within each opponent pair than across the two pairs. Furthermore, the visual system gradually adapted to opponent shapes while perception was trapped between them, increasing the probability of shifting to the other pair. All observers showed the same effects. These results demonstrate that changes in the percept of multistable stimuli can be highly structured. We will argue that these results suggest that opponent shape coding and high-level neural adaptation play a significant role in determining the dynamics of conscious perception in multistable rivalry.

Supported by NSF SBR-9817643.

Abstract 716 5:45 PM

Segmentation in clutter

Mary J. Bravo & Hany Farid Rutgers University, Dartmouth College

In a cluttered scene, it may be difficult to fully segment an object using only bottom-up cues. In such cases we may segment the object by first detecting one of its salient, distinctive parts and then using this part to predict the location and orientation of other object parts. For a rigid object, the predictive power of the salient part should depend on its symmetry. For example, a sphere which has infinite rotational symmetry (and so looks the same from all viewpoints) should have less predictive power than a cone.

To test this idea we constructed computer-generated, rigid objects composed of two pieces: a "handle" (a simple geometric shape) and a "tool" (two connected cylinders). In each scene, an object was presented at a random orientation amongst clutter composed of cylinders resembling the tool. A small black or white ring was placed around one of the tool's cylinders at a location that varied across trials. Similar rings were also placed on the clutter. The observer's task was to report the color of the ring located on the tool. Because the tool was camouflaged against the background of clutter, response times were expected to depend on the degree to which the salient handle could be used to predict the tool's location and orientation in the clutter. That is, response times were expected to depend on the symmetry of the handle.

The results supported this idea: response times increased monotonically as the symmetry of the handle increased from 0-fold to 2-fold to 4-fold. Response times for handles with infinite symmetry, however, were no longer than those with 4-fold symmetry.

We conclude that observers can use a salient part to predict the location and orientation of the rest of an object. The predictive power of these salient parts depends, up to a limit, on their symmetry.

Abstract 717 6:00 PM

Border ownership coding: global structure in local feature maps

Rudiger von der Heydt, Fangtu T. Qiu, & Todd J. Macuda Johns Hopkins U., USA, Johns Hopkins U., USA, Johns Hopkins U., USA

The distinction between effects of stimulation inside and outside the "classical receptive field" has become an important concept in studying visual cortical neurons. We will present examples of this seemingly confusing mixture of local and global information in single cells and discuss how it might be used in the system. Feature selective cells of area V2 have small "minimum response fields" (outside which an optimally oriented contrast border does not produce a response), which means that they signal the precise localization of features. However, many cells show also strong modulation of responses depending on whether the local contrast border is part of a figure on one or the other side of the receptive field (Zhou et al, J Neurosci 2000). This "border ownership effect" can be produced by stimulus features far outside the classical receptive field -- assigning borders to figures (or object surfaces) requires global context information. Border ownership modulation is not a marginal effect. In terms of number of cells affected and strength of modulation, it is comparable to the modulation produced by direction of motion or color. This is understandable since image segmentation and border ownership representation are fundamental requirements for visual object recognition. The representation of local and global information in single cells poses the question of how this information can be read by subsequent stages. We find that orientation and border-ownership selective cells often code color and local contrast polarity as well. The key finding is that various stimulus dimensions are represented factorially. For example, for each orientation, cells exist for all kinds of color selectivity, and for both sides of border ownership. Therefore the single dimensions can be read out by relatively simple mechanisms using linear combinations of the responses of those neurons. In this sense, the various dimensions of visual information are represented explicitly.

Supported by NIH EY02966

Abstract 718 6:15 PM

Learning to segment and recognize novel objects evolves in parallel

Mark J. Brady, Daniel Kersten, & Stacy Ziegenhagen University of Minnesota, USA, University of Minnesota, USA

Purpose. Top down and bi-directional models of vision generally assume that higher level object models must be utilized to segment or recognize objects in complex scenes.

This assumption leads to a paradox in the case where an observer is learning to recognize novel objects in realistic scenes. In the early stages of object learning, how is the observer to segment the novel objects so that they may be available as examples for recognition learning? Previously (Brady, 1998, IOVS) it was shown that observers are able to perform a kind of bootstrapped learning, wherein they learn to recognize objects from apparently unsegmentable examples. However, although the example scenes appeared to be unsegmentable, it remained to be shown to what extent the scenes were unsegmentable at the outset of training. In this experiment, we study the ability to segment during bootstrapped recognition learning. Methods. Novel objects were 3D, computer generated, organic looking objects. Each object was covered with a camouflage pattern consisting of images of other novel objects. Each observer was assigned six objects to learn and three to segment unlearned. Training and testing scenes consisted of the object of interest in the foreground and other camouflaged novel objects in the background. Object locations, background objects and camouflage were varied in every scene. Training consisted of sessions where the training scenes were presented along with an identifying sound effect. In recognition testing, observers were shown a unique scene and asked to name the object. In segmentation testing, observers were asked to trace the object of interest's outline. Results. Observers demonstrated significantly better segmentation ability with learned as opposed to unlearned objects. Conclusions.. The ability to segment objects in these stimuli is not immediate. Rather it evolves in parallel with the ability to recognize novel objects.
Acknowledgments: This work supported by the following grants: NIH R01 EY 12691 and NIH EY0 2857

Tuesday PM Talks (South Hall)
Depth and Distance

Moderators: Teng Leng Ooi & Jack Loomis

Abst #	Time	Authors
719	3:00	Rushton
720	3:15	Yang, Purves
721	3:30	Ooi, He, Wu
722	3:45	Phillips, Voshell
723	4:00	Kelly, Beall, Loomis
724	4:15	Strumpf, Feria, Braunstein

Abstract 719 3:00 PM

Perception of egocentric direction: retinal and extra-retinal influences

Simon K. Rushton York University

Perception of egocentric direction, that is the direction of an object relative to the body, is critical for visual guidance of action. What information is used to judge the direction of an object? Classically it is assumed that extra-retinal information about the orientation of the head on the shoulders, and the eye in the head, is combined with retinal object location to transform from a retinal to trunk-centric coordinate frame. However, theoretical analysis indicates that it should be possible to pick up head-centric direction directly from retinal or optic information, or that retinal information could be used to determine eye-orientation.

I report a series of experiments that bear on this matter. Observers performed a body-alignment procedure to indicate the perceived egocentric direction of an object (they turn to face a target object so that if they began walking they would end up colliding with it). Perceived egocentric direction was perturbed with displacing prisms. It is found that in a laboratory setting, prisms have less of an effect (in line with Rock et al's report of 'immediate adaptation') than would be expected from their optical displacement and the consequent error in extra-retinal eye-orientation signal. Typically, the effect is between 60% and 65% of that expected.

This finding is robust and holds when observers align themselves with point-lights in an otherwise dark room, or view alignment targets monocularly. In these two case potentially useful information contained in the field of vertical and horizontal disparities is absent. However, a particularly striking finding is that approximately 95% of the expected effect of the prism is observed when the experiment is performed out of doors, in an open field, with distant targets.

The consequence of these results for understanding of the perception of egocentric direction, and the interesting case of visual guidance of locomotion, will be discussed.

Acknowledgement: This research is supported by Nissan Technical Center, North America, Inc.

Abstract 720 3:15 PM

The probabilistic foundation of visual space

Zhiyong Yang & Dale Purves Duke University

An assumption in many studies is that visual space (i.e., the space we perceive) is metrical. For example, perceived space has often been considered a Riemann space of constant curvature. In such cases, perceived spatial relationships should be independent of the context of the visual scene. This category of assumptions, however, is inconsistent with numerous experimental observations showing that the relationship between the perceived and the physical parameters of scene geometry is systematically distorted. In the absence of a principled account of what this distortion of physical space actually means, other investigators have assumed that visual space is either affine or subject to some other transformation of physical space. Here we have explored an alternative hypothesis, namely that visual space is generated solely by the statistical properties of the physical world. To this end, we acquired and analyzed a database of natural scenes in which the distances of all object points from the image plane were measured with a laser range scanner. The probability distributions of these distances are scale invariant, a feature that accords with the human perception of distance and location under impoverished stimulus conditions. Furthermore, the probability distributions of the physical sources of visual stimuli (i.e., their distance, depth, size, and surface orientation) were found to be systematically influenced by the range

distribution of the surround. These context-dependent probability distributions of physical sources generally account for the known distortion in the perception of distance, depth, size, and orientation (e.g., the “terrain influence” on distance judgment, and the well-known contextual effects that influence the perception of orientation). Our results thus suggest that visual perceptual space, for reasons of biological advantage, is straightforwardly determined by the probability distributions of the sources underlying visual stimuli. This work was supported by NIH grant #NS 28610.

Abstract 721 3:30 PM

Delineating the perceived ground surface from a direction constancy rule

Teng Leng Ooi, Zijiang J He, & Bing Wu Southern College of Optometry, USA, U. of Louisville, USA

Perceived direction is largely veridical; for example, a target in the dark is seen along its projection line from the observer (Ooi et. al., 2001). This direction constancy rule is used by the visual system to localize an object. Adherence to the direction constancy rule can also reveal how we perceive the ground surface. Namely, it predicts that when depth is underestimated due to insufficient depth cues, the perceived ground surface is slant with its far end upward. Only in violation of the direction constancy rule, is the ground surface perceived as compressed with a zero degree slant. This prediction is consistent with our earlier observation in a reduced cue (dark) condition, where we found that small light targets (1.5-7.5 m) on the floor, or 0.5 m above, were located as if they were on an implicit ground surface with its far end slant upward. For targets at 0.5 m above the floor, the apparent slant was about 15 deg (Wu et. al., 2000). Here, we provide an additional proof for the implicit representation of the ground surface in the dark, by applying the direction constancy rule to the depth foreshortening effect (e.g., Loomis & Philbeck, 1999). Our observers matched the vertical length (in depth) of a fluorescent L-shaped stimulus to its horizontal length (fixed at 30 cm). The stimulus was viewed from five different distances (2.5-7.5 m) and placed flatly either on the floor or 0.5 m above. Arguably, if the flat L-shaped stimulus is perceived as if on an implicit slant surface of about 15 deg, the aspect ratio measured should reflect this implicit slant. Indeed, this is what we found. Thus, the foreshortening effect in the dark is related to the subjective slant of the implicit ground surface, in which the direction constancy rule is a major player.

Supported by SCO Research Funds; IRIG grant from UofL

Abstract 722 3:45 PM

Distortions of posterior visual space

Flip Phillips & Martin Voshell Skidmore College Vision Laboratories, Skidmore College Vision Laboratories

Purpose. The study of spatial vision is a long and well traveled road (which, of course, converges to a point at the horizon). Its various distortions have been widely investigated empirically, and most concentrate, pragmatically, on the space anterior to the observer. The visual world behind the observer has received less attention; it is the structure of this space that these experiments address.

Methods. An initial `field' experiment using surveyed locations and physical poles arranged in a large pasture was followed by several experiments using a computer graphics simulation of the ecological setup. A series of egocentric pointing tasks were performed in which the subject was instructed to make a controlled observation of their posterior visual space, after which they adjusted a mechanical pointer to indicate the perceived location of an object in that environment.
Results. Subjects' responses reflect systematic and consistent distortions in their perception of the visual world behind them. For the various presentation and observation conditions the subjects consistently `spread' their perceptual representation of their posterior space in a hyperbolic fashion. Directions to distant, peripheral locations were consistently overestimated by 5 to 10 degrees, and variability increased as the target was moved toward the center of the observer's back.
Conclusions. The perceptual representation of posterior visual space is of primary importance in certain sports, such as rowing, and in vehicular navigation (c.f. Voshell and Phillips in these proceedings). Our results show systematic perceptual distortions in the posterior visual world when viewed statically. Investigations currently underway examine these distortions when moving through and navigating this space.

Abstract 723 4:00 PM

Accurate judgments of exocentric direction in large scale space

J. W. Kelly, A. C. Beall, & J. M. Loomis University of California, Santa Barbara, USA

Judgments of exocentric direction are quite common, especially in judging where others are looking. In this experiment, subjects were shown two targets in a large field and were asked to judge the direction specified by the targets. They did so by noting which point on a distant fence appeared collinear with the two targets. Thus, subjects had to imagine a line connecting the targets and then extrapolate this imagined line to the fence. The targets ranged in egocentric distance from 5 to 20 m with target-to-target angular separations of 45, 90, and 135 deg. Subjects estimated the point of collinearity by marking a hand-held 360 deg panoramic cylinder representing their vistas. The two targets and the judged point of collinearity were often in quite different directions; in some conditions, only one or two of these three points were within the subjects' momentary field of view. Overall, performance was quite accurate--the mean estimates in the 60 different configurations exhibited absolute errors averaging only 5 deg and signed errors were even smaller. To perform with such accuracy, subjects must have perceived the relative locations of the two targets quite accurately and must have exhibited little systematic error in the sensorimotor integration process involved in extrapolating the imagined line in space.
Supported by: ONR grant N00014-01-1-0098

Abstract 724 4:15 PM

Judging distance without a continuously textured ground surface

Cary Strumpf Feria* & Myron L. Braunstein University of California, Irvine, USA
*VSS 2002 Student Award

According to Gibson's (1950) ground theory, continuous surfaces provide the basis for visual distance perception. One implication of this theory is that distance perception will be impaired when a continuously textured ground surface is not present. Accordingly, Sinai, Ooi, and He (Nature, 1998) found that judged distance along a ground plane was reduced when the ground surface consisted of two different textures.
The purpose of the present study was to examine the types of texture discontinuities that affect exocentric distance judgments along a ground surface. Observers viewed displays of a moving scene consisting of a ground plane and three vertical poles. The plane was either continuously textured or was divided along the depth dimension into two or three differently textured areas. Observers judged the distance between two poles that were separated in depth by adjusting the separation of two poles that were separated horizontally.
In the first experiment, judged depth separation was reduced when the poles were located in regions of different texture, replicating Sinai et al.'s result. In the second experiment, we found that judged depth separation was reduced even with the poles in areas with the same texture, if a region with a different texture was located between the poles being judged. In the third experiment, the same parallel line texture was used in both regions, but the regions were offset horizontally, producing a discontinuity at the border.
We found that a discontinuity, without a change in texture, is sufficient to reduce the judged depth separation. Overall, these results provide evidence that any discontinuity in the texture of the ground surface, even if it does not involve a change in the type of texture, reduces judged distance along the ground plane.
Supported by NIH Grant 1R01EY12437.

Tuesday PM Talks (South Hall)
Reach and Grasp

Moderators: Nicola Bruno & Mel Goodale

Abst #	Time	Authors
725	5:00	Cuijpers, Brenner, Smeets
726	5:15	de Grave, Brenner, Smeets
727	5:30	Brenner, Smeets
728	5:45	Bruno, Bernardis
729	6:00	Franz, Bülthoff, Fahle
730	6:15	Whitney, Westwood, Goodale

Abstract 725 5:00 PM

On the role of shape perception when grasping objects

R. H. Cuijpers, E. Brenner, & J. B. J. Smeets Erasmus University Rotterdam, Netherlands

Grasping has successfully been used as a tool to study the visual processing of object properties such as size and orientation. Even the grasping of irregularly shaped objects has been studied. In this study we want to examine the processing of a simple object shape property: the aspect ratio of ellipses. For that purpose we tracked the finger positions of eight subjects while they picked up cylinders with an elliptical base. We used seven 10 cm tall cylinders. One axis of the elliptical base was always 5cm whereas the length of the other was determined by the aspect ratio, which varied from 0.4 to 1.6 in steps of 0.2. On each trial a cylinder was placed either 30cm or 60cm in front of the subject in one of six orientations, which varied in steps of 30 degrees. The starting position of the hand was always 30cm in front and 30cm to the right of the subject. Our subjects usually picked up the non-circular cylinders along the cardinal axis that was most perpendicular to the direction in which their hand was moving. When neither axis was close to perpendicular, an "arbitrary" axis was chosen. Surprisingly, this behaviour was independent of the aspect ratio, and was the same even for nearly circular cylinders. The maximum grip aperture was related to the grip aperture at pickup but was independent of the object orientation. The cylinder with a circular base was picked up at convenient locations depending on the direction of approach of the hand.
We conclude that the global shape determines where the object will be grasped, but that the way the fingers move to the chosen positions only depends on the positions themselves. This grasping behaviour corresponds to the predictions of a simple minimum-jerk model of the movements of the digits towards the end positions. Nonetheless, the grasping of an object is very sensitive to the distinction between circular and elliptical objects: as soon as an object is non-circular it will be grasped at one of its cardinal axes.

Abstract 726 5:15 PM

Pointing towards the Brentano illusion

Denise D. J. de Grave, Eli Brenner, & Jeroen B. J. Smeets Erasmus University Rotterdam, The Netherlands; Erasmus University Rotterdam, The Netherlands; Erasmus University Rotterdam, The Netherlands

Perceptual judgements are often influenced by illusions that do not influence our performance in motor tasks. We assume that this is not because of a dissociation between visual processing for perceptual and motor tasks, but because illusions only produce biases in the analysis of certain aspects of the visual information. To test this assumption we investigated how the Brentano version of the Müller-Lyer illusion influences pointing. Subjects made open loop pointing movements from several starting positions (an endpoint of the illusion or a position outside the figure) to the center of the illusion. As soon as subjects moved their hand, the illusion and target point disappeared. When the movement stopped the illusion appeared again, with the target aligned with the position that the subject had reached. Our hypothesis was that the illusion will have a stronger influence on pointing when length information provides a useful cue about the distance to be moved. Thus a larger effect was expected in pointing movements from an endpoint of the figure to the center, than in movements from outside the figure. The results indeed show a bigger effect of the illusion on pointing movements from an endpoint of the figure to the center than for movements from outside the figure.

An additional implication of this finding is that subjects do not only use visual information about the endpoint of the movement to guide their hand, but that they also use cues about the distance to be moved.

Abstract 727 5:30 PM

Fast corrections based on the direction of cursor motion
Eli Brenner & Jeroen B.J. Smeets Erasmus University Rotterdam, The Netherlands

If an object toward which you are moving your hand is suddenly displaced, you will make fast, unconscious corrections to your hand's movement. When reaching out to touch an object you will even do so if you are unable to see your moving hand or to detect the displacement (Goodale, Pélisson & Prablanc, Nature 320, 748-750, 1986.), suggesting that visual information about the intended endpoint of the movement is sufficient. Sometimes, however, visual information about the endpoint cannot be sufficient. For instance, people also make fast corrections when moving a cursor to a target with a computer mouse (Brenner & Smeets, Perception 30S, 97, 2001). They respond just as readily when the cursor is displaced as when the target is displaced, suggesting that they are relying on relative positions. To test this suggestion we placed subjects in front of a computer screen and asked them to quickly bring a cursor to a target by moving a mouse. Once they reached the target it disappeared and a new one appeared elsewhere. On some trials the target, the cursor, or both were displaced when the cursor was half way to the target. When the target and the cursor jumped in the same direction subjects reacted much less vigorously than if either jumped on its own, as would be expected for a reaction based on relative positions. On other trials, however, the cursor subtly changed its direction of motion with respect to the direction in which the mouse was moving. Although relative positions change very gradually when the cursor changes direction, subjects reacted strongly to such a perturbation. Moreover they reacted far less distinctly to a change in target position if the cursor changed direction at the same time (so that the cursor would reach the target if the subject continued moving as usual). We conclude that the fast corrections in the cursor task are based on visual information about the direction of cursor movement as well as the position of the target.

Abstract 728 5:45 PM

When does action resist visual illusion? Effector position modulates relational influences on motor programs
Nicola Bruno & Paolo Bernardis Università di Trieste, Italy, Università di Trieste, Italy

Actors viewed horizontal segments either in isolation or embedded in patterns that produce spatial-relational effects (Kanizsa's compression illusion or the "dumbell" version of the Müller-Lyer compression - expansion illusion). They were asked to reproduce the apparent width of these segments by the amplitude of open- or closed-loop motor responses (after having positioned a finger on position A, choose a position B on the left of A such that apparent width = B - A). A touchmonitor was used to present the displays and to record movement amplitudes and times. In open-loop motor responses, displays were turned off as soon as actors raised their finger from position A. In closed-loop responses, displays could be viewed continuously during the actions. Four conditions were investigated: (1) open-loop responses starting from A at the left endpoint of the segment; (2) open-loop responses from A at the right endpoint of the segment; (3) closed-loop responses from A at the right endpoint of the segment; and (4) open-loop responses from A aligned horizontally with the left endpoint of the segment but displaced vertically below that segment. With both kinds of display, results in conditions (2) and (3) demonstrated relational effects comparable to those measured in standard visual matching experiments, whereas results in conditions (1) and (4) showed essentially no relational effects. Overall, these findings are not consistent with models of visual function rigidly positing either effector-relative coding in the dorsal stream vs. object-relative coding in the ventral stream (Milner & Goodale, 1995) or object-relative coding in motor planning vs. effector-relative coding during on-line motor control (Glover & Dixon, 2001). The availability of effector-relative representations of spatial extents in motor programs may depend on subtle geometrical relationships between the initial position of the effector, the direction of the programmed action, and the orientation of the acted-upon spatial extent.

Supported by the University of Trieste.

Abstract 729 6:00 PM

Are motor effects of the Titchener / Ebbinghaus illusion artifacts?
Volker H. Franz, Heinrich H. Bülthoff, & Manfred Fahle Max-Planck-Institute for Biological Cybernetics, Tübingen, Germany, Human Neurobiology, University of Bremen, Bremen, Germany, Max-Planck-Institute for Biological Cybernetics, Tübingen, Germany.

PURPOSE: Previously, we reported effects of the Titchener / Ebbinghaus illusion on grasping (Franz et al., 2000). These contradict a strong version of the action versus perception hypothesis (Milner & Goodale, 1995) which states that the motor system is unaffected by visual illusions. Here, we test whether our grasp effects were artifacts (i.e. generated by non-perceptual mechanisms). This could be the case if the motor system treated the illusion inducing context elements as obstacles and tried to avoid them. To
test for this possibility, we varied the distance between context elements and target.
METHODS: An aluminum disc (31, 34, or 37 mm in diameter, 5 mm in height) was positioned as target on a board. Around the target either small or large context discs (10 or 58 mm in diameter) were drawn at near or far distances (24 or 31 mm midpoint to nearest point on context circles). Close to the board a monitor was mounted on which a comparison disc was displayed. In the perceptual task 52 subjects adjusted the size of the comparison stimulus to match the size of the target. In the grasping task subjects grasped the target. Subjects wore shutter glasses and could not see their hand during grasping. The grasp trajectory was recorded and the maximum preshape aperture was calculated.

RESULTS: The motor illusion responded to the variation of distance between context elements and target in exactly the same way as the perceptual illusion. None of three different obstacle avoidance hypotheses can explain these results. CONCLUSIONS: Our results suggest that the same signals are responsible for the perceptual and for the motor illusion. This either indicates that the action versus hypothesis needs modification, or that the Titchener illusion is generated before the separation of the perceptual and the motor streams.
Supported by DFG grant Fa119/15-3 and by the Max-Planck Society.

Abstract 730 6:15 PM

The influence of distant motion signals on fast reaching movements to a stationary object
David Whitney, David Westwood, & Melvyn A. Goodale U. of Western Ontario, Canada

Purpose: Visual motion is a special kind of information: since it loses its behavioral relevance quickly, it is crucial for time-constrained behavior. For this reason, one might expect that visual motion should be rapidly available to motor systems as well as to perception. We examined whether visual motion information in one region of the visual field influences fast reaching movements to, as well as perception of, an object in another part of the field and compared the time courses for these two measurements. Methods: A square wave grating translated vertically on a monitor and then reversed direction. A brief stationary flash was presented next to the grating (separated by ~10 deg) at various times before or after the grating reversed direction. The endpoint accuracy of reaching movements to the flash was measured and compared to perceptual localization of the flash using the same stimulus. Results: Perceptual task: The flash appeared shifted in the direction of the nearby grating's motion. Motor task: Reaching endpoints were also shifted in the direction of the nearby motion. The time course of the reaching mislocalizations was consistent with that of the perceptual illusion. Conclusions: The motion of one object influenced reaching movements to a spatially-separated stationary object, showing that, unlike many other kinds of visual information, motion signals over large regions of the visual field are taken into account before manual localization takes place. The mechanism(s) subserving perceptual and motor localization share a common motion input.
Supported by NIH.

Wednesday AM Talks (North Hall) Visual Search I

Moderators: Jeffrey Schall & Vera Malijkovic

Abst #	Time	Authors
731	8:30	Zelinsky
732	8:45	Mazer, Gallant
733	9:00	Bichot, Rossi, Ungerleider, Desimone, Schall
734	9:15	Maljkovic, Chang
735	9:30	Rajashekar, Cormack, Bovik, Geisler
736	9:45	Horowitz, Wolfe, Hyle

Abstract 731 8:30 AM

A theory of gaze behavior during real-world visual search
Gregory J. Zelinsky SUNY Stony Brook, USA

At the recent Psychonomics meeting, I introduced a computational model capable of describing the spatial coordinates of eye movements made during visual search. This model uses filter-based image processing techniques to represent real-world targets and search displays, then compares these representations to derive a search saliency map. The target of a simulated saccade is determined by the weighted centroid of activity on this map, with this centroid changing over time as a moving threshold removes those saliency map points offering the least evidence for the target. As a result of this moving threshold pruning points from the saliency map, a sequence of eye movements are produced that bring simulated gaze to the map's "hotspot". Saccade programming is further constrained by a simulated fovea that retinally transforms the search display as the model's "eye" converges on the target. The model terminates with a target present response if any point on the saliency map exceeds a target present threshold. The model ends with a target-absent response if all saliency map activity is removed by the moving threshold without a target being detected. Current work extends this model to include an account of individual fixation durations. Temporal dynamics are produced by preventing the model from making an eye movement until a criterion distance is reached between the current fixation point and the centroid. Fixation duration is defined by the number of threshold movements needed to achieve this criterion distance. I test these model assumptions by monitoring the eye movements of observers viewing the same search displays input to the model, then comparing the simulated sequences of saccades and fixations to the behavioral data. Preliminary findings reveal considerable spatio-temporal agreement between these gaze patterns, both at an aggregate level (e.g., general tradeoffs between saccade latency and accuracy) as well as in the behavior of individual observers.

Abstract 732 8:45 AM

Evidence for perceptual saliency maps in area V4 during freeviewing visual search

James A. Mazer & Jack L. Gallant University of California Berkeley, USA

Exploration of a natural visual scene involves active eye movements that foveate salient features and facilitate feature identification. Eye movements are thought to be directed by saliency maps that encode the location of interesting features in the scene.

To identify saliency maps we trained a macaque to perform an attentionally demanding visual search task. The task was designed to mimic natural visual exploration and incorporated both natural stimuli and untrained voluntary eye movements. Search targets and distracters were cut from high quality B&W natural scene photographs. Matches were indicated with a touch bar.

We recorded the activity of 60 neurons in extrastriate area V4 along with eye movements during visual search. We found task related attentional modulation consistent with a perceptual saliency map. Neurons were more selective during search than in a passive viewing condition. To further characterize this effect we computed perisaccadic time histograms, conditioned by search target. In 22/60 (37%) neurons we found target-specific additive and multiplicative modulation. Cells were inhibited or facilitated immediately after the search target was cued and remained modulated for the remainder of the 20-30 s trial. In 30/60 (50%) cells we observed presaccadic facilitation of visual responses. Elevated visual responses predicted saccades towards the receptive field.

These effects suggest that V4 functions as a saliency map during visual search. Search target specification causes a persistent top-down modulation of spatiotemporal selectivity that optimizes V4 neurons for match identification. Putative matches are indicated by bottom-up correlations between the modulated neuronal filters and local features in the visual scene. High-activity regions in V4 represent likely matches and are most likely to be foveated by the next saccade.

Abstract 733 9:00 AM

Neuronal mechanisms of priming during popout visual search

Narcisse P. Bichot, Andrew F. Rossi, Leslie G. Ungerleider, Robert Desimone, & Jeffrey D. Schall National Institutes of Health, USA, National Institutes of Health, USA, National Institutes of Health, USA, National Institutes of Health, USA, Vanderbilt U., USA

Even during a simple popout search task, monkeys like humans are affected by trial-to-trial changes in stimulus features, as well as changes in target location. We investigated the neuronal mechanisms underlying such sequential effects, generally referred to as perceptual priming.
We recorded from neurons in the frontal eye field (FEF) of monkeys performing a popout search. As in previous studies, it was found that the repetition of stimulus properties improved performance. This feature-based facilitation of return was reflected in the neuronal discrimination process in FEF. Neurons discriminated the target from distractors increasingly earlier and increasingly better as the number of trials with the same stimulus features increased, reflecting improvements in saccade latencies and accuracy, respectively. The neuronal correlates of priming of popout were mediated by both target enhancement and distractor suppression. In contrast to the feature repetition effect, we found that the repetition of target position increased the latency of saccades to the target, but did not affect accuracy. This location-based inhibition of return was also reflected in the neuronal discrimination process in FEF.
Although changes in behavioral performance associated with priming of popout are reflected in the neuronal selection in FEF, we found that top-down feedback from the prefrontal cortex was not necessary for the expression of this effect. Target selection ability was tested in monkeys with unilateral prefrontal lesions. Orientation discrimination thresholds were measured for a target grating that differed from surrounding distractor gratings in color. Orientation thresholds increased with increased frequency of target and/or distractor color change (especially in the case where colors changed on every trial), but performance in the hemifield contralateral to the lesion was not differentially affected by the frequency of color change relative to performance in the control hemifield.
Supported by NIMH IRP and NEI grants RO1-EY08890, P30-EY08126 and T32-EY07135

Abstract 734 9:15 AM

Unconscious memory, not conscious expectancy, underlies probability effects in visual search

Vera Maljkovic & Peter S. Chang U. of Chicago, USA

In visual search tasks performance can be manipulated by changing the probability of occurrence of the upcoming stimulus. This "frequency effect" is generally attributed to a form of conscious expectancy. Contrary to this belief, we show that frequency effects can be completely accounted for by an unconscious memory-based mechanism.

Subjects discriminated the cut-off side of an odd-color diamond in a three-element display. We changed the ratio of red- to green-target stimuli from 20% to 100%. Across all conditions the run-lengths of red- and green-target stimuli were kept constant at 3 by interleaving irrelevant blue-yellow stimulus combinations with relevant red-green trials (the clustering manipulation). We observed a large frequency effect with a single irrelevant stimulus: e.g., responses to red targets became faster when red appeared 100% than when it appeared 20% of the time relative to green. The effect became smaller with 3 irrelevant stimuli and was completely abolished by inserting 7 irrelevant stimuli.

It was previously shown that in this task each trial leaves an implicit memory trace for the target defining feature that lasts ~8-10 trials, and that individual traces sum. In the absence of clustering, frequency effects are due to the fact that more frequent stimuli have longer run lengths, thus more memory is allowed to accumulate because of repetition of the same target feature, leading to response facilitation. The clustering manipulation enabled us to control the amount of memory that accumulates, consequently modulating the frequency effect. A single irrelevant stimulus allowed most memory accumulation

and thus a large frequency effect. With seven irrelevant stimuli there was no accumulation and responses to the target appearing 100% and 20% of the time did not differ.

These results demonstrate that implicit working memory, with its inherent unconscious coding of frequency distributions, can completely explain probability effects in visual search.

NIH EY13155 grant to V. Maljkovic

Abstract 735 9:30 AM

Image properties that draw fixation
Umesh Rajashekar, Lawrence K. Cormack, Alan C. Bovik, & Wilson S. Geisler U. of Texas at Austin, USA

Purpose. Regardless of the task, efficient selection of fixation points must ultimately be based on image data, yet the image properties that attract gaze are largely unknown. It is thus difficult to, e.g., implement good fixation strategies in foveated artificial vision systems. We therefore sought to elucidate the image properties that attract gaze by combining accurate eye tracking with modern image analysis techniques. Methods. Subjects searched for targets embedded in 1/f noise. The noise in a region of interest (ROI) around each fixation was averaged over many trials yielding gaze attraction images analogous to the discrimination images of [1]. In another paradigm, subjects studied several hundred natural images, and ROIs around each fixation were accumulated. These ROIs were then subject to Principal Components Analysis (PCA) to reveal commonalities (other techniques including Independent Component Analysis are currently being explored). Results. Gaze attraction images indicate that subjects fixate likely targets (as opposed to randomly sampling the image), and they often search for a characteristic feature instead of the entire target. Results from the second paradigm indicate that statistics of ROIs in natural scenes are often different from those of randomly selected regions from the same images. Conclusions. The pixel-averaging technique of [1] can be successfully combined with accurate eye tracking to reveal image structure that attracts gaze. This technique can potentially reveal image structure that draws fixation in a wide variety of search tasks. Accurate eye-tracking can also be combined with image analysis techniques such as PCA to reveal statistics of natural images at the point of fixation. This promises to compliment recent work on natural image statistics and their relationship to the neurophysiological properties of the visual system.
[1] Beard and Ahumada (1998) SPIE Proc. Human Vis. and Elec. Im. III, v3299.

The first author was supported by an Interdisciplinary Research Grant from the University of Texas.

Abstract 736 9:45 AM

Memory in visual search: Do the eyes have it?
Todd S. Horowitz, Jeremy M. Wolfe, and Megan Hyle Brigham & Women's Hospital and Harvard Medical School, USA, BWH and HMS, USA, BWH, USA

Theories of visual search have generally assumed that rejected distractors are marked so as to avoid further processing of these items (memory-driven search). To test this assumption, Horowitz and Wolfe (1998) developed the randomized search paradigm, in which standard static search is compared to dynamic search in which items are randomly replotted at new locations throughout a trial. Memory-driven search predicts that search slopes computed from means should double in the dynamic condition (with medians, the dynamic:static ratio should be 1.38:1). We have repeatedly found that slopes are similar in the two conditions. Recently, a number of studies have utilized the random search paradigm to explore this issue. Particular interest has been devoted to the question of whether there is memory for overt shifts of attention as measured by eye movements. Some studies have replicated our results, some have not. We present new data addressing this question. We had subjects perform a 2-AFC search for items which required fixation. Stimuli were lower-case trigrams presented in 9 point Palatino font. Targets were "bab" and "hoh". Distractors were drawn from the set {"beb", "bib", "bob", "bub", "hah", "heh", "hih", "huh", "kak", "kek", "kik", "kok", "kuk", "dad", "ded", "did", "dod", "dud"}. Averaged over 16 subjects, dynamic and static median slopes were 211.06 ms/item and 217.88 ms/item, respectively. These were not significantly different ($F(1, 15) < 1$). While error rates were greater for dynamic (0.073) than static (0.023) searches ($F(1, 15) = 12.75$, $p < .005$), slope differences are not significant even when corrected for errors ($F(1, 15) < 1$). We propose a framework to explain when we should and should not expect to observe evidence for memory in visual search.

This work was supported by a grant from AFOSR.

Wednesday AM Talks (North Hall) Visual Search II

Moderators: Peter Thompson & Brian Rogers

Abst #	Time	Authors
737	10:30	Woodman, Luck
738	10:45	Arsenio, Oliva, Wolfe
739	11:00	Spivey, Tyler
740	11:15	Wolfe, Torralba, Horowitz
741	11:30	Gobell, Tseng, Sperling

Abstract 737 10:30 AM

Interactions between perception and working memory during visual search
Geoffrey F. Woodman & Steven J. Luck University of Iowa

Many theories of visual attention propose that working memory and perception interact during the processing of complex scenes (e.g., Desimone and Duncan, 1995). In addition, previous research with monkeys has suggested that target objects are preferentially processed during visual search because template representations in working memory bias perceptual mechanisms in a top-down manner. Does the human

visual system also automatically allocate attention to objects that match the contents of visual working memory? We addressed this question in a series of experiments using a dual-task paradigm. Subjects were required to store an object representation in visual working memory and then perform a visual search task while maintaining this representation. Both behavioral and ERP data indicated that the contents of visual working memory did not lead to the automatic orientation of attention toward similar items. Contrary to several theories of attention, these findings demonstrate that holding an object representation in visual working memory is not sufficient to ensure that attention automatically selects similar objects. These findings also suggest that the visual system may use perceptual attention mechanisms to temporarily maintain representations of objects after such attention mechanisms are freed from the demands of the visual search task. Thus perceptual attention may also aid in the maintenance of object representations in a manner that is similar to the way in which attention has been demonstrated to aid in spatial working memory tasks.

Supported by grant 1 F31 MH12995-01 and MH63001 from NIMH and grant SBR 98-09126 from NSF.

Abstract 738 10:45 AM

Exorcizing "Ghosts" in Repeated Visual Search.

Helga C Arsenio, Aude Oliva, & Jeremy M Wolfe Brigham and Women's Hospital, Boston, USA.
Harvard Medical School, Boston, USA

Purpose: We have found that inefficient visual searches remain inefficient even when observers search repeatedly the same scene. Surprisingly, observers mimic a visual search strategy when confronted with a realistic scene from which objects have been removed - as if compelled to search thorough the remembered "ghosts" of objects. What aspects of the visual scene cause observers to "search the ghosts"? Method & Results: We developed a hybrid visual and memory search task termed panoramic search. Subjects view a changing portion of an extended scene as if they were turning their heads. At any moment, some objects are revealed and others are hidden. Subjects reported on the presence of an object, whether or not it was currently visible. The visual set size is the number of items currently visible. The memory set size is the number of items not currently visible. After 400 trials of training, search through the memory set is efficient (slope near zero). Search through the visual set is less efficient (10 msec/item). Then, objects were removed from the scene. In the Same Scene condition, the scene remains on the screen (without objects). Search through the invisible memory set was efficient. Search through the invisible visual set (the "ghost set") was less efficient (10 msec/item). After 200 trials with no objects visible, this search became efficient. In the Different Scene condition, participants saw a new scene. It had the same spatial layout as the training scene, but a different gist (e.g. kitchen->office). The "ghost" effect vanished (efficient search for visible and memory sets). In the No Scene condition the entire scene was removed. The screen is blank. The memory search was efficient. Conclusion: Observers seem constrained to search a familiar scene for known objects for many trials after those objects have been removed. Changing or removing the scene eliminates this inefficiency.

Abstract 739 11:00 AM

Standard- and triple-conjunction search modulated by linguistic input

Michael J. Spivey & Melinda J. Tyler Cornell University, Upstate Medical University

Recent eye-tracking research has demonstrated that visual perception plays an important role in on-line spoken language comprehension. To test for the inverse -- an influence of language on visual processing -- we modified the basic visual search task by introducing spoken linguistic input. In classic visual search tasks, targets defined by only one feature appear to "pop-out" regardless of the number of distractors, suggesting a parallel search process. In contrast, when the target is defined by a conjunction of features, the number of distractors in the display causes a highly linear increase in search time, suggesting a serial search process. However, we found that when a conjunction target was identified by a spoken query, e.g., "Is there a red vertical?", delivered concurrently with the visual display, the effect of set size on search time was dramatically reduced (Spivey, Tyler, Eberhard, & Tanenhaus, 2001). It appears that some immediate target feature processing may be possible upon hearing the first adjective. Moreover, the second adjective's featural processing may be limited to the set of objects that exhibit the first adjective's feature. This result was compared to a control condition where the spoken delivery of target identity (using the exact same speech files) entirely preceded display onset, and another control condition where target identity was delivered visually before each trial. In both control conditions, steep linear search functions obtained. In our most recent experiments, we have replicated these effects with triple-conjunction displays. For visual search in particular, these results suggest that the incremental linguistic processing of the spoken target features may allow visual search to process at least certain portions of a conjunction display in a parallel fashion. For vision in general, the results point to a more fluid interaction between visual and linguistic processes than typically acknowledged.

Abstract 740 11:15 AM

Remodeling visual search: How gamma distributions can bring those boring old RTs to life.

Jeremy M Wolfe, Antonio Torralba, & Todd S Horowitz Brigham & Women's Hospital and Harvard Med, USA, MIT, USA, Brigham & Women's Hospital and Harvard, USA

Subjects in even simple visual search tasks often produce RT distributions with long positive tails. Typically, these long RTs are treated as noise resulting from vigilance or motor errors and are discarded. We propose instead that the skewed shape of RT distributions might tell us about the underlying cognitive architecture. These distributions turn out to be well modeled by gamma distributions (Schneider and Shiffrin Psych Rev, 1977,84, 1; McElree & Carrasco, JEPHPP, 2000, 25,1517). Gamma distributions are produced by summing processes whose durations are distributed exponentially. The distribution

has two parameters: One reflects the number of sub-processes being summed; the other, the time constant of the exponential distribution of those sub-processes. Many models of visual search assume that attention is deployed from one item to the next at a relatively constant rate. If we suppose, however, that deployments are exponentially distributed in time, then we would predict gamma distributed RTs, though matters are complicated by added components in the measured RT such as motor response times. We evaluated this supposition using 4000 trials from each of 10 subjects performing a difficult spatial configuration search task. Target present and absent trials were gamma distributed. Gamma parameters are most readily interpreted for absent trials because the number of items selected by attention should be roughly constant across trials. Here fits of the parameter reflecting the number of deployments of attention increased linearly with set size while the time constant parameter remained relatively constant across set size. We describe a revised version of the Guided Search model, employing exponentially distributed deployment times, which produces a good fit to the experimental data. Supported by AFOSR

Abstract 741 11:30 AM

Two variations of a novel search task to investigate the nature and limits of the distribution of visual attention.
Joetta Gobell, Chia-huei Tseng, & George Sperling University of California at Irvine

In order to demonstrate that attention is distributed disjointly, we created a search task with a high penalty for attention to intervening areas.

The area to which observers must attend is defined by a square-wave grating. A single target is located in one of the even strips (along with distractors), and ten false targets (identical to the real target) are located in the odd strips (also with distractors). To successfully report the location of the real target (versus the many false ones), the observer must both attend even strips and strongly ignore odd strips.

With only two strips, one above, one below fixation (or one left, one right of fixation), it is easy to attend to one and ignore the other. As the number of strips increases, performance declines. Yet even with 12 strips, including six disjoint attended areas, analysis shows that all six strips are--to some degree--attended, and the intervening strips are--to a greater extent--unattended.

A color-coded square wave grating (instruction grating) is used to indicate the areas to be attended and ignored. In one version of the task, the instruction grating is turned off before stimulus presentation. In another version, the instruction grating remains on, superimposed on the search stimulus.

The data from both procedures indicate the attenuation of attentional modulation (between attended and unattended areas) with increases in spatial frequency. The results from these tasks are a critical ingredient for models of the distribution of spatial attention across the visual field as a combination of attentional modulation and visual acuity.

Supported by Air Force Office of Scientific Research, Human Information Processing Program.

Wednesday AM Talks (South Hall) Motion II

Moderators: Irving Biederman & James Townsend

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742	8:30	Royden, Conti
743	8:45	Rogers, Anstis
744	9:00	Murakami
745	9:15	Thompson
746	9:30	Tripathy
747	9:45	Anstis, Ito

Abstract 742 8:30 AM

A model using velocity differences to compute heading can explain an illusory transformation of optic flow fields.
Constance S. Royden & Daniel M. Conti College of the Holy Cross, USA

When an observer moves in a straight line, the image velocities on the retina (the optic flow field) form a radial pattern. The center of this pattern coincides with the observer's direction of motion. When a field of dots moving in an expanding radial pattern is superimposed on a field of dots moving with uniform lateral motion, the perceived position of the center of expansion shifts in the direction of motion of the laterally moving dots (Duffy and Wurtz, 1993). In this study, we show that the vectors computed from the differences between the expanding velocities and the lateral velocities form a radial pattern with its center shifted in the direction of the laterally moving dots, as in the illusion. We further show that a computational model (Royden, 1997) that computes heading using motion opponent operators also shows this shift in the computed center of expansion. To compare the model responses with those of human observers, we created a strong version of the illusion, in which each dot in the expanding field is spatially paired with a dot in the laterally moving field of dots. All dots had limited lifetimes of 240 msec, with a total trial duration of 800 msec. The radial field simulated observer approach toward a plane at a distance of 50 cm with a speed of 42.0 cm/sec. The maximum dot speed was 10.6 deg/sec at the edge of the 25 x 25 deg viewing window. The speed of the lateral dots was varied between trials. The stimulus created a strong illusion of the shifted center of expansion. The average shift in response for 5 observers was -0.09, 2.79, 6.99 and 9.26 deg for lateral dot speeds of 0, 2.0, 6.0, and 10.0 deg/sec respectively. The average shift in the computed center from the model simulations for the same stimuli were 0, 2.02, 6.58 and 11.92 deg, very similar to the human results. These results suggest that a motion opponent process is responsible for this illusory transformation, and may also be important in computing heading.

Supported by NSF #IBN-0196068

Abstract 743 8:45 AM

After-effects of expansion: no evidence for a change-of-size mechanism

Brian Rogers & Stuart Anstis University of Oxford, UK, UCSD, USA

After prolonged viewing of an expanding pattern, a stationary test pattern shows a negative after-effect of apparent contraction. This after-effect could be the result of mechanisms responding to the contours moving outwards across the retina – a conventional MAE – or, alternatively, it could be due to mechanisms sensitive to the changing size (or spatial frequency) of local texture elements. To test for the latter possibility, we measured the after-effects produced by adapting the visual system to an expanding, bandpass filtered, texture pattern in which successive frames were completely uncorrelated, like expanding twinkling noise, so that there was no consistent pattern of outward motion. We also created movie sequences in which the proportion of coherent transitions (same pattern in subsequent frame) to uncorrelated transitions (different pattern in subsequent frame) was systematically varied from 100:0 to 0:100. The after-effects were measured using a sensitive nulling procedure. Results were clear. After adaptation for 60s to an expansion sequence with 100% coherent transitions (as occurs in the normal world), there was a substantial after-effect such that observers judged a test sequence, which physically expanded at 15-20% of the adapting rate of expansion, to be unchanging in size. The strength of the after-effect decreased linearly with an increase in the proportion of uncorrelated transitions and none of our eight observers saw any significant after-effect when 100% of the transitions were uncorrelated. Size change alone was insufficient to create an after-effect. In sum, we found no evidence for a separate mechanism that responds to the change-of-size (as proposed by Schrater et al. 2001) in the absence of outwardly moving contours. This is consistent with Regan and Beverley's model of a size change mechanism based on detecting opposite directions of motion rather than a size change per se.

Abstract 744 9:00 AM

An adaptation-free jitter illusion perceived in a static random-dot disk surrounded by a flickering random-dot field

Ikuya Murakami NTT Communication Science Laboratories

We have previously reported a jitter aftereffect that seems an error of compensation for image slip on the retina (Murakami & Cavanagh, 1998, 2001). After adaptation to dynamic noise in an annulus, a static noise pattern covered the disk and annulus regions; the disk portion appeared to jitter coherently. Dynamic-noise adaptation was interpreted to desensitize motion detectors in the annulus, creating differential-motion codes between the disk and annulus, when both regions actually suffer from the same retinal slip due to small eye movements. Here I present a new version of similar jitter illusion, which one can easily get on-line: that requires no adaptation, lasts forever, and allows quantitative assessment of motion deficits in the annulus.
On a uniform background of mean luminance, two random-dot fields (Julesz-type: 50% black, 50% white) were presented concentrically. The border between the disk and annulus was blurred by a sigmoidal contrast modulator. The disk was shown constantly, whereas the contrast of the annulus was modulated temporally, e.g., at 9.4 Hz (80 ms on-duty, 27 ms off) for the best condition. A compelling illusion was seen: the physically static random-dot pattern in the disk appeared to jitter coherently in random directions, whereas the annulus did not. When the eye was moved either by providing a pursuit target or by inducing reflexive movements, the illusory motion was directionally consistent with expected retinal slip. Matching experiments not only quantitatively confirmed these observations, but also estimated the extent of illusory jitter to be comparable to small eye movements. I propose that given the same retinal slip in the disk and annulus, the flicker elicits noisy directional responses of motion-energy units, degrading velocity estimation in the annulus. A subsequent process for retinal-slip compensation may use these artificially weakened signals as a frame of reference, resulting in undercompensation for velocity in the disk.

Abstract 745 9:15 AM

Adapting to missing fundamental square waves: a replication of an unreported experiment.

Peter Thompson U of York UK

Adelson (1982) reported that a square wave grating, missing its fundamental and stepped to the right in 90 deg phase jumps, appears to move to the left. This result, unpredicted by correspondence and cross-correlational theories of motion perception, is easily explained by looking at the spatio-temporal characteristics of the stimulus, since the largest component of the stimulus, the 3rd harmonic actually does move to the left, the jump being 270 deg of its cycle to the right which is equivalent to a 90 deg jump of its cycle to the left. An obvious question (and one that almost certainly has been asked several times) is what happens if we adapt to this 90 deg jumping missing fundamental stimulus; in which direction will a subsequently viewed stationary 3rd harmonic appear to move? We have carried out a series of experiments adapting to 90 deg jumping square waves, with and without their fundamental component, and testing on a variety of stationary stimuli. In one critical condition we have found that following adaptation to the 90 deg rightward-jumping square-wave grating a stationary 3f-only test stimulus appeared to move to the left, i.e. in the same direction as the 3f component of the adaptation pattern. Although this result might be interpreted as support for the global motion determining the direction of the MAE we shall present evidence to support the view that the broad spatial tuning of the movement aftereffect is responsible for this result.

Adelson (1982) Some new motion illusions - and some old ones, analysed in terms of their Fourier components. Investigative Ophthalmology and Visual Science 22 (3) 144

Abstract 746 9:30 AM

Correspondence Noise and Dmin in Random-dot Kinematograms
Srimant P. Tripathy University of Bradford

Correspondence noise is a major factor limiting the detection of motion in random-dot kinematograms, whether detection performance is measured using threshold coherence or Dmax [Barlow & Tripathy, 1997 Journal of Neuroscience 17 7954-7966; Tripathy & Barlow, 2001 Perception(Suppl.) 30 32]. The previous studies provide a unified theoretical approach for studying the factors limiting threshold coherence and Dmax. Can this unified theory provide an explanation for Dmin, the smallest detectable coherent displacement for the dots of a kinematogram?

This study assumes that for kinematogram stimuli, motion is detected by global motion detectors that sum the outputs from arrays of local detectors, each having bi-local catchment regions. For such motion detecting systems, several factors could contribute towards the existence of a Dmin:
(i) There might exist a physiological lower limit to the spatial separation between the two catchment regions of the local detector.
(ii) The local detectors could undersample the stimulus plane for small displacements; the smaller the local detectors, the greater their required number for tiling the stimulus plane.
(iii) The areas of the two catchment regions for each local detector could limit the smallest detectable displacement; these areas must be small so as to reduce correspondence noise but large enough for the detection of non-rigid motion in the real world.

The theory from Tripathy & Barlow (2001) has been extended to incorporate the above constraints. Theoretical predictions for the changes in Dmin produced by changing dot density or the proportion of coherently moving dots compare favourably with results from computer simulations for two-frame motion. Psychophysical experiments are in progress to test which of the above three constraints limit performance. This study brings us closer towards the goal of providing a unified theoretical framework for studying Dmin, Dmax and threshold coherence.

Abstract 747 9:45 AM

Vector summation in split-dot motion
Stuart Anstis & Hiroyuki Ito UCSD, Kyushu University, Japan

Contrast affects motion strength. Two small, touching dots, of the same or different contrasts and luminance polarities, jumped back and forth along short, orthogonal, crossing paths. Dots were small enough to fuse into a single perceived motion (larger dots would give two transparent motions). Observers reported the perceived direction of the motion, which we found to vary all the way around the clock as the relative dot contrasts varied, even though the stimulus geometry never changed. We found that the visual system takes the vector sum of small moving dots of all contrast levels and polarities. The background luminance at which a black dot and a white dot made equal contributions to the motion percept was at the arithmetic (not geometrical) mean of the two luminances. On this background the two dots had equal Weber contrasts. We examine the role of reversed phi and static displacement.

Wednesday AM Talks (South Hall) Face Perception II

Moderators: Irving Biederman & James Townsend

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748	10:30	Sadr, Fatke, Massay, Sinha
749	10:45	Spencer-Smith, Innes-Ker, Townsend
750	11:00	Nederhouser, Mangini, Biederman
751	11:15	Elgavi-Hershler, Hochstein
752	11:30	Martin-Malivel, Mangini, Fagot, Biederman

Abstract 748 10:30 AM

Aesthetic Judgments of faces in degraded images
Javid Sadr, Bastian Fatke, Charisse L. Massay, & Pawan Sinha MIT, USA, U. of Munich, Germany, MIT, USA, MIT, USA

What makes a face beautiful? Facial symmetry and averageness have been proposed as important determinants of attractiveness, and experiments with newborns have investigated the innateness of such preferences. It has been reported that neonates prefer to look at faces judged by adults as more attractive (Walton et al, 1993; Slater et al, 1998). However, considering the limited visual acuity of newborns, it is unclear whether reliable aesthetic judgments can be made given stimuli as degraded as those available to the neonatal perceptual system. Indeed, it has not been established that adults can make reliable aesthetic judgments with similarly degraded visual stimuli. We have addressed this issue by assessing the ability of adults to judge facial attractiveness as a function of image degradation, examining also the relative contribution of featural versus configural information.

Subjects were asked to rate the attractiveness of 19 pictures of female Caucasian faces representing a wide range of attractiveness. Likert-scale ratings of the faces, as well as exhaustive pairwise comparisons, were used to establish rank orders. Subjects saw the images at various blur levels, always proceeding from the most to the least blurred conditions. In a second study, only the eyes, nose, and mouth of each face were shown.

We evaluated the consistency of the ratings of the blurred faces and of the internal features relative to those of the original images. The results demonstrate the subjects' ability to reliably rate the attractiveness of faces even at a resolution of five cycles across the face, and to provide ratings highly consistent with those by subjects who viewed the corresponding high-resolution images. Our findings suggest that it is possible to make reliable aesthetic judgments of faces with very little image information, and that attractiveness ratings are

significantly better correlated with overall facial configuration than with featural details.

Sponsored in part by an A. P. Sloan fellowship to P. SinhaJ. Sadr is an HHMI Pre-Doctoral Fellow.

Abstract 749 10:45 AM

Motion contributes to the interpretation of emotional facial expressions

Jesse Spencer-Smith Äse Innes-Ker & James T. Townsend University of Illinois, Indiana University, Indiana University

Most research on expression recognition uses still photographs of high emotional intensity expressions, whereas in real life expressions tend to be dynamic and of low emotional intensity. The present study uses photorealistic 3-D animated images of ecologically valid expressions (Spencer-Smith et. al., 2000) in a seven-alternative forced choice task. We demonstrate that very low emotional intensity expressions are accurately identified when presented in a dynamic fashion, while accuracy with static displays are near chance. Additionally, sad expressions are identified either as sad or happy depending on the direction of presentation (increasing or decreasing emotional intensity). In two experiments, participants viewed pairs of images of low emotional intensity expressions (anger, disgust, fear, happiness, sadness and surprise) presented serially in three display conditions. In the first condition, stimuli were presented in the order lower intensity->lightly higher intensity, resulting in apparent motion in the direction of increasing emotional intensity. In the second condition, intervening noise resulted in the perception of two static images; in the third, the stimuli were presented in decreasing order. Accuracies in the first condition approached those found for high emotional intensity static images in previous studies, while in the remaining condition accuracies were near chance. Sad expressions presented in the reverse order were identified as happy.

Abstract 750 11:00 AM

The matching of smooth, blobby objects--but not faces--is invariant to differences in contrast polarity for both naïve and expert subjects.

Marissa Nederhouser, Michael C. Mangini, & Irving Biederman University of Southern California

There is a striking cost in face matching performance when members of a sequentially presented pair of faces differ in contrast polarity (i.e., reversal of brightness), but no such costs are apparent when matching objects such as chairs (Subramaniam & Biederman, 1997). This result holds true even when the faces and chairs, on mismatch trials, are of equal similarity, as assessed by a Gabor-jet similarity measure. Unlike face matching, object matching can generally be accomplished by using differences in parts and nonaccidental shape properties that would be unaffected by changes in contrast polarity. Would object recognition remain invariant when such differences were not available? Subjects matched sequentially-presented images of a pair of smooth, blobby, asymmetric volumes generated from rotations of the harmonics of a sphere. Stimulus pairs on mismatch trials spanned a large range of similarity. The highly similar pairs were far more similar than the faces or Greebles in typical face or Greeble recognition experiments. The Gabor-jet similarity measure was highly correlated with both RTs and error rates on mismatch trials. Changes in contrast polarity had no effect on the matching of these stimuli, either for naïve subjects or for "experts" that had practiced for over 8,000 trials with images of positive contrast. The invariance to object contrast held throughout the range of similarity, for both expert and naïve subjects. Practice markedly lowered RTs and error rates so that the performance of the experts was not only lower after practice than earlier in practice but also significantly better than the controls on the very first trials with blobs of negative contrast. These results suggest that faces are special with respect to sensitivity to direction of contrast.

Abstract 751 11:15 AM

Vision at a glance: Faces do pop-out from a variety of other objects

Orit Elgavi-Hershler & Shaul Hochstein Neurobiology Department and Neural Computation Center, Hebrew University, Jerusalem, Israel

It has been a basic tenet of the search literature that only elements that differ in a basic feature such as orientation or color would pop out from an array of distractors. More recent research has shown, however, that high-level concepts may pop out as well. Furthermore, experiments generally used a uniform array of distractors for search tests. In Experiment I subjects were presented with line drawings of faces, cars and houses as targets or distractors. Reaction time was independent of set size from 16 to 64 items/array when the target was a face and distractors were cars or houses, but increased with size when the target was a car or a house on a background of houses or cars, respectively. These results were obtained even when the distracting houses or cars differed in size and shape. We were concerned that the different outlines of round faces vs. linear houses and cars might serve as a low-level distinguishing feature. Experiment II therefore used a variety of real-life photographs containing faces and many other objects. Search for faces still had no set-size effect. The data indicate that important object categories are not detected by relatively slow, focused conjunction search, but by a faster system that is comparable to feature search. The results are in accord with recent RSVP experiments indicating that perception and categorization of high-level objects can be extremely rapid. Specifically, the results indicate that the visual system may be using a fast system with spread attention to find the gist of the scene, including object categories, as suggested by Reverse Hierarchy Theory (see Hochstein & Ahissar, VSS 2000).

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