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## Voluntary versus Automatic Control over the Mind's Eye's Movement

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### ABSTRACT

Three experiments are reported that test the hypothesis that shifts of attention can be mediated by automatic as well as voluntary control. In these experiments, subjects were induced to shift their attention, but not their fixation, through the use of two types of visual cue. The experiments examined differences between the cues on three criteria for comparing automatic versus nonautomatic processes: capacity demands, resistance to suppression, and sensitivity to changes in expectancy. According to all criteria, one of the cues was shown to induce shifts of attention more automatically than the other. This indicates two separable modes of control over the allocation of attention.

### INTRODUCTION

Attention can be shifted from one locus in the visual field to another without shifting eye position. Two experimental results invite this conclusion: First, subjects are faster and more accurate at detecting or recognizing a target in a visual array if the position of the target is known before the array is presented than if it is not (Jonides, 1976; Smith & Blaha, 1969; Eriksen & Hoffman, 1974; Posner, Nissen, & Ogden, 1978). Second, misinforming subjects about a target's location harms performance relative to giving no location information (Jonides, 1976; Posner et al., 1978). Moreover, these "benefits and costs" in performance are not caused by movements of fixation. They persist even with stimulus presen-

tations too brief to permit a saccade, and they are found when eye position is measured and remains fixed.

What controls movements of attention? An examination of the experimental procedure that is frequently used to elicit attention shifts suggests one answer. Frequently, subjects are presented with a visual marker in advance of each stimulus array, with the marker located near the impending location of the target item (Eriksen & Hoffman, 1972, 1973, 1974; Eriksen & Rohrbaugh, 1970; Holmgren, 1974; Van Der Heyden & Eerland, 1973). Such a marker would be a high contrast, salient discontinuity in a nonfoveal area of the visual field. Intuition and some experimentation suggest that such a cue may automatically capture attention much as it might automatically elicit an eye movement to the cued location, if a functional eye movement were permitted in these experiments (Todd & Van Gelder, 1979).

But peripherally located visual cues are not necessary to cause shifts of attention. Helmholtz (1925) realized this long ago when he remarked that "it is possible, simply by a conscious and voluntary effort, to focus the attention on some definite spot in a field" Various casual observations lead one to the same conclusion. For example, in order to detect the dim illumination of distant stars, many astronomers have developed the ability to focus attention *voluntarily* on a part of the peripheral visual field while maintaining fixation at the center. But one does not even need to be extensively skilled or practiced to engage in a voluntary shift of attention: We have all, at one time or other, watched an event "out of the corner of our eyes" without actually foveating the event of interest.

Experimental data also support the claim that the location of attention is subject to voluntary control. Posner et al. (1978), for instance, gave subjects *centrally* located visual cues (arrows) to indicate the *peripheral* positions of impending targets in a detection task. Introspection suggests that such cues, unlike the peripheral visual markers just described, do not automatically draw attention to the cued location; rather, they seem to stimulate a voluntary shift of attention.

These and other experiments (Jonides & Somers, 1977; Shaw, 1978; Shaw & Shaw, 1977) support the hypothesis that attention shifts can be guided by two mechanisms: On the one hand, certain salient stimuli have reflexive control over attention allocation such that when one of these stimuli occurs, a shift of attention to the stimulus is automatically elicited. On the other hand, subjects have internal control over the spatial allocation of attention so that, when motivated, they can voluntarily shift attention from one part of the field to another.

We tested this hypothesis by having subjects engage in a visual search task under the guidance of one of two cues. One was chosen because of its likelihood of automatically drawing attention (an arrowhead in the periphery), whereas the other (an arrowhead at the point of fixation) was chosen because it was presumed to cause a voluntary shift of attention (see Todd & Van Gelder, 1979, for a

discussion of stimuli that control shifts of the eyes, and presumably attention, in a voluntary or reflexive manner).

The hypothesis, then, was that the two types of cues would mediate shifts of attention in qualitatively different ways—one via automatic control and one via voluntary control. Evaluation of the hypothesis required some empirical criteria of automaticity. To avoid ambiguous results, a strict position was adopted by choosing three criteria for automatic processes and testing whether a difference in automaticity between the types of cues could be demonstrated according to *all three* criteria. The experiments that follow report the results of tests against these criteria.

## EXPERIMENT 1: CAPACITY

Perhaps the most frequently cited feature of an automatic process is its minimal use of mental capacity. According to many accounts, as a process becomes more automatic, the operations involved are executed with ever lessening demands on attentive resources. Presumably, this is due in part to the stereotypy of operation that characterizes most (if not all) automated processes.

In the present experiment, a standard laboratory paradigm was used to assess capacity demand. Subjects engaged in a memory span task while performing visual search under the direction of either peripheral or central cues. If peripheral cues are processed more automatically than central cues, subjects should be disrupted less by the memory task when using peripheral cues during search.

### Method

*Design.* There were two conditions in the experiment, in both of which the primary task was the identification of an L or R that appeared among seven other letters. In the peripheral cue condition, each search display was preceded by an arrowhead that was placed near one of the letter positions. In the central cue condition, an arrowhead was also used as a locational cue, but it was placed in the center of the display where subjects were told to fixate. The delay between cue and search array was 90 msec.

The cost-benefit technique of Posner et al. (1978) was used to assess shifts of attention. On 70% of the trials (valid trials) with either cue the arrowhead correctly indicated the position of the impending target. On the remaining 30% of the trials (invalid trials), the arrowhead pointed to a nontarget location. We diagnosed shifts of attention by examining differences in performance between valid and invalid trials. This corresponds to adding together costs and benefits in the sense defined by Posner et al. (1978).

*Subjects.* Eight undergraduates served as paid volunteers in two experimental sessions of 1 hr each.

*Apparatus.* A computer controlled the presentation of stimuli, which were displayed on a graphic display device. Subjects were seated such that the viewing distance from the screen was approximately 60 cm. The testing room was kept dimly illuminated throughout the experiment.

*Stimuli.* The stimulus arrays consisted of letters evenly spaced around the circumference of an imaginary circle of  $7.5^\circ$  diameter. Each letter was  $1.2^\circ$  in height and  $.8^\circ$  in width. Each stimulus array was constructed by first locating an uppercase L or an uppercase R at one of the eight array positions and then randomly selecting uppercase letters from the remainder of the alphabet without replacement to fill the seven remaining display positions. On peripheral cue trials, the stimulus arrays were preceded by an outline arrowhead ( $.8^\circ$  in length) that pointed to one of the eight array locations. The arrowhead was positioned in the display such that its tip was  $.7^\circ$  from the closest position of the letter to which it pointed. On the central cue trials, an arrowhead also preceded the letter displays, but it was always positioned in the center of the imaginary circle on which the letters were placed.

In the first experimental session, a subject received three blocks of 80 trials from one of the two conditions, preceded by 30 practice trials appropriate to that condition (peripheral for half the subjects, central for the other half). The second session contained trials from the remaining cue condition. In both conditions, there were 56 valid and 24 invalid trials with targets appearing equally often at each display position for each type of trial. The practice trials were constructed using the same principles as those used for the test trials. Data from the practice trials are not included in the analyses presented below.

*Procedure.* Subjects were told about the design of the experiment and about the two conditions in which they would participate. This included instructions about cue validities. Then they were told the order of events on each trial: First, they would be read a list of three, five, or seven randomly chosen digits. Following this, they could initiate a trial that began with a dot appearing in the center of the screen and remaining in view for 2 sec. The dot would be replaced by the cue which was displayed for 25 msec. Next, the screen would be blank for the duration of the delay (90 msec), and then an eight-letter display would be presented for 25 msec. Subjects were told to press a left response key if the display contained an L or a right key if it contained an R. They were instructed to respond as quickly yet as accurately as possible. Finally, subjects were instructed to recall aloud the digit string in serial order. Subjects were told to regard the digit task as secondary and not to let it detract from performance on the search task. Nevertheless, they were told to be accurate in their recall.

We exercised two precautions to ensure that subjects maintained fixation throughout the trials. First, we vigorously instructed and reminded subjects about the importance of maintaining fixation throughout the experiment. Second, we

used a delay, 90 msec. for which the total duration of cue plus delay plus display was 140 msec. This value is about one-half of the average saccade latency reported in experiments similar to the present one (Colegate, Hoffman, & Eriksen, 1973). Thus, even the fastest saccades to the target should have been rendered nonfunctional.<sup>1</sup>

## Results and Discussion

*Reaction Times and Errors.* Figure 11.1 presents the mean response times and error rates for central and peripheral cues as a function of memory load. Separate analyses of variance for each dependent measure were used to analyze these results. The analyses included the factors of cue type (central versus peripheral) and memory load (three versus five versus seven items) in addition to a subjects factor.

The analysis of response times revealed a reliable main effect of memory load,  $F(2, 14) = 95.24, p < .001$ , and a reliable interaction of this factor with cue type,  $F(2, 14) = 10.07, p < .01$ . The main effect of cue type was not significant ( $F < 1$ ). Examination of Fig. 11.1 shows the cause of the reliable interaction: Response times to central cues are affected by memory load more than responses to peripheral cues.

The analysis of error rates revealed no reliable interaction of cue with memory load,  $F(2, 14) = 1.76, p > .05$ , although each of the main effects was significant,  $F(1, 7) = 10.13, p < .02$  for cue type,  $F(2, 14) = 10.44, p < .01$  for memory load.

*Memory Scores.* On the basis of assumptions underlying the use of dual-task methodology, the reaction-time results indicate that processing the central cue is a more capacity-demanding task than processing the peripheral cue. To ensure that this conclusion is warranted, we examined the accuracy of subjects' memory scores. The result of this examination was the following: For list lengths of 3, 5, and 7, respectively, subjects correctly recalled 2.93, 4.53, and 5.56 items in the peripheral cue condition and 2.93, 4.38, and 4.75 items in the central cue condition. The data reflect the use of a strict scoring criterion in which a digit was counted as correct only if it was recalled in the correct serial position. Notice that on the average (and especially with list length = 7) performance is worse on trials with a central cue than on those with a peripheral cue. Analysis of the memory scores confirmed that there was a reliable main effect of cue,  $F(1, 7) = 19.95, p < .001$ , and memory load,  $F(2, 14) = 87.35, p < .001$ , and a reliable interaction of these two variables,  $F(2, 14) = 9.02, p < .01$ . So both the

<sup>1</sup>Pilot experimentation confirmed the success of these precautions. In this pilot work, subjects' fixations were monitored while the same two precautions as in Experiment 1 were exercised. We found that subjects refixated the display on 7% or less of all trials. The results of the pilot study were unchanged by deleting the trials on which refixations occurred.

response times and the memory scores indicate the greater difficulty of processing the central cue.

*Costs and Benefits.* A final analysis confirms the position presented here. We subtracted response times and error rates for valid trials from the comparable scores for invalid trials. The difference scores are measures of costs plus benefits in performance. Our hypothesis was that the greater automaticity of the peripheral cue should render it more invulnerable to interference by the memory task. This would be indicated by a greater invariance of costs plus benefits as a function of memory load for the peripheral than for the central cue. Our analyses confirm this prediction.

Figure 11.2 plots costs plus benefits in response times as a function of memory load. There is an overall effect of cue type,  $F(1, 7) = 22.59$ ,  $p < .01$ , and of memory load,  $F(2, 14) = 4.52$ ,  $p < .05$ . Of greater interest, however, is the reliable interaction of these two effects,  $F(2, 14) = 4.73$ ,  $p < .05$ . The interaction was also found for the error rates reported in Fig. 11.2,  $F(2, 14) = 8.87$ ,  $p < .01$ , although neither main effect was reliable,  $F(1, 7) = 1.98$ ,  $p > .05$  for cue,  $F(2, 14) = 1.35$ ,  $p > .05$  for memory load.

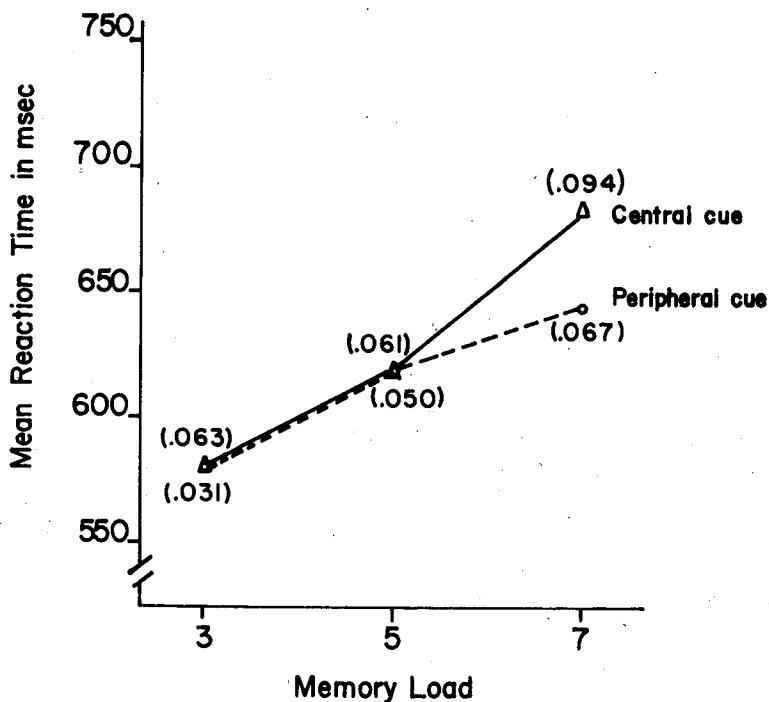


FIG. 11.1. Experiment 1: Mean reaction times as a function of memory load for central and peripheral cues. Numbers in parentheses represent proportions of errors.

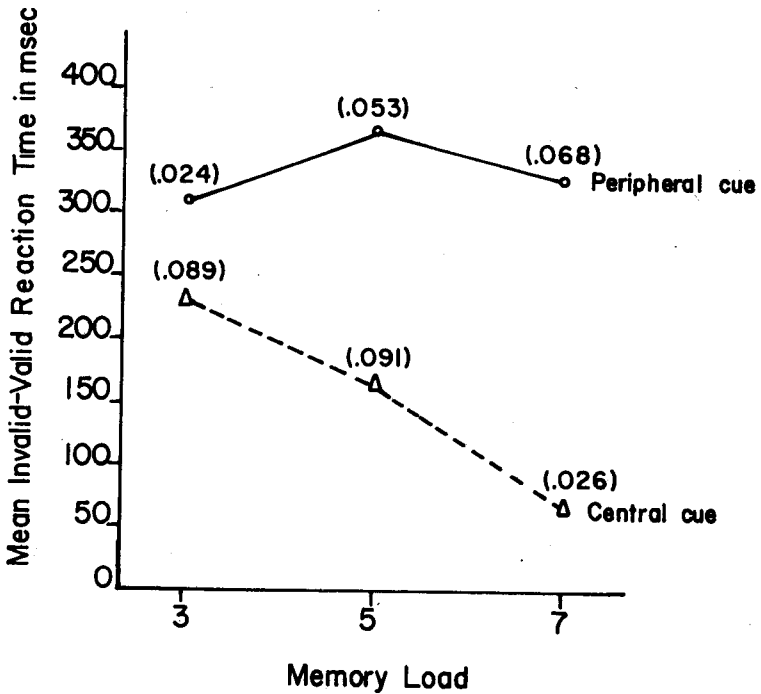


FIG. 11.2. Experiment 1: Mean invalid-valid reaction times as a function of memory load. Numbers in parentheses represent proportions of errors.

Thus, the attention-capturing power of the peripheral cue is relatively unaffected by increased alternative demands on processing capacity. This is exactly what one would predict if the peripheral cue were operating in a more automatic fashion than the central cue.

We consider now two further criteria used to assess the automaticity of processing in this task.

## EXPERIMENT 2: RESISTANCE TO SUPPRESSION

One of the most striking aspects of an automatic process is its resistance to suppression. By this, we mean that, given the proper initiating conditions (i.e., the proper stimulus), an automatic process will begin and end in an autonomous fashion. An attempt to suppress or interrupt processing will either completely fail or be less successful than a similar attempt to interrupt a nonautomatic process.

The classic example of resistance to suppression is the Stroop effect. The problem for subjects here is that the names of the words intrude on the naming of the hues in which the words are printed. But, subjects are aware of this. Their

problem is that, try as they may, they cannot seem to suppress processing of the word names sufficiently to eliminate the interference.

This and other similar phenomena (Shiffrin & Schneider, 1977, Experiment 4d) suggest that measuring the degree to which one can suppress a particular process will provide an indication of the level of automaticity for that process. Consequently, in Experiment 2 we introduced a condition in which subjects were instructed to ignore the arrows that preceded the letter displays. We reasoned that if a peripheral arrow cue provides a more automatic basis for an attention shift than a central cue, then subjects should have more difficulty ignoring it.

## Method

*Subjects.* Eighteen undergraduates were paid for participation in one experimental session.

*Apparatus and Stimuli.* The apparatus and stimulus displays were identical to those of Experiment 1 with three exceptions. First, a delay of 50 msec between cue and display was used. Second, the validity of the cue in the peripheral and central cue conditions was reduced to 12.5%. Because there were eight possible target locations, the one indicated by the cue was therefore only randomly related to the actual location of the target. The reason for the decrease in valid trials is made clear later. Third, the memory load task was eliminated.

*Procedure.* The trial-by-trial procedure was similar to that of Experiment 1, except for the elimination of the memory load task. Subjects received two consecutive blocks of 80 trials for each cue condition, resulting in a total of 320 test trials. The blocks of each cue condition were preceded by a block of 30 practice trials appropriate for that condition. The order of cue conditions was counterbalanced across subjects.

Subjects in the "attend" group were given instructions that were similar to the visual search instructions of Experiment 1. In addition, these subjects were told that there was a "fairly low" cue validity, although they were not told that the validity was at a chance level. Throughout the session, these subjects were frequently instructed to attend to the cue because on the average, they were told, it would improve their performance.

The second group of subjects was instructed to ignore the arrow cues. They were told about the actual cue validity and the random relationship between cue and target. Furthermore, these subjects were shown data similar to those of Experiment 1 to convince them that the experimenter could assess whether they had actually ignored the cue. In this way, the need to ignore the directionality of the cues in both peripheral and central conditions was emphasized.

## Results and Discussion

Reaction times and error rates are presented in Table 11.1. Two analyses of variance, one for each group, assessed the effects of cue (peripheral versus central) and validity (valid versus invalid) for each of the dependent measures.



The analyses of reaction times revealed the following effects. For the group that was instructed to attend to the cue, there was a reliable main effect of validity,  $F(1, 8) = 20.83$ ,  $p < .001$ ; no reliable effect of cue types ( $F < 1$ ); and an insignificant interaction of the two variables,  $F(1, 8) = 1.43$ ,  $p > .05$ . The interaction is consistent with the finding of Experiment 1 that there is a smaller difference between valid and invalid trials for the central than the peripheral cue. That this interaction is not reliable may be attributed to the increased variability of the valid trials in this experiment due to their small number.

Analysis of the reaction times for the group instructed to ignore the cues revealed a somewhat different pattern of results. Again, there was no main effect of cue type ( $F < 1$ ). Also, there was no reliable effect of validity overall,  $F(1, 8) = 2.98$ ,  $p > .05$ . However, there was a reliable interaction of these two variables,  $F(1, 8) = 6.25$ ,  $p < .05$ . As Table 11.1 suggests, this interaction is due to the fact that there is a reliable difference between valid and invalid peripheral cues ( $p < .05$  by Scheffé post hoc test) but no reliable difference between valid and invalid central cues ( $p > .05$ ).

The analysis of the low error rates for each group revealed no reliable effects ( $p > .05$ ).

These results indicate that, when given instructions to ignore an attention-directing cue, subjects can comply when the cue appears in the center of the display, but they cannot do so when it appears in the periphery. In other words, subjects have more difficulty in suppressing an attention response to the peripheral cue, a result that is consistent with our hypothesis that this cue acts in a more automatic fashion than does its central cue counterpart.

There is one aspect of these results that may appear strange initially. The mean difference between response times for valid and invalid trials in the "attend" condition is 95 msec for peripheral cues and 61 msec for central cues. The comparable values for Experiment 1 are 337 msec and 153 msec, respectively. Why is there such a large discrepancy between the experiments?

One obvious possibility is that Experiment 1 also included a memory load variable that may have exaggerated the invalid-valid difference. But as we shall

TABLE 11.1  
Mean Reaction Times and Mean Error Proportions for the  
Two Conditions of Experiments.<sup>a</sup>

Condition	Attend		Ignore		
	Valid	Invalid	Valid	Invalid	
Peripheral	RT	666 (155)	761 (120)	714 (150)	812 (131)
	Errors	.039 (.042)	.067 (.029)	.061 (.042)	.086 (.026)
Central	RT	679 (149)	740 (113)	763 (197)	761 (122)
	Errors	.045 (.046)	.070 (.026)	.050 (.035)	.045 (.020)

<sup>a</sup>The values in parentheses each represent one standard deviation from the respective means.

see, a similar size effect also obtains in Experiment 3 in which no memory load variable is involved. A more plausible possibility involves the cue validity. In Experiment 1, validity was 70%, whereas in the present experiment it was 12.5%. In another series of experiments, Jonides (1980) has shown that there are systematic and roughly symmetrical reductions in the magnitudes of costs and benefits with reductions in cue validity. The discrepancy between the first two experiments can be resolved on the basis of these findings.

The fact that cue validity can have an effect on the magnitude of costs and benefits for a peripheral cue as well as a central cue suggests that subjects do have some measure of control over whether they attend to the peripheral cue. Of course, as the data of the "ignore" condition in the present experiment show, subjects do not have total control: They cannot completely ignore the peripheral cue even if motivated to do so. Thus, a reasonable conclusion might be that the operation of the peripheral cue is not completely automated. Perhaps there are two components to its processing, an automatic and a nonautomatic one. The automatic component is revealed by the identical differences between invalid and valid trials for the attend versus the ignore conditions. The nonautomatic component is revealed by the change in invalid minus valid response times with cue validity. This may be an interesting hypothesis for future research; but for the present our main purpose is to demonstrate a difference in the processing of central and peripheral cues. The present experiment is support for such a hypothesized difference.

### EXPERIMENT 3: EXPECTANCY

In Experiment 2, we discovered that it is difficult to ignore a peripheral cue when it precedes a stimulus display, apparently because the presence of such a cue initiates a shift of attention on many trials regardless of instructions to ignore the cue. The result suggests the following generalization: The proper stimulus conditions alone may often be sufficient to trigger an automatic process in the present task. From this it follows that a peripheral cue should remain an effective stimulus to capture attention regardless of whether subjects expect it to be presented or not. This stands in contrast to the effectiveness of a central cue. Here we hypothesize that the controlled processing that is required to render this cue effective would leave it subject to changes in expectation. The present experiment tests this notion: that is, whether the potency of the two types of cues is influenced by subjects' expectations about their occurrence. We predict that the automaticity of the peripheral cue should render it less subject to such influence. We test this prediction by mixing trials with the two types of cues and varying the probability that each cue will be presented. Presumably, if one cue is made much more probable than the other, then subjects will come to expect its occurrence more frequently.

## Method

*General Design.* There were two groups of subjects in the experiment. Each group was presented a series of visual search trials as in Experiment 1 (though without the memory load task) with either peripheral or central cues preceding each trial in a mixed random order. For one group (80 C-20 P), central cues occurred on 80% of all trials and peripheral cues occurred on the remaining 20%. For the other group (80 P-20 C), peripheral cues appeared on 80% of the trials, whereas central cues appeared on 20%.

*Subjects.* Twenty-four undergraduates were paid for participation in two 1-hr sessions. Twelve were assigned to the 80 C-20 P group, 12 to the 80 P-20 C group.

*Apparatus and Stimuli.* The apparatus was identical to that described for Experiment 1. The test stimuli likewise were constructed according to the same principles used for Experiment 1. In the present experiment, two delay values were used, however: 25 msec and 100 msec. Subjects were presented with 400 test trials in each session at one of these two delays. The order in which subjects were presented with the two delay conditions was determined randomly.

*Procedure.* In addition to general instructions about stimulus events, 70% cue validity, and cautions about speed and accuracy, subjects were told about the uneven probability of central and peripheral cues. They were further instructed that although the two cues were randomly intermixed, a trial-by-trial expectation for the more frequent cue would be correct much more often than not.

## Results and Discussion

*Reaction Times.* Figure 11.3a and b display the reaction-time results for the 80 P-20 C and 80 C-20 P groups, respectively. An analysis of variance was used to examine trends in the data. It included the factors of expectancy condition (80 P-20 C versus 80 C-20 P), delay (25 msec versus 100 msec), cue type (peripheral versus central), validity (valid versus invalid), and subjects. The analysis revealed several reliable effects. As the figures clearly show, valid cues produce responses that are faster than those produced by invalid cues,  $F(1, 22) = 77.70, p < .001$ . Furthermore, as in Experiment 1, the difference between valid and invalid cues is greater for peripheral than central cues,  $F(1, 22) = 89.82, p < .001$ . The most relevant interaction for the hypothesis underlying the experiment, however, is the reliable four-way interaction among expectancy, cue, validity, and delay,  $F(1, 22) = 20.51, p < .005$ . Its interpretation is revealed by examining Fig. 11.3. Note first that the difference between valid and invalid central cues is much smaller (and, in fact, not statistically reliable by post hoc test) in the 80 P-20 C than in the 80 C-20 P condition at a delay of 25 msec. At the same delay, however, the difference between valid and invalid peripheral cue trials is about the same magnitude in the two expectancy conditions. This pattern

of results is different at a delay of 100 msec. Here, the difference between valid and invalid central cues as well as the difference between valid and invalid peripheral cues remains the same in the two expectancy conditions. So it appears that, at a short delay, varying the probability of the central cue has marked consequences for resulting costs and benefits; varying the probability of the peripheral cue has no such effect. Subjects can, however, compensate for the unexpectedness of the low probability central cue if given sufficient delay between its presentation and the presentation of the display. For the peripheral cue, no compensation is necessary. It retains its potency in capturing attention regardless of its probability of occurrence within the range explored. This confirms the hypothesis that the peripheral cue operates in a more automatic manner than does

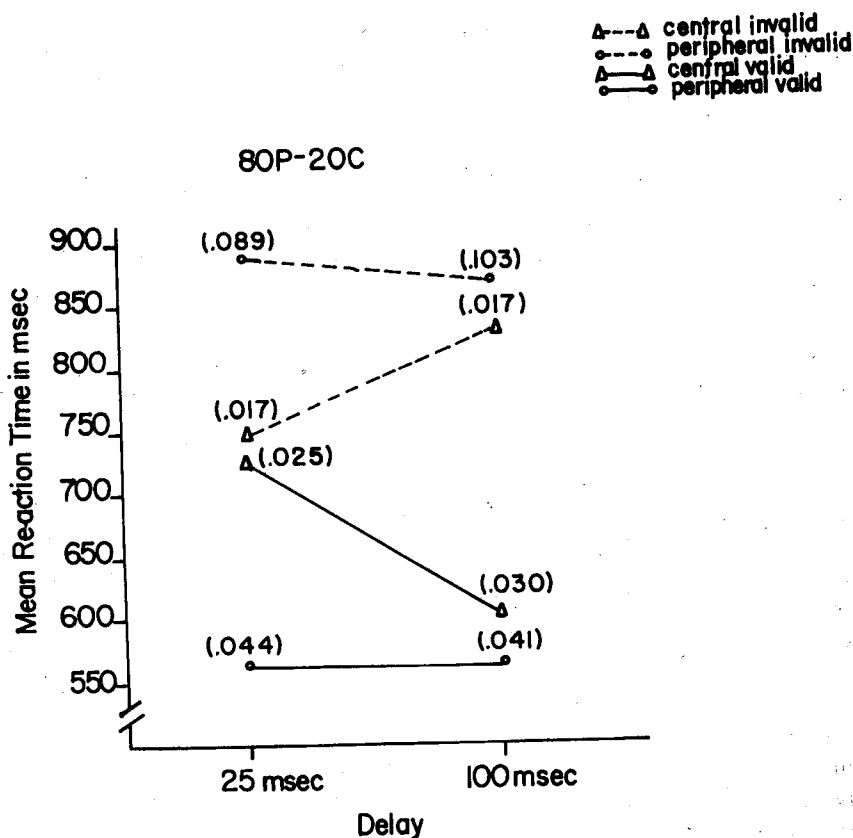
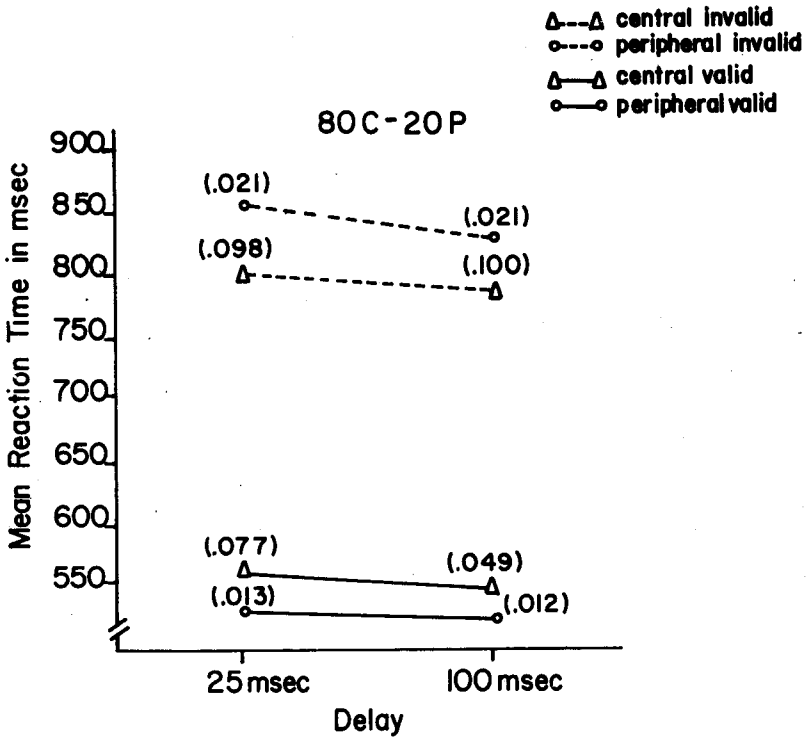


FIG. 11.3. Experiment 3: Mean reaction time as a function of the delay between cue and display for the valid and invalid trials with central and peripheral cues. Numbers in parentheses represent proportions of errors. Panel a displays data for the 80 P-20 C expectancy condition; panel b displays similar data for the 80 C-20 P condition.



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the central cue, insofar as automatic processing is characterized by insensitivity to variations in expectancy.

The remaining reliable effects in the analysis of variance can all be interpreted in light of the reliable four-way interaction. The interaction of delay with validity,  $F(1, 22) = 5.78, p < .05$ , is a result of the overall smaller effect of cue validity at a delay of 25 msec. That this is due to the 80 P-20 C expectancy condition is indicated by the reliable interaction of these two variables with condition,  $F(1, 22) = 9.75, p < .01$ . Finally, the reliable three-way interaction of expectancy condition, validity, and cue type,  $F(1, 22) = 19.31, p < .001$ , also follows from the previous analysis: Although there is a larger effect of validity on peripheral than central cues, this is more true of the 80 P-20 C condition than of the 80 C-20 P condition.

*Errors.* As Fig. 11.3 shows, the error rates were generally quite low. An analysis of variance identical to the one for reaction times was used to analyze the data. The only reliable main effect was that for cue validity,  $F(1, 22) = 40.22, p < .001$ . Two interactions were also highly significant: The first was an interaction of expectancy condition by cue type,  $F(1, 22) = 191.03, p < .001$ ; the second was a three-way interaction between these two variables and validity,

$F(1, 22) = 59.17, p < .001$ . These two interactions are apparently due to higher error rates for the trials on which expected cues appear than for trials on which unexpected cues appear. It is not immediately clear why this should have been so. In any case, because the error rates are different from the contrasts of interest for the reaction times, we are confident that subjects are not trading speed for accuracy to affect the interaction of interest in the reaction times.

Overall, the results of the experiment support the hypothesis that motivated it: If a peripheral cue attracts attention more automatically than a central cue, it should be less subject to changes in subjects' expectations about its occurrence. It is.

## GENERAL DISCUSSION

The experiments just described have established four properties of peripheral cues:

1. The processing of the cues does not draw heavily on cognitive resources, at least in comparison with the processing of central cues.
2. It is more difficult to suppress a shift of attention induced by a peripheral cue than one induced by a central cue. This conclusion is supported by the persisting costs and benefits that accrue to a peripheral cue when subjects are instructed to ignore it. Such effects do not persist when subjects ignore central cues.
3. Peripheral cues maintain their attention-capturing property even when subjects do not particularly expect their occurrence. This is not true of central cues: Their effectiveness in causing attention shifts is directly related to subjects' expectations about their occurrence.
4. Peripheral cues are more effective in drawing attention in the sense that they produce greater costs plus benefits in processing times and accuracy than central cues.

Taken together, these results support the hypothesis that the two cues differ in the extent to which they engage attention automatically. One could attribute this difference in automaticity to any or all of several differences between the cues: One possibility is that the peripheral cue, by dint of its position in the display, is more precise in its localization of the cued letter. A second alternative is that the central cue is rendered relatively less effective than the peripheral cue because "deeper" encoding of it (analysis of the direction in which it points, as opposed to simple determination of its position) is required before its indicated location is revealed to the subject. Finally, a third plausible account of the effectiveness of the peripheral cue hinges on its similarity to visual stimuli that elicit reflexive saccades. According to this possibility, the peripheral cue effectively captures

attention because it exploits a predisposition of the visual system to be especially sensitive to salient discontinuities off the fovea (Todd & Van Gelder, 1979).

Whatever the difference between the cues, however, they both seem to have one common effect: They concentrate a disproportionate share of subjects' processing resources on the cued location. As Jonides (1980) has shown, a class of models that accounts nicely for this effect is one in which processing resources are initially spread evenly over all potential target positions. When a cue appears, it causes more of these resources to be assigned to the cued location than to the others, producing costs and benefits in performance. According to this class of models, the peripheral cue of the present experiment is simply more effective in causing a reallocation of resources, because it has automatic control over these resources. This greater control is not shown as a faster shift of attention compared with a central cue (overall reaction times to the cues do not differ). Rather, the peripheral cue seems to differ from the central by virtue of its ability to attract attention on a greater proportion of trials. It is in this sense that it is more effective.

We should make clear, of course, that we are not here claiming that the visual characteristics discussed above are *necessary* to engage selectively an automatic processing mechanism, only that they are sufficient. One may well imagine that some experimental manipulation could cause a central cue to act automatically as well. For example, the work of Shiffrin and Schneider (1977) suggests that training regimens that use consistent versus varied mapping with a *single* type of cue may cause the cue to act automatically or not. This might be tested in the present paradigm in two ways: One might provide subjects with extensive consistent mapping training with a central cue to produce its effect automatically; or one might provide varied mapping training with a peripheral cue to try to eliminate its automatic effect (actually, the question of how a process once automated can be made nonautomatic is itself an interesting one). In any case, the *present* experiments suggest only that certain stimulus characteristics may be sufficient to engage automatic shifts of attention.

## Significance

What is the significance of having established two modes of control over attention shifts? First of all, in doing so, these experiments add to the growing body of literature concerned with voluntary versus automatic control over perceptual and cognitive processes. This literature has begun to establish a range of phenomena in which automatically guided mechanisms can develop. At some point, this collection of phenomena will contribute to a general theory of automaticity that will help us better understand the executive mechanisms that control cognitive activity.

But there is also a more specific implication of the present experiments that merits further exploration. Although the psychological literature has long con-

tained evidence of our ability to shift attention, there has only been sparse concern with the role that these shifts may play in general perceptual processing. Recently, Nissen, Posner, and Snyder (1978) have commented on the possible "functional relationship" between attention shifts and saccades. Both phenomena are characterized by benefits in processing information at the attended location and costs in processing nonattended stimuli. Both are characterized in terms of a spotlight metaphor according to which attention can be devoted to only one location at a time. Furthermore, both seem typically to occur together (although they can be separated, as our experiments, for example, show). Perhaps the demonstration of automatic and nonautomatic control over attention shifts adds further evidence to the emerging similarity between saccades and attention shifts, especially in view of the fact that a similar feature seems capable of eliciting automatic shifts in both systems. This strengthens the case for a "functional relationship" as proposed by Nissen et al. (1978). Further research, however, will be required to establish the nature of that function.

### ACKNOWLEDGMENTS

This research was supported by National Science Foundation Grants BNS 77-16887 and 79-07373. I thank David Bauer, Laren Birenbaum, Bruce Iden, Deborah Reyher, and Barbara Zeeff for their help in collecting data and David Bauer and David Irwin for their help with data analyses. Requests for reprints should be addressed to Department of Psychology, University of Michigan, 330 Packard Road, Ann Arbor, Mich. 48104.

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# The eyes have it! Reflexive orienting is triggered by nonpredictive gaze

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Normal subjects were presented with a simple line drawing of a face looking left, right, or straight ahead. A target letter F or T then appeared to the left or the right of the face. All subjects participated in target detection, localization, and identification response conditions. Although subjects were told that the line drawing's gaze direction (the cue) did not predict where the target would occur, response time in all three conditions was reliably faster when gaze was toward versus away from the target. This study provides evidence for covert, reflexive orienting to peripheral locations in response to uninformative gaze shifts presented at fixation. The implications for theories of social attention and visual orienting are discussed, and the brain mechanisms that may underlie this phenomenon are considered.

A moment's introspection reveals that in everyday life, gaze shifts can provide a rich and complex source of social information. For instance, at a loud party one can communicate the desire to leave by simply "catching" a friend's eye and then looking toward the door. The use of gaze shift as a social cue would, of course, have had many evolutionary advantages as well. For example, a sudden shift in gaze could signal the occurrence of crucial events in the environment, such as the approach of a predator or the presence of a food source.

Given the wealth of information that gaze shifts can provide, it is not surprising to discover that lesion and single-cell recording studies with nonhuman primates indicate that specific brain areas are specialized for the processing of gaze information. For instance, in single-cell recording experiments with the macaque monkey, Perrett and his colleagues have found specific cells in the superior temporal sulcus (STS) that respond to particular orientations of both head and gaze (Perrett et al., 1985). Similarly, Campbell, Heywood, Cowey, Regard, and Landis (1990) have found that STS lesions in the rhesus monkey impair gaze direction discrimination.

Research with human infants suggests that the development of these specialized brain areas begins to affect behavior at a very young age. As early as 2 to 3 months, babies look preferentially at the eyes of a schematic face (Maurer, 1985), and by 3 months they are also able to discriminate changes in an adult's eye direction (Hains & Muir, 1996). In the second half of their 1st year, infants

begin to show the ability to look in the same general direction as an adult's gaze and head turn. And by the age of 12 months, infants reliably look to where someone else is looking, regardless of whether a shift in gaze is accompanied by a head turn (Corkum & Moore, 1995; but see a recent study by Hood, Willen, & Driver, 1998, suggesting that infants as young as 10 weeks old orient to gaze shifts alone).

The goal of the present study was to explore whether gaze shifts would produce shifts of attention in adults. Our manipulation was very simple, yet, as we will show, very powerful. We modified the standard Posner cuing paradigm (Posner, 1978, 1980) so that subjects were presented with a schematic face<sup>1</sup> that looked left, right, or straight ahead. They were instructed to maintain fixation on the face at all times, and *they were informed that the gaze direction of the schematic face did not, in any way, predict the location of the response stimulus.*

Our findings indicate that response time (RT) was facilitated when a target appeared at the location where the eyes were looking (the cued location). This facilitation effect occurred early, was relatively short-lived, and was not accompanied by any RT delay at the uncued location. These findings bear the hallmarks of reflexive shifts of covert attention (Cheal & Lyon, 1991; Jonides, 1981; Müller & Rabbitt, 1989).

## METHOD

### Subjects

Twenty-four introductory psychology students (19 females and 5 males) participated in the present experiment for course credit. All subjects reported normal or corrected-to-normal vision. Testing time totaled approximately 2 h, and was divided between 2 days.

### Apparatus

The experiment was controlled by a 6100 Power Macintosh computer, with stimuli presented on a 14-in. Apple color monitor set to black and white. RT and accuracy measures were based on keyboard responses. Subjects were seated approximately 57 cm from the monitor, and the experimenter ensured that subjects were centered with respect to the monitor and keyboard.

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This research was supported by a graduate student award to C.K.F. from the Natural Sciences and Engineering Research Council of Canada (NSERC) and by grants to A.K. from NSERC (170077) and the Alberta Heritage Foundation for Medical Research (00134). The findings reported in this article were presented at the annual meeting of the Cognitive Neuroscience Society, March 1997, Boston. Correspondence should be directed to C. K. Friesen or A. Kingstone, Department of Psychology, University of Alberta, Edmonton, AB T6G 2E9, Canada (e-mail: cfriesen@psych.ualberta.ca or alan@psych.ualberta.ca).

### Stimuli

The target stimulus demanding a response was a black capital letter F or T measuring 0.8° wide and 1.3° high. The face display, illustrated in Figure 1, consisted of a white background with a black line drawing of a round face subtending 6.8° and centered in the middle of the monitor. The face contained two circles representing the eyes, a smaller circle representing the nose and fixation point, and a straight line representing the mouth. The eyes subtended 1.0° and were located 1.0° from the central vertical axis and 0.8° above the central horizontal axis. The nose subtended 0.2°. The mouth was 2.2° in length and was centered 1.3° below the nose. Black filled-in circles appeared within the eyes and represented the pupils. The pupils subtended 0.5°, were centered vertically in the eyes, and were just touching left, just touching right, or centered in the eyes. The target letters were presented 5.0° to the left or right of the eyes, as measured from the center of the nearest eye to the center of the target letter.

### Design

The experiment consisted of detection, localization, and identification response conditions, and all subjects participated in all three conditions. Two of the response conditions were presented on the 1st day of testing, and one condition was presented on the 2nd day. The order of response conditions was counterbalanced across subjects. Each of the three conditions was composed of 500 trials, with a block of 20 practice trials preceding 10 test blocks of 48 trials each. Additionally, for half of the subjects, the detection condition included 30 catch trials (no target presented) randomly selected from the three gaze direction cues. (In this case, there were 10 test blocks of 51 trials.) On target trials, gaze direction, target location, target identity, and cue–target stimulus onset asynchrony (SOA) duration were selected randomly and equally within each block.

### Procedure

Figure 1 provides a representative illustration of the sequence of events on a target trial. The start of a trial was signaled by the presentation of a face with blank eyes. After 680 msec, pupils appeared within the eyes, looking left, right, or straight ahead. Following this cue, a target letter appeared to the left or the right of the face. The face, pupils, and target remained on the screen until a response was made or 2,700 msec had elapsed, whichever came first. The intertrial interval was 680 msec.

Cue–target SOA, measured from the appearance of the pupils to the appearance of the target, was selected from four possible durations: 105,

300, 600, and 1,005 msec. On cued-target trials, the eyes looked left or right, and a target appeared at the location where the eyes were looking; on uncued-target trials, the eyes looked left or right, and a target appeared at the location where the eyes were not looking. On neutral trials, the eyes looked straight ahead, and a target could appear to the left or the right of the face.

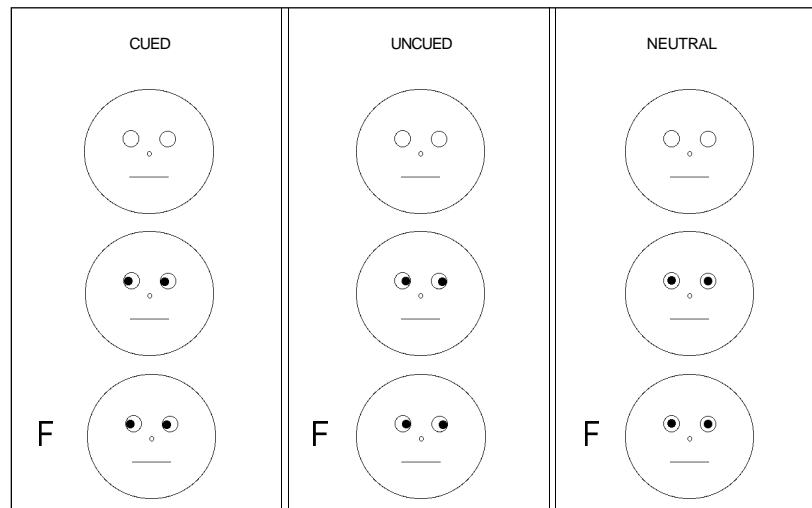
In the detection response condition, subjects were instructed to indicate that they had detected the appearance of a target on the screen by pressing the space bar on the computer keyboard with the index finger of their preferred hand. If a target did not appear, subjects were not to respond. In the localization condition, subjects were instructed to indicate whether a target appeared to the left or the right of the face by pressing the “z” key with their left index finger for a target on the left, and the “/” key with their right index finger for a target on the right. In the identification condition, subjects were instructed to indicate the identity of the target letter by pressing the “z” key with their left index finger for the target letter F and the “/” key with their right index finger for the target letter T. For the localization and identification conditions, the “z” and “/” keys were labeled with colored stickers indicating L and R (localization), or F and T (identification).

Before beginning each response condition, subjects were told that a drawing of a face with blank eyes would appear in the center of the screen signaling the start of each trial, and that it was important that they fixate their eyes on the nose in the center of the face while it was on the screen. Subjects were told that after the appearance of the face, pupils would appear in the eyes looking left, right, or straight ahead, and that after that, a letter (either F or T) could appear either to the left or the right of the face. Subjects were informed that the direction in which the eyes looked was not predictive of the location or identity of the target letter or of when it would appear, and they were instructed to respond as quickly and accurately as possible to the target.

Subjects were informed of the number of trials and blocks in each response condition, and they were instructed to press the space bar to initiate each new block of trials after they had taken a rest break and were ready to proceed. Before they began the experiment, they were offered an opportunity to ask questions about the procedure and were reminded once more of the importance of maintaining central fixation.

## RESULTS

Anticipations, incorrect responses, and timed-out trials were classified as errors and were excluded from analy-



**Figure 1.** Examples of cued, uncued, and neutral trial sequences. Each trial began with the presentation of a face with blank eyes. After 680 msec, pupils appeared in the eyes, looking left, right, or straight ahead (the gaze cue). Then, after 105, 300, 600, or 1,005 msec, the letter F or T (the target) appeared to the left or the right of the face.

sis. Error data are shown in Table 1. Anticipations, defined as responses with a latency of less than 100 msec, accounted for 0.44% of the target trials in the detection condition, 0.05% of the trials in the localization condition, and 0.01% of the trials in the identification condition. Keypress selection errors accounted for 0.01% of the target trials in the detection condition, 1.35% of the trials in the localization condition, and 4.82% of the trials in the identification condition. Timed-out trials accounted for less than 0.02% of the test trials in each of the three response conditions. In the detection condition, the false alarm rate for the 12 subjects given catch trials was 2.8%. The overall error rate in the detection condition was identical (0.47%) whether or not subjects received catch trials.

A three-way analysis of variance (ANOVA) was conducted on the percent errors, with SOA (105, 300, 600, and 1,005 msec), cue validity (cued-target, neutral, and uncued-target), and response condition as within-subjects factors. There was a main effect of response condition [ $F(2,23) = 37.630, p < .0001$ ], reflecting that the error rate increased across detection, localization, and identification conditions, respectively. Error rate did not vary significantly as a function of SOA or cue validity, and there were no significant interactions [all  $F$ s  $< 2.5$ , all  $p$ s  $> 0.10$ ].

### The Three Response Conditions

Mean RTs for the detection, localization, and identification response conditions are presented in Table 1 and illustrated in Figure 2. For each response condition, a separate ANOVA was conducted with SOA (105, 300, 600, and 1,005 msec) and cue validity (cued-target, neutral, and uncued-target) as within-subjects factors. As indicated below, analysis confirmed that for each response condition, RT was facilitated on cued-target trials rela-

tive to neutral and uncued-target trials. Additionally, response latencies became shorter as the cue-target SOA was lengthened, reflecting a standard foreperiod effect (Bertelson, 1967; Mowrer, 1940). The SOA  $\times$  cue interaction was never significant.

For the detection condition, the ANOVA results were as follows: SOA [ $F(3,23) = 31.782, p < .0001$ ], cue [ $F(2,23) = 9.920, p < .0003$ ], and SOA  $\times$  cue [ $F(6,23) = 1.286, p > .25$ ]. In the localization condition: SOA [ $F(3,23) = 41.441, p < .0001$ ], cue [ $F(2,23) = 21.710, p < .0001$ ], and SOA  $\times$  cue [ $F(6,23) = 1.112, p > .35$ ]. In the identification condition: SOA [ $F(3,23) = 14.543, p < .0001$ ], cue [ $F(2,23) = 7.386, p < .005$ ], and SOA  $\times$  cue [ $F(6,23) = 1.442, p > .20$ ].

These analyses suggest that performance as a function of SOA and cue did not vary significantly across the different response conditions. This was confirmed by an ANOVA that included response condition as a within-subjects factor. There was now a main effect of response condition [ $F(2,23) = 194.140, p < .0001$ ], with RT being fastest for detection responses and slowest for identification responses, and with localization responses falling in the middle. As before, the main effects for SOA [ $F(3,23) = 49.482, p < .0001$ ] and cue [ $F(2,23) = 39.500, p < .0001$ ] were highly significant. The only significant interaction was between response condition and SOA [ $F(6,23) = 2.703, p < .0164$ ], reflecting the fact that whereas the foreperiod effect was the same for all response conditions up to the 600-msec SOA, it varied at the longest SOA. At 1,005 msec, RT continued to fall in the detection condition, but it held steady in the localization condition and became slower in the identification condition. When the 1,005-msec SOA was removed from the analysis, the response condition  $\times$  SOA interaction disappeared [ $F(4,23) = 0.905, p > .45$ ]. No other

**Table 1**  
Mean Response Times (in Milliseconds), Standard Deviations, and Error Rates (%) for the Three Response Conditions

Cue Condition	Detection			Localization			Identification		
	<i>M</i>	<i>SD</i>	% E	<i>M</i>	<i>SD</i>	% E	<i>M</i>	<i>SD</i>	% E
105-msec SOA									
Cued	335	59	0.10	361	56	1.25	505	56	4.69
Neutral	350	63	0.00	367	52	1.25	509	53	4.38
Uncued	347	53	0.21	373	49	1.46	507	49	4.27
300-msec SOA									
Cued	311	53	0.73	334	51	1.04	478	53	4.90
Neutral	321	53	0.73	350	53	2.19	488	59	5.31
Uncued	323	47	1.46	355	48	1.98	489	52	5.00
600-msec SOA									
Cued	309	55	0.21	327	51	1.04	469	59	3.96
Neutral	314	51	0.31	339	51	1.15	485	52	5.42
Uncued	322	51	0.83	342	43	1.46	485	59	4.58
1,005-msec SOA									
Cued	308	51	0.42	331	50	1.04	482	62	4.58
Neutral	311	54	0.10	339	56	1.56	499	74	5.42
Uncued	311	53	0.52	337	54	1.46	483	61	5.52

Note—Error rates represent the percentage of test trials excluded as anticipations, keypress selection errors, or timed-out trials. SOA, stimulus onset asynchrony.

interactions approached significance [all  $F_s < 2$ , all  $p_s > .15$ ]. Figure 2D presents the mean RTs collapsed across response conditions as a function of SOA and cue.

Figure 2 suggests that the cuing effect may have disappeared at the longest SOA. To test this observation, we conducted individual  $t$  tests on the valid versus invalid RTs at each SOA, collapsed across response condition. Results indicated that there was a cuing effect at the 105-, 300-, and 600-msec SOAs [all  $t_s(23) > 2.85$ ; all  $p_s < .005$ ],

but no cuing effect at the 1,005-msec SOA [ $t(23) = 1.11$ ,  $p > .23$ ].<sup>2</sup>

Figure 2 also suggests that the significant cuing effects were due to facilitation at the cued location relative to the neutral and uncued locations, with no significant difference between the latter two. That is, it appears that gaze direction is producing an attentional benefit (RT at the cued location < RT at the neutral location) with no attentional cost (RT at the neutral location = RT at the un-

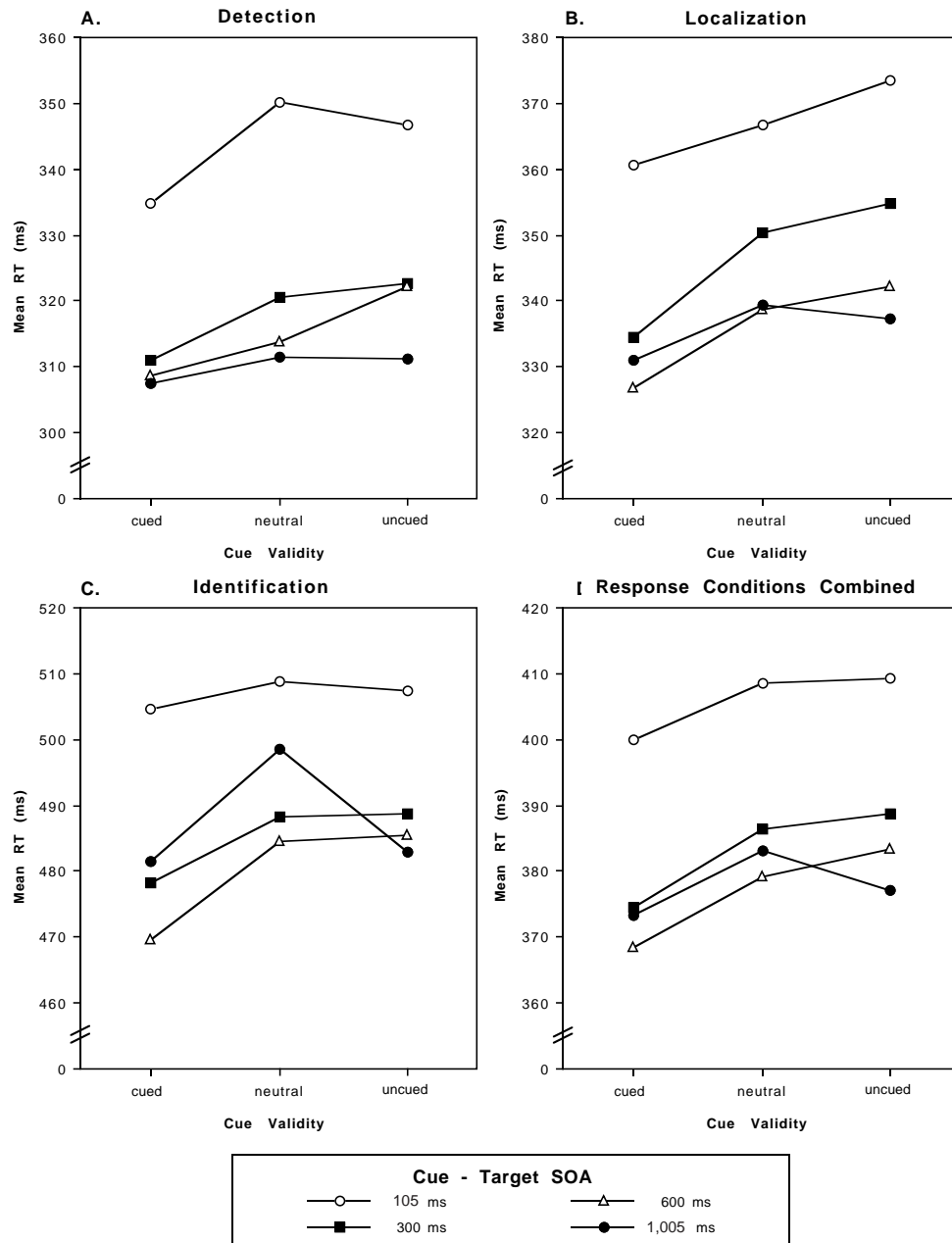


Figure 2. Mean response times (RTs) as a function of cue–target stimulus onset asynchrony (SOA) and cue validity for the (A) detection, (B) localization, and (C) identification response conditions, and (D) for the three response conditions combined.

cued location). To test this observation, we conducted two tests at each of the significant SOAs, one to assess the attentional benefits of the gaze cue (cued vs. neutral RTs) and one to assess the attentional costs (uncued vs. neutral RTs). These tests revealed that there was a significant RT benefit at the 105-, 300-, and 600-msec SOAs [all  $t_s(23) > 2.66$ ; all  $p_s < .01$ ], and no attentional cost [all  $t_s(23) < 1.33$ ; all  $p_s > .18$ ].

## DISCUSSION

The adult subjects in our study fixated on a simple line drawing of a face looking left, right, or straight ahead. Despite the fact that they were told that gaze direction did not predict where the target would occur, subjects were fastest to respond to the target when gaze was directed toward the target. This effect was reliable for three very different types of target response: detection, localization, and identification.

It is our position that the facilitation effect produced by the gaze cue reflects the involvement of exogenous (reflexive) covert<sup>3</sup> attention. There are at least four pieces of evidence that converge on the conclusion that the orienting is reflexive: (1) The cuing effect emerged rapidly (appearing at the short, 105-msec cue–target SOA in two of the three response conditions and by the 300-msec SOA in all conditions), (2) the cuing effect occurred even though the subject was informed that the gaze cue did not predict the target location, (3) the cuing effect exhibited a relatively short time course (disappearing by the 1,005-msec cue–target SOA), and (4) it was characterized by benefits at the cued location (cued-target RT < neutral RT) without costs at the uncued location (uncued-target RT = neutral RT). Each of these findings possesses the signature of exogenous orienting. For instance, it has been widely reported that compared with endogenous (volitional) orienting, exogenous orienting emerges quickly (Cheal & Lyon, 1991), occurs whether the cue is predictive or not (Jonides, 1981), persists for a relatively short duration (Müller & Rabbitt, 1989), and produces benefits without costs (Posner & Snyder, 1975).<sup>4</sup>

An important difference between our study and previous experiments that have studied reflexive orienting to a peripheral location is that in our study, the attentional cue was presented at central fixation. Typically, a reflexive attentional shift is produced by a nonpredictive abrupt onset occurring at a peripheral location. In contrast, central cues have been used to induce voluntary attentional shifts to peripheral locations by predicting that a target will appear in the periphery (see Klein, Kingstone, & Pontefract, 1992, for a review). The fact that a nonpredictive centrally presented gaze cue can initiate a reflexive shift of attention to a peripheral location suggests that the human brain may be specialized to shift attention in response to gaze direction.

A wealth of convergent evidence implicates the parietal cortex in spatial orienting (for a review, see Posner & Petersen, 1990). Research with nonhuman primates indicates that gaze direction is analyzed in the STS of the temporal cortex (e.g., Campbell et al., 1990; Perrett et al., 1985) and in the amygdala (Kling & Brothers, 1992). Rich reciprocal connections between the amygdala and the STS (Young et al., 1995), and between the STS and parietal cortex (Harries & Perrett, 1991), provide a likely network through which brain mechanisms specialized for gaze processing might trigger reflexive shifts of attention.

It should be noted that in our study, reflexive orienting to gaze direction occurred without giving rise to the inhibition of return (IOR) phenomenon. In studies of reflexive orienting to nonpredictive peripheral cues, IOR is typically revealed as delayed RT at a cued/attended location relative to an uncued/unattended location when the cue–target SOA exceeds 300–500 msec. The absence of IOR in the present study raises the possibility that there might be interesting differences between reflexive orienting in response to nonpredictive gaze direction and reflexive orienting in response to nonpredictive peripheral cues. Because IOR is known to be dependent upon the activation of the superior colliculus (Rafal, Calabresi, Brennan, & Sciolto, 1989; Rafal, Posner, Friedman, Inhoff, & Bernstein, 1988), it is our speculation that in the

present study, a reflexive shift of attention in response to gaze direction may not have involved activation of the superior colliculus.

Some investigators hold that shifting attention in response to gaze direction is an important step in the development of a theory of mind (e.g., Baron-Cohen, 1995). An alternative view is that attentional shifts to gaze direction might merely reflect the development of an appreciation that gaze direction can be an important cue to interesting aspects within the environment (Corkum & Moore, 1995). Our study does not favor either position, although it does highlight the powerful effect that gaze direction can have on attentional orienting. Our adult subjects shifted attention in response to an elementary, schematic face that looked left or right. They knew that the face was not a real face and that it did not represent a person with a mind, and they also knew that the face's gaze was not predictive of an important environmental event. Nevertheless, their attention was shifted reflexively over hundreds of trials.

Our study demonstrates that a nonpredictive shift in gaze can trigger reflexive orienting. This orienting occurs across a wide variety of responses; it appears rapidly and is short-lived; it is revealed as RT benefits at the cued (gazed-at) target location without any corresponding RT cost at an uncued target location; and it appears to be so fundamental that it can be triggered solely by the gaze of a simple schematic face.<sup>5</sup>

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- ston, 1995). We reasoned that if the attentional effect of gaze direction were robust, a basic face-like stimulus would produce the effect while minimizing extraneous complexities associated with real faces (e.g., face asymmetry, hair, gender, etc.).
2. An analysis of cued versus uncued RTs within the individual response conditions confirmed that there was a cuing effect for the three shortest SOAs in all three conditions, with the exception of the 105-msec SOA in the identification condition.
3. Although we did not monitor subjects' eye movements in our study, we are confident that eye movements to the cued location were not involved in producing our cuing effect. It is well known that for simple detection tasks (such as our detection and localization response conditions), subjects will spontaneously avoid making eye movements to the target (Posner, 1980). Additionally, if eye movements were responsible for our cuing effects, one would expect to observe both RT benefits and RT costs. We only found RT benefits. Finally, one would also expect the cuing effect to persist at the 1,005-msec SOA. It did not.
4. Posner and Snyder (1975) established that stimulus-driven exogenous activation produces benefits without costs. Interestingly, exogenous spatial orienting has rarely satisfied this criterion, producing RT costs as well as benefits. This may be due to the fact that there is no obvious neutral condition for a peripheral exogenous spatial cue. The present study would seem to be an exception, with the eyes-straight-ahead serving as a natural neutral condition.
5. A recent target detection study by Langton and Bruce (1997, in press; see also Driver et al., in press) yielded evidence of reflexive orienting to centrally presented photographs of human faces that were turned to the left, to the right, up, and down. Although gaze direction was confounded with head orientation in Langton and Bruce's study, their finding of reflexive orienting to a centrally presented social attention cue converges with ours.

#### NOTES

1. There is evidence to suggest that people respond as well to schematic eyes and faces as they do to real faces (Von Grünau & An-

(Manuscript received October 6, 1997;  
revision accepted for publication January 30, 1998.)