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An illusion of coherent global motion arising from single brief presentations of a stationary stimulus

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Abstract

We describe a new illusion in which a single stationary stimulus appears to undergo coherent global motion. Contrast relationships between the stimulus elements suggest the illusion arises via processing of Off- and On-channel signals that remain independent until after passing through low-level motion detectors. We propose that patterns of activation resulting from biphasic temporal impulse response functions in the magnocellular pathway are the basis of the illusion, and describe a model to account for the illusory motion percept.

Keywords: Illusion; On-channel; Off-channel; Apparent motion; Biphasic impulse functions

1. Introduction—The illusion

While demonstrations of perceived global form arising from coherent motion cues are familiar, perceptions of coherent global motion generated by static form cues are more novel (e.g. Ross, Badcock, & Hayes, 2000). The experiments reported here describe a new illusion of the latter type: Glass patterns (Glass, 1969) composed of opposite luminance polarity dot-pairs (Fig. 1b), when presented briefly and on their own, look like they move. That is, circular Glass patterns appear to rotate about the centre of the display, radial patterns to pulse in and out, linear patterns to translate, and so on. The dependence of motion on the pattern configuration suggests the effect is not Gamma motion (Kanizsa, 1979) and also suggests the illusion is not the product of eye-movements. Observers have described the illusory motion as a "jitter".

Pilot experiments established that the effect was limited to patterns composed of opposite luminance-polarity pairs: Glass patterns composed of same-luminance polarity dot-pairs (Fig. 1a and c) always appear stationary (Fig. 1d). During debriefings, subjects indicated that while they were able to identify the direction of the jitter on any particular trial, the direction was ambiguous in that it seemed to change spontaneously across presentations: A circular pattern that appeared to rotate counter-clockwise (CCW) on one trial sometimes appeared to rotate clockwise (CW) on later trials, and so on. These observations were tested more formally in Experiment 2.

During debriefing subjects also reported that while the illusion appears to last the entire presentation for short duration presentations (<200 ms), they perceived the jitter only at the beginning and end of presentations lasting 400 ms or longer. In this way the illusion is different to apparent motion percepts such as reverse phi (Anstis & Rogers, 1975), long- and short-path motion (Pantle & Turano, 1992), and the effect described by Ross et al. (2000). It seems, therefore, that the illusory jitter described here is indeed novel. The aim of this brief report is to describe some of the limiting conditions for the illusion and to propose a possible mechanism.

2. General methods

Subjects: The data from five subjects are reported here. Subjects AB and vdZ are authors. Subjects RB,

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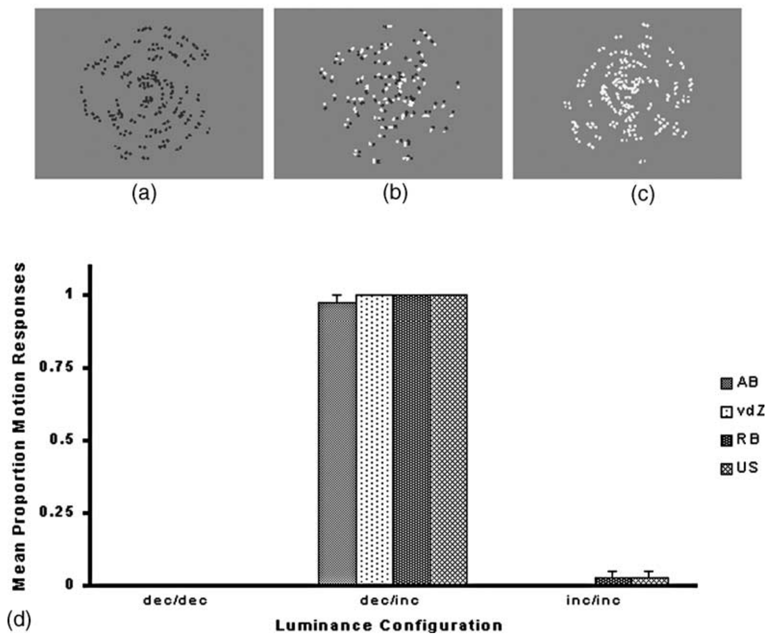

Fig. 1. The effect of luminance configuration on illusory global motion perceptions: (a) decrement/decrement, (b) decrement/increment, and (c) increment/increment circular Glass patterns. (d) Means (+standard errors) for 100 ms presentations of circular patterns from four subjects (naïve: RB, US, authors: AB, vdZ). Only decrement/increment patterns elicited motion perceptions. The effects are consistent for presentation durations between 50 and 400 ms, when illusory motion lasts the entire presentation. Salience of the illusion decreases on 800 and 1600 ms presentations, but the effect is still perceived on more than 70% of trials. Subjects never reported perceiving motion from control patterns (not shown). All dots had the same contrast with the background (Michelson contrast = 0.5). Dots within pairs in decrement/decrement (dec/dec) and increment/increment (inc/inc) patterns had a contrast with each other of zero. The contrast between decrement/increment (dec/inc) pairs was 0.8.

US, and ME were naïve observers. All subjects had normal vision or corrected to normal vision.

Stimuli and procedures: Stimuli were presented on a linearised Sony Multiscan E200 flat-screen monitor. Glass patterns were constructed by generating 100 dots in random positions within the display field. Partner dots were then generated according to an algorithm that defined either circular, radial, or linear patterns. Each dot subtended 12′, and the total display had a diameter of 18.7° visual angle. The distance between the centres of dots in a pair was 21′. All patterns were presented with square-wave stimulus onset and offset. Background luminance was held at 18 cd/m^2. Subjects viewed stimuli from 57 cms. Control stimuli were random dot patterns with luminance profiles equivalent to the Glass patterns. Stimuli were presented in blocks consisting of equal numbers of experimental and control stimuli randomly interleaved. Blocks were repeated and mean responses for each subject in each condition were calculated as an average across blocks. Subjects indicated their responses with key presses on a standard keyboard: In Experiment 1 subjects were asked, on each trial, to signal whether the pattern moved (press key "m") or was stationary (press key "z"). In Experiment 2 subjects signalled whether they perceived motion CW (press key "l") or CCW (press key "a").

3. Experiment 1

In the pilot experiments dots within same luminance-polarity pairs had a Michelson contrast with each other of zero, while dots within opposite luminance-polarity pairs had a Michelson contrast with each other of 0.8. All dots had the same contrast with the background (Michelson contrast = 0.5). In other words, dots within opposite-polarity dot-pairs were symmetrical in contrast about the background. The aim of this experiment was to determine whether the illusion depends on contrast between dots within pairs per se, or on the contrast of dots with the background.

4. Methods

Stimuli: In all patterns the between-dot Michelson contrast for dots within pairs was 0.4. Decrement/decrement (dec/dec) patterns were composed of dot-pairs both of which were darker than the background and had contrasts with it of 0.5 and 0.125 respectively. Increment/increment (inc/inc) patterns were composed of dot-pairs both of which were lighter than the background and had contrasts with it of 0.5 and 0.125 respectively. Additionally, three types of decrement/increment patterns were tested: Decrement/increment A patterns (dec/incA) and decrement/increment B patterns (dec/incB) tested contrast asymmetries about the background. For dec/incA patterns the decrement dot had a contrast with the background of 0.28 and the increment dot had a contrast with the background of 0.12. For dec/incB patterns the contrast between the decrement dot and the background was 0.125 and the contrast between the increment dot and the background was 0.29. Decrement/increment C patterns (dec/incC), as earlier patterns had been, were symmetrical in contrast about the background. Both decrement and increment dots had a Michelson contrast of 0.2 with the background. All patterns were presented for 100 ms.

5. Results

Patterns composed of decrement/decrement pairs always appeared stationary, even when the decrement dots within a pair had different contrasts with the background. Similarly, increment/increment dot-pair patterns were consistently reported as stationary (Fig. 2). This suggests that a contrast difference *between* dots within pairs, while necessary, is not sufficient for the illusion to occur. Using the same procedures described here, we have subsequently examined decrement/decrement dot-pair patterns constructed such that one dot had a low contrast with the background (Michelson contrast = 0.2) and the other dot high contrast (Michelson contrast = 0.9) and such patterns never elicit illusory motion. Similarly, increment/increment patterns made up of one high and one low contrast pair never appear to move. No control patterns elicited perceptions of illusory motion.

All patterns composed of decrement/increment dot-pairs appeared to move (Fig. 2). That is, of the patterns so far tested, any composed of dot-pairs with one member of each pair driving the Off-channel and the other driving the On-channel gave rise to the motion illusion. It seems, therefore, that dots within pairs must be of opposite luminance polarity if the pattern is to give rise to perceptions of illusory motion.

6. Discussion

Visual motion perception is usually elicited by images undergoing changes in spatial position over time. The generation of a coherent and immediately available motion percept (as opposed to illusions such as the pinwheel—Fraser & Wilcox, 1979) in the absence of such changes suggests that processing of the stimulus may introduce a spatio-temporal element not inherent in the stimulus itself. One possibility is that the illusion is based on an Off- and On-channel processing latency such that information about the decrement element is processed faster (or slower) than information about the increment element. The illusory motion would be, therefore, a type of apparent motion. This account implies the processes giving rise to the illusion are to be found at the point of integration of Off- and On-channel information and that the perceived direction of motion will be contingent upon the configuration of the decrement and increment elements. That is, the direction of the illusory motion should be predictable.

Another possibility is that the illusion is based on independent transient biphasic processing of light increment and decrement signals like those thought to occur within the magnocellular pathway (Burr & Morrone, 1993; Marrocco, 1976; Saito & Fukada, 1986; Swanson, Ueno, Smith, & Pokorny, 1987). The temporal profile of biphasic responses combined with the spatial arrangement of decrement/increment dot-pairs within Glass patterns may combine to generate a

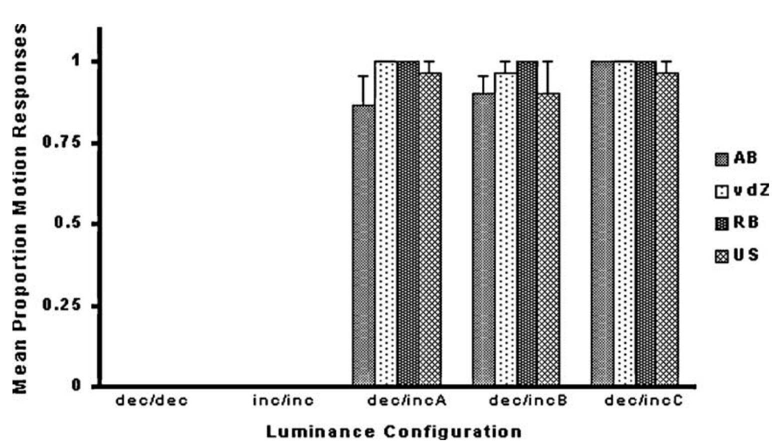

Fig. 2. The effect of luminance differences between dots within pairs on the perception of illusory global motion. Dec/dec and inc/inc patterns examined effects arising from differences between dots. The data (means and standard errors) show these patterns always appeared stationary: Same luminance polarity pairs do not elicit illusory motion. Only patterns composed of decrement/increment dot-pairs (dec/incA, dec/incB, dec/incC—see Section 4) were perceived as moving. It seems as if any opposite luminance-polarity pair will generate the effect.

spatio-temporal signal like that normally created by a moving stimulus: A light increment elicits first excitation and then inhibition in the On-channel. Similarly, an adjacent light decrement elicits excitation and then inhibition in the Off-channel. If we assume that decrements and increments elicit inhibitory responses in the On- and Off-channels respectively then while one dot in a decrement/increment pair elicits excitation then inhibition in a channel, the other dot elicits inhibition then excitation in the same channel—Fig. 3. This has the consequence that over time the On-channel, say, responds with excitation to the increment dot and then later (and less so) to the spatially adjacent decrement dot. Low-level motion detectors will be driven by the displacement of the peak of excitation over time just as they are by a stimulus that really is moving. The output from the low level mechanisms forms the basis of the perceived motion. One consequence of this model is that motion signals are generated in opposite directions by the On- and the Off-channels. That is, the sum of motion signals in each direction (CW and CCW in concentric patterns, for example) is equivalent.

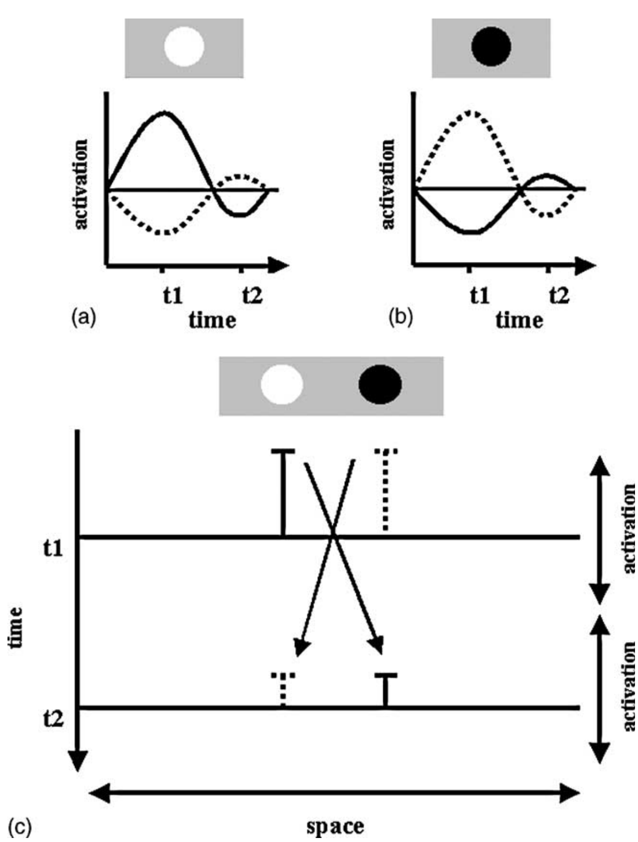

Fig. 3. Biphasic temporal impulse functions in Off- and On-channels arising in response to (a) luminance increment dot, and (b) luminance decrement dot. Solid lines represent On-channel responses, broken lines Off-channel responses. If excitation at two temporal slices, t1 and t2, is plotted across space (c), we see that for decrement/increment dot-pairs the peak of excitation moves over time from (in this case) left to right for the On-channel and right to left for the Off-channel.

7. Experiment 2

The aim of Experiment 2 was to discriminate between the two models described above. A processing latency model predicts that the perceived direction of illusory motion elicited by decrement/increment dot-pair patterns should be consistent across trials and the same for all observers. So, for example, circular Glass patterns with decrement dots CW of increment dots should appear to move in the opposite direction to patterns in which decrement dots are CCW of the increment dots. The biphasic impulse function model, however, predicts no differences between these conditions. Both configurations of decrement/increment pairs will generate the same signal and be ambiguous to observers.

8. Methods

Stimuli and procedures: Patterns were concentric Glass patterns presented for 1600 ms and composed of decrement/increment pairs. In separate blocks, subjects were required to report whether the direction of perceived motion was 'CW' or 'CCW' at either stimulus onset or offset. So-called *Balanced* patterns had 50% of the dot-pairs arranged so the decrement dot was CW of the increment dot and 50% of the pairs arranged so the decrement dot was CCW of the increment dot. Pilot experiments had shown these patterns reliably elicited illusory motion percepts. *Consistent A* patterns were constructed such that within dot-pairs the decrement dot was always CW of the increment dot. *Consistent B* patterns were constructed such that the decrement dot was CCW of the increment dot.

9. Results

The data (Fig. 4) support the biphasic impulse function model. They suggest no consistent pattern of responses at stimulus onset or offset. In other words, perceived direction-of-motion is ambiguous and cannot be predicted on the basis of luminance configuration.

10. General discussion

The data presented here suggest that the illusion of jitter is the result of low-level independent processing of On- and Off-channel information. Edwards and Badcock (1994) showed that dots switching luminance polarity (dark to light or light to dark) from frame to frame during a motion display do not effectively drive the global motion system. They took that as evidence that On- and Off-channel processing is independent at initial motion detection stages. The biphasic impulse

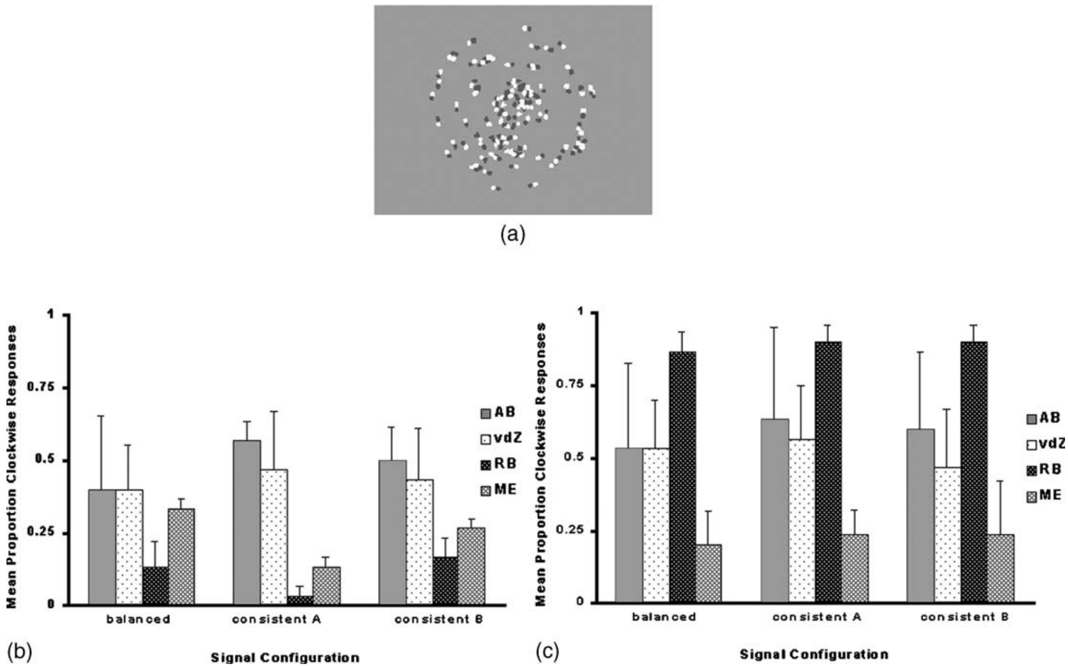

Fig. 4. Perceived motion from patterns composed of decrement/increment dot-pairs. (a) A *balanced* circular Glass pattern composed of equal numbers of dot-pairs in which the decrement dot was positioned CW and CCW of the increment dot. Stimuli with consistent luminance configurations (*Consistent A* and *Consistent B* (see Fig. 1b)) did not generate opposite direction-of-motion percepts and did not differ at either stimulus onset (b) or stimulus offset (c) from the perceived direction-of-motion elicited by control (*Balanced*) stimuli.

model is consistent with those findings: Excitation within the On-channel, say, to a light increment is combined with excitatory rebound to a spatially proximal light decrement that initially generated inhibition within the same channel (see Fig. 3). To a low-level motion detector this spatial and temporal change in excitation acts like a moving stimulus.

With that in mind, we propose the illusory motion perception arises from a sequence of three magnocellular processes. First, the individual stimulus components (dots) elicit independent biphasic impulse functions within the On- and Off-channels. Next, the On- and Off-channels input to low-level, possibly Reichardt (1961), motion detectors. The interaction of the activity generated by the decrement and increment dots is facilitated by the spatial proximity of the dots forming a pair in the Glass pattern. Finally, local motion signals with common directions of displacement are summed, probably in extrastriate cortex (Morrone, Burr, & Vaina, 1995), to give rise to the illusory global motion percept.

The model we propose is consistent with perceptual effects arising from stimulus presentation in several respects. It successfully accounts for the occurrence of the illusion at stimulus onset and offset, as abrupt changes in the visual field are known to drive effectively the magnocellular pathway (Ohtani, Ejima, & Nishida, 1991; von Grunau, 1978). It is also consistent with the observation that the global form of the stimulus is not evident independently of the motion signal. That is, within the model summation of local signals (to generate a global percept) occurs only as a property of magnocellular processing in extrastriate cortex. Finally, it successfully predicts ambiguous direction-of-motion percepts arising from presentations of the stimulus. It does not explain why the perceived direction of motion is sometimes seen in one direction and sometimes in the opposite direction, although there are many examples of perceptually ambiguous stimuli. Whilst further testing of the model is required, the proposed neural correlates of the illusion represent a novel account of On- and Off-channel processing within the magnocellular visual pathway.

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