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A moving display which opposes short-range and long-range signals

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Abstract. A novel display is described which stimulates both the long-range and the short-range motion detecting processes simultaneously, but with opposing directions of movement. The direction in which the stimulus appears to move depends on retinal eccentricity and element size, but adaptation to the display always produces a motion aftereffect (MAE) direction opposite to the direction of the short-range component. The display may offer insights into the properties of the two-process motion detecting system.

Motion perception appears to be mediated by two separate processes: a 'short-range' process, which matches up local pattern elements of the same luminance polarity in successive time frames and operates over short spatial and temporal intervals; and a 'long-range' process, which can give perceived motion by matching up whole forms in successive frames regardless of such detailed properties as luminance polarity, colour, or texture, and is unperturbed by long interstimulus intervals (Braddick 1974; Pantle and Petersik 1980; Anstis 1980; Cavanagh et al, in preparation). Conventional displays stimulate either one or the other process, or both simultaneously with the same direction of motion. For example:

(1) Random-dot kinematograms (Anstis 1970; Braddick 1974; Cavanagh et al, in preparation) are assumed to stimulate solely the short-range process.
(2) Kinematograms containing uncorrelated moving patches (Ramachandran et al 1973; Pantle 1973) are assumed to stimulate solely the long-range process.
(3) Many other displays containing real motion of isolated pattern elements should stimulate both short-range and long-range processes simultaneously with the same direction of motion.

This paper describes a new display which should also stimulate both processes simultaneously, but with *opposing* directions, for example: a leftward moving short-range signal and a rightward moving long-range signal. Several questions arise:

(1) How do the two signals interact? They may act independently, both being visible at once, or they may be rivalrous, with only one of the two components visible at any one time. Alternatively, they may cancel or null each other to give little or no perceived motion.
(2) What stimulus parameters determine which signal, if either, is the dominant one at any particular time?
(3) What is the result of prolonged adaptation to the stimulus? A MAE should be generated in the direction opposite to the short-range adapting component, because the long-range process is believed to be unadaptable. Would the adaptation be effective even if short-range motion was not visible?

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The display consisted of a computer-generated movie, each frame of which showed a square-wave grating of vertical black and white bars. At every tenth bar there was a reversal in spatial phase so that two adjacent bars were black (or white), as shown in figure 1. On each frame the right-hand bar of each of these pairs was complemented, ie changed from black to white or vice versa. This had two consequences:

(1) A double-width bar changed in luminance polarity and moved rightward by one bar width. The rightward displacement (open arrows in figure 1) should be detected by the long-range process but not by the short-range process, because only the long-range process can follow form independently of texture (Ramachandran et al 1973) or luminance polarity (Anstis and Mather, in preparation).

(2) As the right-hand bar of a dark pair changed to white (frames 1 and 2 in figure 1), a black/white edge moved leftward by one bar width. This leftward motion (solid arrows in figure 1) should be detected by the short-range process because no change in luminance polarity is involved.

The visual effects generated by the display, and described below, can be readily demonstrated on an Apple II computer by the movie-making technique of Cavanagh and Anstis (1980). The program is available from the authors. To confirm them, the stimulus

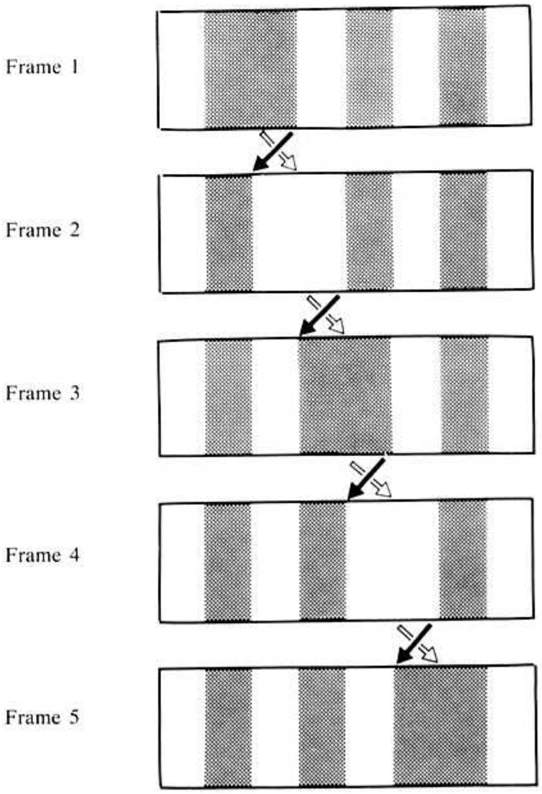

Figure 1. Stimulus to generate opposing short-range and long-range motion signals. A small segment of the grating is shown, in five successive movie frames placed one above the other, though they were actually superimposed spatially. In frame 1 the segment contains one broad and two narrow dark bars. In frame 2 the right-hand half of the broad bar complements (ie changes from black to white). Two motion components result: a long-range signal (open arrow) from the rightward displacement of a complementing broad bar; and a short-range signal (filled arrow) from the leftward displacement of a dark/bright edge. The displacements cover equal distances, but in opposite directions. The sequence continues in frames 3 to 5. Perceived direction depends on eccentricity and bar width, but motion aftereffects always move rightwards (opposite to the short-range component).

was displayed by a PDP-11/23 computer and Grinnell graphics facility, and six subjects made forced-choice decisions on the perceived direction of the stimulus and its MAE. The display consisted of a 3 deg by 3 deg patch of grating (contrast 0.5) on a uniform background. The mean luminance of the background matched that of the grating, at 67 cd m^{-2}. Each frame lasted 16.7 ms (one TV frame), and three bar widths were used: 2, 4, and 8 min. The direction of the complementing bars in the grating varied randomly from trial to trial.

We found that:

(1) The components were rivalrous. Only one direction of motion was ever apparent in the display, either the short-range component or the long-range component.

(2) The direction which was seen depended on retinal location and bar width: (i) in central vision, short-range motion was always seen (100% reports) for narrow bars having small displacements, and long-range motion was seen (83.3% reports) for broad bars having large displacements; for intermediate bars responses were split fairly evenly, with reports of short-range motion in 58% of the trials and reports of long-range motion in 42% of the trials;

(ii) at an eccentricity of 5 deg (to the centre of the grating), only short-range motion was ever seen for all bar widths.

(3) MAE direction was always opposite to the direction of the short-range component, regardless of which component was visible during adaptation (cf Anstis and Cavanagh 1980). The measured duration of the aftereffect declined as the bar width increased (see also Anstis and Mather, in preparation). In central vision, mean durations were 10.72 s for 2 min wide bars, 6.65 s for 4 min wide bars, and 1.47 s for 8 min wide bars. At any one bar width, MAE duration did not depend on whether the subject had reported motion of the long-range component or the short-range component during adaptation (for the 4 min wide bars, MAEs following reports of long-range motion lasted 7.04 s, and MAEs following reports of short-range motion lasted 6.36 s).

The rivalrous interaction obtained with this stimulus is reminiscent of the monocular rivalry reported elsewhere for orientation and spatial phase (Campbell et al 1973; Atkinson and Campbell 1974), and supports the notion that the two components are detected by functionally distinct processes. The direction perceived presumably reflects the relative strengths of the two responses to the same stimulus; both the decline in MAE duration and the decline in the frequency of seeing short-range motion for gratings with wider bars (and larger displacements) can be attributed to poorer activation of the short-range process by such stimuli. The rivalry is probably not a consequence of simple inhibitory interactions between the two processes, because MAEs (mediated by short-range detectors) were not reduced when long-range motion was perceived during adaptation. Instead, it may reflect a higher decision process based on the fact that contours on real moving objects can only have one direction of motion at any one time.

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