

Rapid Communication

Dichoptically Cancelled Motion

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We sought to determine whether or not motion-from-texture mechanisms have access to monocular input. Adopting a strategy used by Kolb and Braun (1995), we created drifting textures that were invisible to purely binocular processes. Monocular signals readily conveyed motions defined by local orientation and flicker. However, when left-eye and right-eye signals were displayed simultaneously, only flicker motion was visible. We conclude that motion-from-texture mechanisms do not have access to monocular input. Further evidence suggests that motion from texture involves attentional tracking.

Motion from texture Attentional tracking 2nd-order motion

INTRODUCTION

A monocularly viewed figure composed of slashes (/) against a ground composed of backslashes (\) can be *dichoptically cancelled* by simultaneously presenting a complementary

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figure of back-slashes against a ground of slashes to the other eye. (See Fig. 1.) In brief displays both figure and ground appear as Xs, yet the figure can be located (Kolb & Braun, 1995; Morgan, Mason, & Solomon, 1997). Thus, we can conclude that monocular input is available to a mechanism that computes texture boundaries. Since texture boundaries are known to be capable of conveying motion (Chubb & Sperling, 1991), it is reasonable to ask whether or not dichoptically cancelled textures could convey motion.

FIGURE 1 HERE.

GENERAL METHODS

For dichoptic displays the left-eye and right-eye images were presented in alternate video frames (at a monocular frame rate of 60 Hz) and separated by liquid crystal glasses through which maximum and minimum display luminances were 3.2 and <0.02 cd/m², respectively. For monocular displays either the left-eye or right-eye image (chosen randomly) was presented with zero contrast. Display resolution was 22.6 pixels/cm. The viewing distance was 21 cm. Thus the effective visual resolution was 8.3 pixels/degree. The PSYCHOPHYSICA (Watson & Solomon, 1997) software used in these experiments is available on the internet at <http://vision.arc.nasa.gov/mathematica/psychophysica.html>.

Rather than slashes and back-slashes, we used Gabor patterns with randomised phases. Each Gabor pattern is a 2.3 cycle/degree sinusoidal grating multiplied by a circular Gaussian with a space constant of 0.22° . Left-eye Gabor patterns were orthogonal to corresponding right-eye Gabor patterns.

In an attempt to minimize fixation disparity and eye movements, observers were instructed to fixate upon the central pixel which maintained maximum luminance throughout the experiment. Separate keypresses initiated stimulus exposures and indicated responses. Audio feedback was provided. One observer was naive (ACM) the other was highly trained (JAS).

FIGURE 2 HERE.

**EXPERIMENT 1: VISIBILITY OF DICHOPTICALLY CANCELLED
TEXTURE BOUNDARIES**

In order to compare texture and motion perceptions with similar stimuli, we constructed displays wherein different texture regions formed gratings [Fig. 2(a)]. To assess texture perception, observers reported the global orientation of static gratings (either horizontal or vertical). To ensure a fair comparison between monocular perception, which may be aided by iconic memory (Coltheart, 1980), and dichoptic perception, which may not, postmasks were used in this experiment. Static gratings and subsequent postmasks (with randomised local orientation) were displayed for equal durations.

Psychometric functions are shown in Fig. 3. With dichoptically cancelled textures, brief displays (100 - 200 msec) were sufficient to produce orientation discrimination with 75% accuracy. The duration of dichoptic displays is crucial. If they are sufficiently long and the two images are sufficiently different, then perception will alternate between the two images (Howard & Rogers, 1995). However, this rivalry does not occur for displays less than 200 msec; the two images fuse to form a combined percept (Howard & Rogers, 1995). Thus we can conclude that monocular input is available to a mechanism that computes texture boundaries on the basis of local orientation.

Monocular orientation discrimination was even easier. 75% accuracy could be obtained with 20 - 40 msec displays (Fig. 3). This suggests that binocular input is also available to a (possibly different) mechanism that computes texture boundaries on the basis of local orientation.

FIGURE 3 HERE.

**EXPERIMENT 2: VISIBILITY OF DICHOPTICALLY CANCELLED
MOTION FROM TEXTURE**

To assess motion perception, all gratings had the same global orientation (horizontal) and observers tried to report their directions of drift (either up or down). The gratings drifted in quarter-cycle steps as alternate rows of the grating (wavelength = 4 Gabor patterns = 3.9 degree) changed their orientation. [See Fig. 2(a).] On each trial, left-eye and right-eye gratings drifted through one complete cycle.

With monocular displays direction discrimination by our novice observer was 75% accurate at 1 Hz [Fig. 4(a)]. With dichoptic displays there is no evidence that she could discriminate between opposite directions at all. With monocular displays our highly trained observer attained 75% accuracy at 3 Hz. With dichoptic displays his performance was better than chance only at the lowest temporal frequencies: 60% at 2.1 Hz and 63% at 0.99 Hz. Thus, if monocular input were available to a mechanism that computes motion from texture, then that mechanism must greatly favor binocular input. Alternatively, motion-from-texture mechanisms do not have monocular input and JAS's slightly-better-than-chance performance was a consequence of rivalry during some of the long displays. (Since all of these gratings drifted one full cycle, the 2.1 and 0.99 Hz gratings were displayed for 590 and 1,260 msec, respectively.) This alternative is supported by the additional finding that JAS's performance drops to chance when the 2.1 Hz grating drifts through just one-half cycle (a 350 msec display).

FIGURE 4 HERE.

Our results with monocular displays are consistent with those of Chubb and Sperling (1991) who also examined direction discrimination with gratings defined by local orientation. Specifically, direction discrimination is possible, but not perfect for temporal frequencies between 2.5 and 4 Hz. The performances of highly trained observers (JAS's performance here and CC's in Chubb and Sperling's experiment) are consistent with that of

the attentional tracking mechanism, as described by Lu & Sperling (1995). They found that 75% accuracy could be obtained at 4 Hz, but not at 8. If attentional resources are indeed required for direction discrimination with gratings defined by local orientation, then our results suggest that attentional resources cannot be directed to monocular levels of visual processing. Note that this conclusion is complementary to theirs. Using a stimulus invisible to purely monocular processes, Lu & Sperling (1995) showed that motion energy mechanisms do not have access to binocular signals. Using a stimulus invisible to purely binocular processes, we show that motion-from-texture mechanisms do not have access to monocular signals.

EXPERIMENT 3: VISIBILITY OF DICHOPTICALLY CANCELLED MOTION FROM FLICKER

Attentional tracking mechanisms may not have access to monocular information, but what about the putative "2nd-order" mechanism that filters, rectifies and computes motion energy from visual stimuli (Lu & Sperling, 1995)? Using a stimulus similar to Experiment 2's, we constructed a grating defined by flicker. Initially, the orientation of each Gabor pattern is random. Then, as the grating (again, wavelength = 4 Gabor patterns) drifts one-quarter cycle, alternate *pairs* of rows change their orientation. In the next quarter cycle, another pair (containing one row of the previous pair and one new row) changes and so on. [See Fig. 2(b).] Oriented filtering does not reveal the direction of this grating's drift to motion-energy (Adelson & Bergen, 1985; Watson & Ahumada, 1983) or Reichardt (1961; van Santen & Sperling, 1985) mechanisms. Some combination of temporal differentiation and point-wise nonlinearity is required.

In this experiment, each stimulus was displayed for just 202 msec in order to prevent rivalry. Thus the faster a grating's drift, the further it drifted. Here performances with monocular and dichoptic displays are similar. Both observers attained 75% accuracy

with temporal frequencies between 4 and 5 Hz [Fig. 4(b)]. Thus we can conclude that monocular input is available to standard 2nd-order motion mechanisms.

CONCLUSION

Discrimination with dichoptically cancelled textures requires access to monocular information. We have shown that mechanisms which compute motion from flicker have such access while mechanisms which compute motion from texture do not. Furthermore, our results are consistent with the notion that motion-from-texture is computed from the spatiotemporal locus of attention. We conclude that attention cannot be directed to monocular levels of visual processing.

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FIGURE LEGENDS

FIGURE 1. A dichoptically cancelled figure/ground.

FIGURE 2. Dichoptically cancelled motion. Five consecutive frames produce one complete cycle of motion defined by either local orientation (a) or flicker (b). When discriminating between global orientations, one frame of a was displayed either as illustrated here, or with the images rotated 90°. Gabor patterns with randomised phases are used to ensure that texture boundaries are computed on the basis of local orientation in (a).

FIGURE 3. Results: orientation discrimination, gratings defined by local orientation. Error bars reflect Bernoulli standard errors.

Cumulative gaussians have been (maximum-likelihood) fit to each psychometric function with the constraints of a minimum accuracy of 50% and a maximum accuracy of 99%.

FIGURE 4. Results: direction discrimination. (a) Gratings defined by local orientation. (b) Gratings defined by local flicker.