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Effects of adaptation to Glass pattern structure and to path of optic flow

John Ross *, J. Edwin Dickinson

School of Psychology, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia

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Abstract

The effects of adaptation to radial and rotational polar optic flow on the classification of noisy test patterns are shown to be very similar to the effects of adaptation to polar Glass patterns on the classification of noisy Glass patterns (Clifford, C. W. G. & Weston, E. (2005). Aftereffect of adaptation to Glass patterns. *Vision Research*, *45* 1355–1363.). In both cases there is a large shift in the signal strength at which test patterns are classified as radial or rotational with equal probability. Two asymmetries were discovered: (1) adaptation to optic flow alters the classification of Glass patterns, but the reverse is not true; and (2) adaptation to Glass patterns decreases detectability of patterns of the same type, but adaptation to optic flow has little effect on the detectability of patterns of any type. We conclude that the mechanisms that detect radial and rotational Glass patterns are independent and independently adaptable, but that the mechanisms that detect the path of optic flow, when directional effects are cancelled out, are linked in an opponent, push–pull fashion.
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Keywords: Adaptation; Glass patterns; Optic flow; Path of motion

1. Introduction

There is evidence that adaptation to polar Glass patterns (Glass, 1969) makes their global structure more difficult to see, though their component dipoles can be clearly seen in their original positions. McGraw, Badcock, and Khuu (2004) reported that global structure dissipated on prolonged fixation and Clifford and Weston (2005) showed that after adaptation to full-strength polar patterns, noisy patterns of low signal strength were likely to be classified incorrectly, radial as rotational and vice versa.

Glass patterns and optic flow patterns, illustrated in Fig. 1, have much in common. They are similar in construction (Ross, Badcock, & Hayes, 2000); they share an anisotropy in their Fourier spectra (Barlow & Olshausen, 2004); and information about both is assembled by cortical neurons with large receptive fields (Duffy & Wurtz, 1991; Gallant, Braun, & Van Essen, 1993; Morrone, Burr, & Vaina, 1995; Wilson & Wilkinson, 1998). But whether the two are linked analytically, and if so how, is uncertain. Early evidence suggested that the analysis of optic flow was conducted within dorsal regions of the cortex and of global pattern within ventral regions, making the affinity of Glass patterning and optic flow mysterious. Recent evidence has emerged that the sites of the analysis of global motion and of global form may not be as separated as previously thought (Braddick, O'Brien, Wattam-Bell, Atkinson, & Turner, 2000; Krekelberg, Vatakis, & Kourtzi, 2005), opening the possibility of functional interconnections between the two.

Here, we first confirm the results of Clifford and Weston (2005), and then ask whether the classification of noisy optic flow patterns is altered by adaptation to noiseless patterns as the classification of noisy Glass patterns is. We find that adaptation to optic flow that reverses in direction to cancel out the classical directional aftereffect, does alter the classification of noisy bidirectional test patterns. It also alters the classification of static noisy Glass patterns, suggesting that it may be the path of motion that is being adapted. But there is no converse effect: adaptation to Glass patterns, even though they are shown in sequence to appear to be in coherent motion (Ross et al., 2000), has little or no effect on the classification of bidirectional

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* Corresponding author.
E-mail address: jr@psy.uwa.edu.au (J. Ross).

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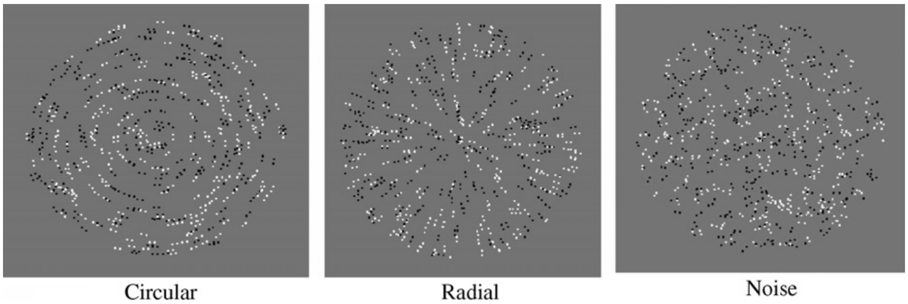

Fig. 1. Types of pattern used in this study. Glass patterns were made from noise and circular or radial patterns. Motion patterns were composed of noise dipoles, moving on circular or radial paths, except in Experiment 5, where the dipoles were replaced by line segments.

optic flow. There is also a difference between Glass patterns and optic flow in the effect of adaptation on pattern detection, as distinct from classification.

2. General methods

2.1. Observers

The observers were the authors (J.E.D. and J.R.) and a member of the laboratory (J.B.B.), experienced in making psychophysical observations but unaware of the purposes of the experiments.

2.2. Stimuli

The types of Glass pattern and optic flow used in this study are illustrated in Fig. 1. They were composed from 400 like-contrast dipoles, half made of white spots and half of black. They were displayed in a circular aperture of diameter 13 deg on a monitor (Hitachi HM-4821-D), under the control of a CRS Visage stimulus generator at a viewing distance of 60 cm. The luminance of the background was 18 cd/m^{-2}, of the white spots 32.4 cd/m^{-2} and of the black spots 7.4 cd/m^{-2}. The diameter of the dots was 7.8 min and their centre-to-center separation 15.2 min.

To compose a noisy Glass pattern of a given signal strength, a proportion of its dipoles were oriented coherently, either in a circular or a radial pattern, and the remaining dipoles were oriented at random, as noise. To compose an optic flow pattern of a given signal strength a proportion of dipoles, selected at random on each frame from a purely noise pattern, were moved coherently, either along concentric circular paths, or along radii, and the remainder were moved at random. Dipoles were chosen for optic flow to make the stimuli for Glass patterns and optic flow as similar as possible in construction, and the were randomly oriented because systematically oriented dipoles have been shown to exert a strong influence on the perceived path of optic flow (Krekelberg, Dannenberg, Hoffmann, Bremmer, & Ross, 2003; Ross, 2004). The signal strength of adapting stimuli was 1, that is all dipoles in Glass patterns were coherently oriented, and all dipoles in motion stimuli moved coherently at a speed of 7 deg/s. During the adaptation period the direction of motion reversed at rate of 2.2 Hz to cancel out the classical MAE, which is direction-specific. During the test phase motion was simultaneously (and transparently) in opposite directions because exposure times were too short to permit reversal. Half the signal dipoles moved in one direction, and half in the opposite direction.

The signal strength of the test stimuli ranged from −0.7, that is 70% of the dipoles were oriented radially (Glass patterns) or moved on radial paths (optic flow patterns), through 0 (no signal), to +0.7, that is 70% of the dipoles were oriented circularly or moved on circular paths.

3. Experiment 1

Experiment 1 was designed (i) to replicate the experiment of Clifford and Weston (2005) who found that adaptation to radial or circular Glass patterns shifted the signal strength at which observers classified subsequent noisy test patterns as circular or radial with equal probability (the point of indifference) away from zero (no radial or circular signal); and (ii) to establish whether adaptation to the path of circular or radial optic flow causes a similar shift in the classification of noisy bidirectional test patterns.

3.1. Procedure

The adaptation stimulus was displayed initially for 20 s, then, as a top-up, for 5 s before each new test stimulus. Each test stimulus was displayed for 0.5 s. During the adapting phase for Glass patterns new exemplars appeared at a rate of 12 Hz to avoid loss of perceived structure (Clifford & Weston, 2005). At this rate of replacement there was a pronounced appearance of coherent motion (Ross et al., 2000), irregularly reversing in direction. During the adapting phase for optic flow the same dipoles remained in motion, and the path of motion was isolated by reversing the direction of motion at a rate of 2.2 Hz.

During the test phase for classification experiments a single Glass pattern was displayed for 0.5 s or motion continued for 0.5 s, half the signal dipoles moving in one direction and half, transparently, in the opposite direction. During the test phase of detection experiments two stimuli were shown, one pure noise, the other containing a signal, each for 0.5 s.

3.2. Results and discussion

Fig. 2a shows that despite some differences in procedure (fewer stimulus elements, 400 as against 2000 dipoles, for each adaptation and test pattern, and more rapid updating of the adaptation stimulus, 12 Hz as against 1 Hz) the Glass pattern results closely replicate those of Clifford and Weston. Fig. 2b shows that the effects of adaptation to the path of optic flow on the classification of subsequent bidirectional test patterns are very similar. Shifts in the point of indifference (Fig. 2c) for Glass patterns were large, and similar in value to found by Clifford and Weston (2005); shifts for optic flow were also large (Fig. 2d).