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Aftereffect of adaptation to Glass patterns

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Abstract

Our visual systems constantly adapt their representation of the environment to match the prevailing input. Adaptation phenomena provide striking examples of perceptual plasticity and offer valuable insight into the mechanisms of sensory coding. Here, we describe an aftereffect of adaptation to a spatially structured image whereby an unstructured test stimulus takes on illusory structure locally perpendicular to that of the adaptor. Objective measurement of the strength of the aftereffect for different patterns suggests a neural locus of adaptation prior to the extraction of complex form in the visual processing hierarchy, probably at the level of primary visual cortex. This view is supported by further experiments showing that the aftereffect exhibits partial interocular transfer but complete transfer across opposite contrast polarities. However, the aftereffect does show weak position invariance, suggesting that adaptation at higher levels of the visual system may also contribute to the effect.

Keywords: Spatial vision; Visual cortex; Psychophysics; Sensory coding; Orientation; Global form

1. Introduction

We studied adaptation to spatial image structure using a stimulus, the Glass pattern (Glass, 1969), whose perception involves pooling orientation information across significant distances of visual space (Wilson & Wilkinson, 1998; Wilson, Wilkinson, & Asaad, 1997). Each Glass pattern consists of a large number of pairs of dots, and is constructed as follows. One dot in each pair is positioned randomly within the stimulus according to a probability distribution uniform over area. The second dot of each pair is then positioned at a fixed distance from its partner in a direction defined by the particular pattern being generated. For example, if the direction of displacement is directly away from the centre of the image then a radial "sunburst" pattern is generated (Fig. 1A). If the displacement is perpendicular to the position vector relative to the centre then the pattern is concentric (Fig. 1B).

The spatial structure in Glass patterns has been termed *static flow* (Kovacs & Julesz, 1992) by analogy with *optic flow*, the pattern of retinal motion generated by self-motion. This seems an appropriate analogy because the static Glass pattern stimulus can be considered as the superimposition of successive frames of a random dot kinematogram (although in optic flow stimuli dot displacement between successive frames typically scales with eccentricity whereas in Glass patterns the distance between the two dots in a pair is independent of position within the pattern). Indeed, it has been argued that the mechanisms responsive to the complex spatial structure in Glass patterns are not so much concerned with the perception of complex form per se but rather with the analysis of the spatial image structure or "motion streaks" that result from the temporal integration of images undergoing global motion (Barlow & Olshausen, 2004).

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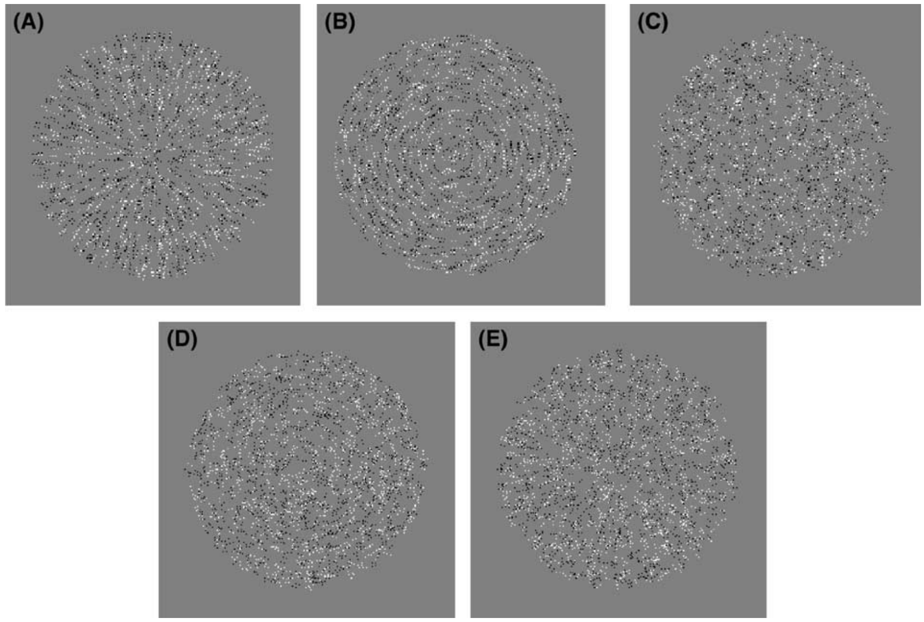

Fig. 1. Aftereffect of adaptation to Glass patterns. (A) Radial and (B) concentric Glass patterns of 100% coherence used as adapting stimuli. (C) Incoherent (0%) pattern composed of randomly oriented dot dipoles. Illustration of the appearance of the incoherent pattern after adaptation to a coherent (D) radial or (E) concentric stimulus. Adaptation causes the test to take on the opposite appearance to the adaptor with an apparent coherence of around 35%.

In studies of optic flow perception, it is common to vary the coherence of stimuli in order to control their visibility (Newsome & Paré, 1988). The coherence of a stimulus is the percentage of elements in the stimulus conforming to the global pattern. It is straightforward to extend the idea of varying stimulus coherence to studies of the perception of static flow in Glass patterns (Maloney, Mitchison, & Barlow, 1987). Following adaptation to a coherently moving dot pattern, a compelling motion aftereffect (MAE) can be observed by testing with a pattern in which all dots move at the same speed as the adaptor but in random directions: a dynamic test stimulus with 0% coherence (Blake & Hiris, 1993; Hiris & Blake, 1992). The directionally ambiguous test is perceived as drifting in the direction opposite to the adapting motion. In the spatial domain, the analogous situation is to adapt to a coherent Glass pattern and then test with a stimulus composed of randomly oriented dot dipoles of the same intra-dipole dot separation (Fig. 1C). When this is done, the test stimulus appears to take on a spatial structure locally perpendicular to that of the adaptor. For example, adaptation to a radial pattern causes an incoherent test to appear to contain concentric structure (Fig. 1D) while adaptation to a concentric pattern produces a radial aftereffect (Fig. 1E). The coherence level of the patterns in Fig. 1D and E used to illustrated the aftereffect (35%) is based on objective measurements of its magnitude, described below.

The aftereffect can be experienced by viewing the movie at the following web address: http://www.psych.usyd.edu.au/staff/colinc/HTML/glass_adapt.htm. On each cycle of the movie, a brief presentation of the same incoherent test pattern is presented on either side of the central fixation point, followed by several seconds of the adapting stimuli. The adapting stimuli to the left and right of fixation are coherent radial and concentric patterns, respectively. This format was chosen for demonstration purposes to facilitate comparison of the effects of adaptation to the two opposite patterns. Over the course of several cycles, the salience of the adapting patterns decreases while the illusion of structure in the test stimuli becomes stronger. The same effects are evident whether the test stimuli are composed of randomly oriented dipoles or of unpaired random dots.

One means of measuring the MAE has been to adapt observers to a constantly moving dot pattern of 100% coherence and then present them with moving test stimuli at varying levels of coherence (Blake & Hiris, 1993; Hiris & Blake, 1992). For example, if the adapting stimulus was moving downwards (+100% coherence) then test stimuli would range from coherent upwards motion (−100% coherence) through random motion (0% coherence) to coherent downwards motion (+100% coherence). Observers would then be required to report whether the test stimulus appeared to be moving upwards or downwards. The stimulus coherence at which observers were equally likely to respond in either direction provides a measure of the point of subjective stationarity: the coherence at which no consistent direction of motion is seen. The difference in the point of subjective stationarity before and after adaptation