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Last but not least

Steady viewing dissipates global structure

1 Introduction

Glass patterns (Glass 1969) have been widely used in the investigation of visual mechanisms mediating global form perception. These stimuli may be produced by randomly placing dots within a field and then providing a partner for each dot, the relative position of which is determined by a common rule. A radial pattern may be produced by placing the second dot on a radial line connecting the original dot with the centre of the field, a concentric pattern by placing the dot orthogonal to that line, or translational in which the partner dots are all displaced in a common direction. These three types of patterns are presented in figure 1, where it can be seen that a strong percept of global form is produced. Dot pair separation is constant in figure 1, but patterns consistent with the superposition of a geometrically transformed copy of the initial dot array can also be produced if dot separation varies with eccentricity. The ability to perceive the global structure is mediated by two distinct processes: a local level, and a subsequent global level of analysis. First, the dot pairs must be integrated to form a dipole. Following this, the local orientation information must be integrated across visual space to recover the global relationship. The manner of Glass pattern construction makes them an ideal stimulus to study both these levels of form processing. Recent psychophysical investigations of global form perception, using Glass pattern stimuli, suggest that the pooling mechanisms for different structural forms might be very different. More complex forms, such as radial and spiral Glass patterns, require global pooling of orientation information across an extended region of space. In contrast, lateral or parallel patterns require only local pooling in order to reveal their structure (Wilson and Wilkinson 1998). This is most likely due to the fact that parallel patterns contain a large degree of sample redundancy, since the dipoles formed from dot pairs all signal the same orientation, unlike rotational or spiral Glass patterns. Here we present a demonstration showing the rapid collapse of global structure under steady viewing conditions. More importantly, the loss of global perception is critically dependent on the underlying structural form. It is more rapid and marked for complex forms, such as concentric and spiral patterns, than it is with simple parallel patterns.

2 Methods

Four types of Glass pattern structure are presented in figure 1: (a) a concentric Glass pattern; (b) a radial Glass pattern; (c) a parallel Glass pattern; and (d) a pattern in which the dipoles are randomly oriented and thus do not form a global structure. The global structure (or lack of it) of each of these patterns should be readily visible to the observer. However, if fixation is carefully held on the fixation mark at the centre of 1a for several seconds, the observer should see the collapse of the concentric global structure, and the pattern take on a random appearance (similar to 1d). A comparable effect can be confirmed for the radial pattern presented in figure 1b. In contrast, the global structure of the parallel pattern presented in 1c is considerably more robust to the adaptation effects of steady fixation. Indeed, it is very difficult to degrade the global structure at all in this pattern, even when fixation is held constant for a considerable length of time. Some individuals who find it difficult

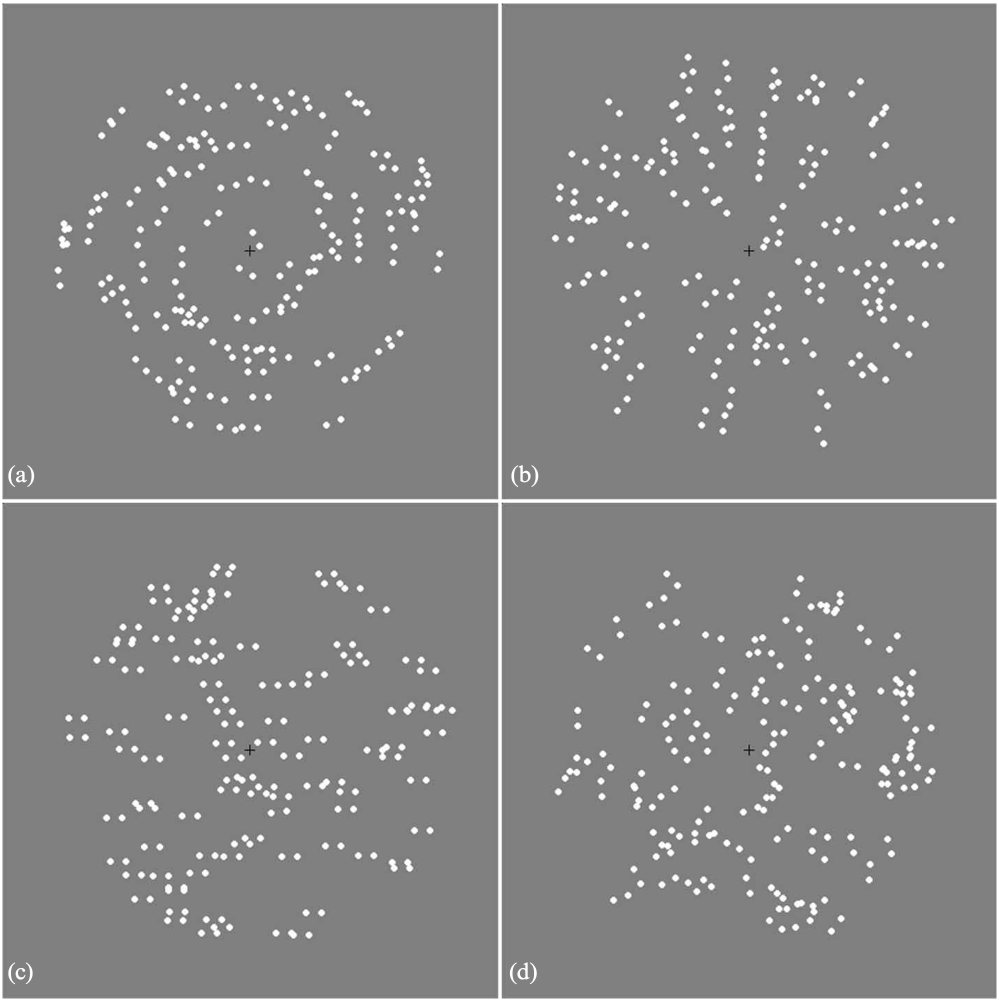

Figure 1. Four types of Glass pattern structure: (a) a concentric Glass pattern; (b) a radial Glass pattern; (c) a parallel Glass pattern; and (d) a pattern in which the dipoles are randomly oriented and thus do not form a global structure. If fixation is held steadily on the fixation mark at the centre of (a) from a distance of approximately 20 cm, the observer should see the collapse of the concentric global structure after several seconds, and the pattern take on a random appearance [similar to (d)]. Repeating the process for (b) produces a similar result. However, steady fixation of (c) has little impact, and the parallel global structure is markedly less affected.

to hold their fixation steady enough over a period of several seconds may have difficulty experiencing this phenomenon, since any small eye movement is sufficient to reinstate the global percept in all of the patterns. Recently, Achtman et al (2003) demonstrated that sensitivity to global structure is robust to manipulations of a number of parameters such as stimulus area, density, element number, contrast, spatial frequency, and polarity. In support, we also find that the loss of global structure in figures 1a and 1b, resulting from steady viewing, occurs for a range of stimulus areas, dot densities, and contrasts,[1] suggesting that the mechanisms involved in both tasks may be common.

[1] Examples of other stimuli can be found at http://www.psy.uwa.edu.au/dbadcock/

3 Discussion

This demonstration has several important implications for the mechanisms involved in global form perception. First, it appears that the global mechanism, responsible for integrating local dipole orientations in order to reveal any underlying global structure, adapts out rapidly under steady viewing conditions. In contrast, the parallel Glass pattern is relatively robust to the influence of steady-viewing conditions. Previous psychophysical experiments have shown that detection thresholds for parallel patterns are consistently higher than for their concentric or radial counterparts (Wilson and Wilkinson 1998). Furthermore, parallel Glass patterns show an entirely different dependence on stimulus area as compared with more complex structural forms (Wilson et al 1998). These findings have led to the suggestion that, while the processing involved in radial and concentric Glass patterns invokes global form mechanisms, parallel Glass pattern detection is restricted to a local level of analysis (Wilson et al 1997; Wilson and Wilkinson 1998). If we accept this processing structure, the present demonstration would appear to suggest that global integration mechanisms are more vulnerable to the influences of steady fixation in the current context than local processing. This disappearance of the global structure with steady fixation is reminiscent of local adaptation which is known to occur when retinal images are stabilised (Pritchard 1961; Kelly and Burbeck 1980). That stabilisation causes patterns to rapidly disappear. Here with steady viewing the global structure is lost rather than the visibility of the local pattern elements. Wilson and coworkers, in addition to quantitative computational models, also present a physiologically plausible framework for these different levels of form processing. They tentatively suggest that the local level of analysis is mediated by simple cells in early striate cortex (V1). On the other hand, the global level of analysis is more compatible with the physiological properties of neurons in primate V4 (Gallant et al 1993, 1996). A subset of neurons in this area have been shown to be particularly responsive to concentric, radial, or hyperbolic stimuli. Kobatake and Tanaka (1994), using a different methodological approach, also showed strikingly strong responses in a large percentage of V4 neurons to more complex structural forms. Furthermore, neuro-anatomical evidence suggests that the integration of multiple orientations, which would be required to mediate global form analysis, is present at V4 and absent at earlier cortical levels such as V1 (Vanduffel et al 2002). More recently, functional magnetic resonance imaging (fMRI) studies in humans have demonstrated stronger activation in area V4 to concentric and radial patterns, as opposed to simple sinusoidal gratings (Wilkinson et al 2000). If, as suggested by Wilkinson and coworkers, units in V4 are responsible for the integration of global form, then the present demonstration suggests that we might reasonably expect to see reduced activity in these units under conditions of steady viewing, in keeping with our perceptual experience. Previous optical imaging studies in primates have demonstrated that cortical activity is strongly linked to perceptual output rather than the physical characteristics of the stimulus (Macknik and Haglund 1999).

This view of global form processing, in particular the distinction drawn between parallel and more complex structural forms, has recently been challenged by Dakin and Bex (2002). They contest that the superior performance observers achieve in detecting rotational or concentric Glass patterns is essentially the result of an interaction between the edge of the aperture and the underlying global structure, ie concentric patterns are more readily detected when presented in circular as opposed to rectangular windows. Although Dakin and Bex (2002) concentrated on the detection of global structure, we investigated whether such edge effects have a role to play in the collapse of global structure under steady fixation. We present a concentric and parallel Glass pattern in a rectangular as opposed to a circular window (see figures 2a and 2b). The observed effects are unchanged. Once again, after a few seconds of steady viewing, the global

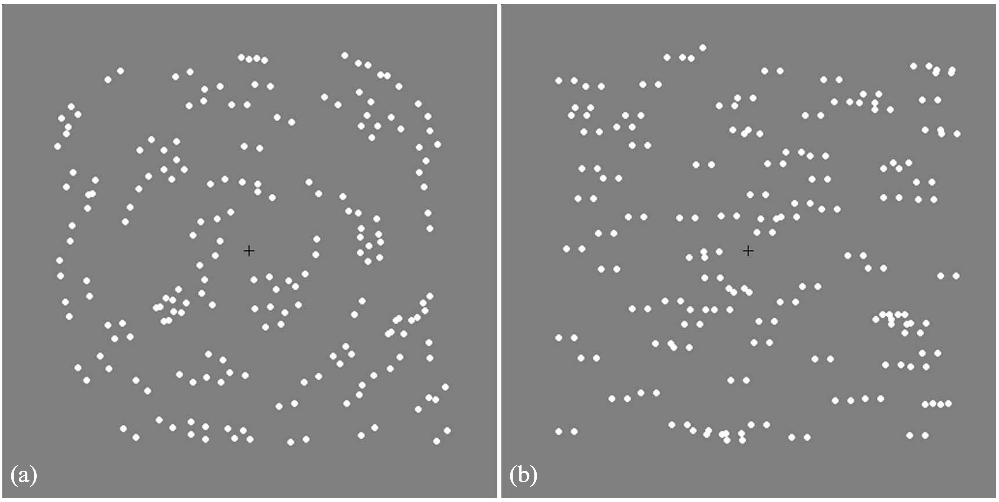

Figure 2. A concentric (a) and a parallel (b) Glass pattern are presented in a square, rather than circular aperture. The observed effects are unchanged, and once again steady fixation at the centre of the concentric pattern (a) results in a collapse of global structure, while the parallel structure (b) remains considerably more robust to the effects of adaptation.

structure in the concentric Glass pattern collapses, whilst the parallel structure in the translational pattern remains perceptually salient. This suggests that aperture shape per se is not critical, but that the mechanisms mediating the perception of global form in each pattern behave differently under steady viewing. Given this, and the previously cited psychophysical and physiological data, it is difficult to support the assertion of Dakin and Bex (2002) that the mechanisms mediating form perception for each type of pattern are essentially the same.

Previous reports have provided examples where global structure becomes more regular or uniform under steady fixation (Anstis 1975). For example, if a pattern of 'wiggly' vertical lines is viewed steadily for a period, the lines appear to take on a more regular appearance. Anstis (1975) suggests that, when the retinal image is stabilised, the visual system regresses to a rather more sparse representation of the image, and local departures from regularity (such as the small wiggles in the lines) are lost. We show that under the correct conditions the converse is also true, and rather than becoming more uniform, global structure can appear considerably more irregular. Anstis (1975) did use patterns that are well detected by local level detectors (eg approximately straight lines or continuous smooth circles) and did not require the global detectors that are necessary for Glass patterns. This difference may account for the differing perceptual effects. A quantification of the temporal dynamics of these steady viewing phenomena has not yet been made. However, it is likely that comprehensive measures will provide important insights into the mechanisms mediating global form perception, and more generally about redundancy reduction in visual processing. These issues are currently the focus of work ongoing in our laboratory.

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