Evidence for spatio-temporal selectivity in attentional modulation of the motion aftereffect

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Abstract—An ignored region of the visual field might be monitored by an intermittent full visual analysis or by a more continuous but restricted analysis. We investigated which type of process is more likely in early vision by studying the effects of diverting attention on adaptation to a range of spatial (0.5, 2, 4, and 6 c/deg) and temporal (1.5 and 10 Hz) frequencies. During adaptation, subjects either fixated an unchanging digit (normal attention), or named the sequence of changing digits which formed the fixation point (diverted). The test field was always a static version of the adapting field, and the strength of adaptation was measured through the velocity and duration of subsequent Motion Aftereffects (MAEs). When attention during adaptation was normal, MAE durations rose with spatial frequency for the 1.5 Hz stimuli, and declined with spatial frequency for the 10 Hz stimuli. When attention was diverted from the 10 Hz stimuli, MAE durations and velocities fell by a similar amount at all spatial frequencies. However, for the 1.5 Hz stimuli, the effects of diversion were very small at 0.5 c/deg, and rose progressively with spatial frequency, so that MAE reductions were largest at 6 c/deg. It appears that diversion hardly affects the encoding of coarse, slow stimuli, but attenuates the encoding of finer and/or faster stimuli. This is consistent with the idea that during diversion the visual system monitors the scene continuously, but over a restricted range of spatial and temporal scales.

Keywords: Attention; motion aftereffect; spatial frequency; temporal frequency.

1. INTRODUCTION

It is clear that, when we ignore a region of the visual field, some kind of monitoring of the ‘unattended’ region still occurs, since appropriate visual events occurring in that region can capture attention. What is less clear is the nature of this monitoring, and how it differs from attentive scrutiny. One possibility is that a full visual analysis of nominally unattended regions takes place, but that this is brief and intermittent. A second is that monitoring is continuous, but that visual analysis is somehow more

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restricted. In this paper, we describe a study that attempts to demonstrate which of these possibilities is the more likely, and the nature of any restriction.

It is widely believed that an early stage of the visual system is composed of parallel sets of channels which can be defined in terms of their spatial and temporal filtering characteristics (see Braddick et al., 1978; and Graham, 1989, for reviews). A relatively small number of such channels is thought to process information from each region of the retina. The exact number is uncertain (and is not critical for the present study), but it has been estimated that there are perhaps 4-6 spatial (Wilson and Bergen, 1979) and 2 or 3 temporal (Thompson, 1983; Mandler and Makous, 1984) channels. The central idea is that the retinal image is encoded at a range of spatial and temporal scales (Watt, 1987). One possibility is that monitoring of an unattended region of space is continuous, but carried out by only a sub-set of these channels.

There is already evidence that attentional processes may involve the switching on and off of such channels. For example, one effect of attending to a stimulus is to enhance its spatial resolution (Yeshurun and Carrasco, 1998), perhaps by switching in higher spatial frequency channels. Again (Kinchla and Wolfe, 1979), subjects can selectively attend to either the coarse or the fine spatial information in hierarchical stimuli such as the large letters composed of small letters devised by Navon (1977). Thus it is possible that, during diversion, some of these channels are still processing information, while others are not.

A technique which may allow the study of this question was devised by Chaudhuri (1990), who showed that the motion aftereffect (MAE) could be reduced if the subject’s attention was diverted from the moving stimulus during adaptation. Chaudhuri studied only the aftereffects of simple linear motion, but it now seems that adaptation can affect several types of motion processing mechanism, which presumably lie at different levels of the visual system. Thus, evidence has been put forward for adaptation of relative motion detectors (Ashida and Susami, 1997), of motion contrast detectors, the centres and surrounds of whose receptive fields are sensitive to opposite directions of motion (Murakami and Shimojo, 1995), as well as of detectors for more complex patterns of motion such as rotation and expansion (Snowden and Milne, 1996, 1997). The receptive fields of these complex motion detectors may be formed by combining the outputs of simpler detectors sensitive to linear motion in one or more directions, which are themselves adaptable. In addition to the spatial characteristics of the adapting and test fields, their temporal characteristics have been found to be important in showing some kinds of aftereffect. Thus attending to one component of a display which contains two directions of motion, such as a counter-phased grating or a transparent motion display, yields an MAE, but only on a dynamic not a static test field (Lankeet and Verstraten, 1995; Culham et al., 2000). When the contrast of one component of a radial counter-phased grating is made slightly higher, its direction of motion always dominates during passive viewing, but, provided that the contrast difference is not too great, attending to the lower contrast component causes its direction of