Perceived contrast following adaptation: the role of adapting stimulus visibility

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Abstract—The issue of whether contrast adaptation can reduce the perceived contrast of gratings oriented orthogonal to the adapting stimulus to a greater extent than parallel gratings has been the subject of considerable debate (Snowden and Hammett, 1992; Ross and Speed, 1996). We compared the reductions in perceived contrast of various test gratings oriented parallel and orthogonal to the adapting stimulus across a range of spatial frequencies (2.25–9 c/deg) and adaptation contrasts (0.19–1.0). Our results show that when the adapting stimulus is low in contrast, parallel adaptation effects are always greater than the effects of orthogonal adaptation. When the adapting contrast is increased, however, the difference between parallel and orthogonal effects is reduced. Further increases in adapting contrast can produce a situation where cross-orientation adaptation effects exceed iso-orientation effects. This was observed at low spatial frequencies (2.25 and 4.5 c/deg) only. The difference in the pattern of results obtained at low and high spatial frequencies can be explained in terms of the adapting stimulus visibility. We conclude that cross-orientation adaptation effects can be greater than iso-orientation effects, but only when the adapting stimulus is highly suprathreshold.

Keywords: Contrast adaptation; spatial frequency; orientation; visibility.

INTRODUCTION

Many important aspects of visual processing have been elucidated through adaptation experiments. Prominent amongst these are the domains of contrast and spatial frequency (Pantle and Sekuler, 1968; Blakemore and Campbell, 1969), colour (McCollough, 1965), motion (Pantle, 1974), shape (Gibson, 1933), spatial position (Whitaker et al., 1997) and orientation (Gibson and Radner, 1937; Blakemore and Campbell, 1969; Georgeson, 1973). Adaptation is a ubiquitous and profound sensory phenomenon. The seminal adaptation experiments of Blakemore and Campbell (1969) showed that prolonged inspection of a visual stimulus may alter an observer’s perception of subsequently presented visual patterns, depending on the similarity of

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the spatial characteristics between the two stimuli. For example, following inspection of a vertical sinusoidal grating, the loss in sensitivity induced by adaptation will only occur if the test stimulus is oriented in the same direction and contains spatial frequencies at or close to that of the adapting stimulus. This result suggests that the visual system contains independent neural mechanisms which are selective to the spatial characteristics of the stimulus. Physiological studies have also shown that neurones within the visual cortex show specific sensitivity to particular primary visual attributes such as spatial frequency, direction of motion and orientation (Hubel and Wiesel, 1962, 1968; Campbell et al., 1968; De Valois et al., 1982; Maunsell and van Essen, 1983). This implicated them as the likely neural resource dedicated to selective detection mechanisms, identified by psychophysical studies. The combined results of the psychophysical and physiological adaptation experiments were responsible for establishing a fundamental sensory principle — unidimensional stimuli will not interact within the visual system unless they contain a common stimulus modality.

The impact of pattern adaptation on visual perception is commonly measured in one of two ways. Following prior exposure to a suprathreshold grating, either the elevation in contrast threshold or change in the perceived contrast of a suprathreshold stimulus can be measured. Both approaches were adopted in an elegant series of experiments conducted by Snowden and Hammett (1992). In this study the authors demonstrated the classic orientation-dependant adaptation effect, where the threshold contrast of a grating following adaptation is markedly elevated if the adapting and test grating share a common orientation. However, a rather unexpected cross-orientation result was found for post-adaptation measures of perceived suprathreshold contrast. Under certain circumstances, adapting to a grating orthogonal to that of the test pattern produced a greater reduction in perceived contrast than when the adapting and test stimuli were parallel. This finding led the authors to propose two modes of adaptation: a subtractive process when the adapting and test patterns were of the same orientation, and a divisive process when the adapting and test patterns were orthogonal in orientation. The results of Snowden and Hammett (1992) strongly suggest qualitative differences in the orientation tuning of the effects of adaptation on contrast detection thresholds and perceived suprathreshold contrast.

The issue of cross-orientation adaptation was re-examined by Ross and Speed (1996). Using a contrast matching procedure, similar to that employed by Snowden and Hammett (1992), they confirmed that when the adapting and test patterns were orthogonal, reductions in perceived contrast were indeed found. However, in contrast to Snowden and Hammett (1992) they were unable to demonstrate a situation where the reduction in perceived contrast invoked by an orthogonal adapting pattern was greater than that of a parallel adapting pattern of the same contrast. This led Ross and Speed to reject a model incorporating dual modes of adaptation and, instead, adopt a single mechanism where the adaptation process modifies the contrast-response transducer function (Ross and Speed, 1991).