Shading and texture: separate information channels with a common adaptation mechanism?

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Abstract—We outline a scheme for the way in which early vision may handle information about shading (luminance modulation, LM) and texture (contrast modulation, CM). Previous work on the detection of gratings has found no sub-threshold summation, and no cross-adaptation, between LM and CM patterns. This strongly implied separate channels for the detection of LM and CM structure. However, we now report experiments in which adapting to LM (or CM) gratings creates tilt aftereffects of similar magnitude on both LM and CM test gratings, and reduces the perceived strength (modulation depth) of LM and CM gratings to a similar extent. This transfer of aftereffects between LM and CM might suggest a second stage of processing at which LM and CM information is integrated. The nature of this integration, however, is unclear and several simple predictions are not fulfilled. Firstly, one might expect the integration stage to lose identity information about whether the pattern was LM or CM. We show instead that the identity of barely detectable LM and CM patterns is not lost. Secondly, when LM and CM gratings are combined in-phase or out-of-phase we find no evidence for cancellation, nor for ‘phase-blindness’. These results suggest that information about LM and CM is not pooled or merged — shading is not confused with texture variation. We suggest that LM and CM signals are carried by separate channels, but they share a common adaptation mechanism that accounts for the almost complete transfer of perceptual aftereffects.

Keywords: Vision; shading; texture; detection; adaptation; tilt aftereffect; luminance; contrast; modulation.

INTRODUCTION

Spatial variations of shading and texture are clearly both important cues in the process of forming a perceptual representation of object boundaries, surface shape and 3D form. Our broad aim in this paper is to study some aspects of the linkage between early spatial filtering mechanisms and these later perceptual processes. To do this we have used two kinds of grating pattern (cf. Fig. 2), and have adopted

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the working assumption that luminance-modulated gratings (LM) and contrast-modulated gratings (CM) are useful probes of the mechanisms underlying the analysis of shading and texture respectively.

Previous psychophysical and physiological work has supported the idea that LM and CM gratings are detected by separate processing channels that might imply a parallel analysis of shading and texture cues. Firstly, there was no facilitation or sub-threshold summation between barely detectable LM and CM gratings, but there was summation between gratings of the same type (Schofield and Georgeson, 1999). Secondly, when detection thresholds for luminance gratings and CM gratings were measured after adaptation to such gratings, there was a highly selective loss of sensitivity. Spatial frequency tuned threshold elevation was substantial only after adaptation to gratings of the same type (Nishida et al., 1997). Together these findings suggest that detection is mediated by separate, adaptable LM and CM channels.

Other lines of evidence, however, have suggested that LM and CM information may be later integrated in the visual system. Physiological studies of cat visual cortex have revealed that some cells, especially in area 18, respond well to both types of stimulus, but closer analysis of the response selectivities suggested that these cells might be combining the inputs from separate LM and CM analyzers (Zhou and Baker, 1993, 1996). Studies of motion perception have also suggested separate LM and CM analyzers (Ledgeway and Smith, 1994; Lu and Sperling, 1995) in a 2-stage integrative scheme (Wilson et al., 1992; Nishida and Sato, 1995) rather like that shown in Fig. 1b. In this paper we ask similar questions about LM/CM integration in spatial vision. The logical possibilities include: no separate channels at all (Fig. 1a), entirely separate channels (Fig. 1c), and a hybrid in which separate channels are combined at a later stage (Fig. 1b).

We have addressed these questions through two types of experiment. In part 1 (Experiments 1 and 2), we look at two perceptual aftereffects from adapting to LM and CM gratings to determine whether adaptation to LM (or CM) transfers to a CM (or LM) test, or not. A high degree of transfer would imply some integrative process. In part 2 (Experiments 3 and 4), we compare detection and recognition of LM and CM gratings, without adaptation, but again with the aim of learning about the independence or integration of LM and CM information. Watson and Robson (1981) were the first to suggest that, with certain assumptions, if the ability to recognize (identify) two very weak stimuli (A, B) was as good as performance in detecting them, then this would point to the existence of separate channels for A and for B. This amounts to a ‘labelled-line’ model, in which the response of one channel (with no response from the other) signals both the presence and identity of the stimulus. The expectation of equal detection and recognition performance holds only when stimuli A and B are sufficiently far apart along some dimension (such as spatial frequency, orientation, etc.) to stimulate non-overlapping channels (Graham, 1989). We therefore applied this idea to test for separate LM and CM channels.