The interaction of depth parameters in motion integration with polar plaids

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Abstract—Many parameters have been investigated as to their effect on the way in which the visual system is able to integrate different motion directions at the same visual location. Of special interest have been parameters that determine the depth relationship between surfaces, such as disparity, relative contrast, and occlusion versus transparency. The preferred stimulus for this research has been the 'plaid', usually constructed from two linear gratings. The present study concentrated not on these Cartesian plaids, but on polar plaids, made from a combination of concentric circles and radial gratings. These kinds of plaids also have a special theoretical significance: within the Lie Transformation Group approach to visual pattern processing, Cartesian and polar stimuli represent different invariances in the visual world. This study compared Cartesian, polar and hybrid plaids as to their propensity to be perceived as coherently moving stimuli. Cartesian and polar plaids were similar in terms of the effects of intersection luminance and relative contrast on coherence, polar plaids being consistently less coherent. Hybrid plaids did not usually cohere at all. Adaptation to an unambiguously coherent plaid decreased perceived coherence when tested with a bistable plaid from the same, and not from the other Lie group, i.e. there was within-group adaptation but no between-group adaptation. Polar plaids also offer the possibility of studying the influence of another depth parameter on motion integration: expansion or contraction of circular gratings, which represent motion-in-depth toward or away from the observer. This motion-in-depth was tested for interaction with disparity or relative contrast in the determination of motion integration. The results were negative under the present conditions. Thus not all depth parameters contribute equally to the determination of the stimulus depth relations affecting the motion integration process.

INTRODUCTION

In many real-life situations, a particular location in visual space may contain more than one local motion direction. From this, the need arises to integrate these different directions in a meaningful way. The system has to integrate those motions that may belong to one complex visual object and leave unintegrated those local motions that are more likely to belong to separate objects. This problem is usually referred to as motion integration. Motion integration has been studied most extensively with plaid stimuli (Adelson and Movshon, 1982). These are complex patterns that are created by the superimposition of two sinusoidal or rectangular gratings that have a difference in their motion directions. Many parameters have been isolated that affect the readiness with which the two gratings can be integrated by the visual system. When integration occurs, this is perceived as the coherence of the two gratings which now form a new, more complex pattern, the plaid, which moves in a new direction, a composite of the two component directions. When integration does not occur, the two component gratings are seen to move independently in their respective directions, sliding over each other.
Parameters of motion integration

For most plaid stimuli, it is true that with prolonged inspection they switch between being seen as coherent and as sliding (von Grünau and Dubé, 1993). The switching between these two states was shown to be affected by prior adaptation to unambiguously coherent or non-coherent plaids, such that the adapted percept became less dominant, while the unadapted percept was not affected. The underlying processes thus appeared to be quite independent, yet must mutually inhibit each other to account for the switching. Using the plaid paradigm, the influence of many parameters on the motion-integration process has been investigated, such as velocity, contrast, spatial frequency, and color (Adelson and Movshon, 1982; Movshon et al., 1985; Krauskopf and Farell, 1990; Stoner and Albright, 1992). Generally, it has been found that coherence is more likely when the two gratings correspond in these parameters.

Two gratings that are perceived as sliding over each other also seem to be transparent in the sense that one seems to be lying in front of the other in depth. The depth relation is ambiguous, and the gratings switch position over time. Depth between the gratings is thus a parameter that is intimately tied to the problem of motion integration. Depth between the gratings can be accomplished in different ways. Adelson and Movshon (1984) introduced a disparity between the gratings and observed that coherence was no longer possible. We have studied this problem in more detail (von Grünau et al., 1993). It was found that two gratings could be made to cohere even if they had large disparities, as long as the intersection luminance was increased beyond the normal range of transparency. Adaptation to stationary stimuli with crossed or uncrossed disparity decreased the dominance of the sliding percept, but did not affect coherence. Thus again, pattern and component motion mechanisms operated quite independently, and the stereodepth mechanism affects motion integration.

Depth between the gratings can also be introduced by other parameters, such as relative contrast and transparency. In both cases, the intersection luminance (ISL) is manipulated. In the first case, intersection luminance is adjusted to match the luminance of one of the gratings, so that the other is occluded. Normally, the higher-contrast grating has a greater tendency to be seen to lie in front of the lower-contrast one. In the latter case, the relative luminance values of the background area, the grating lines and especially their intersections determine whether the gratings are seen as transparent and to slide over each other when in motion (Stoner et al., 1990). These two parameters, relative contrast and transparency, interact to influence motion integration (Vallortigara and Bressan, 1991). It was furthermore shown that binocular disparity, relative contrast and the transparency depth cue interact in motion integration, so that multiple constraints relating to surface segmentation and layering order have to be satisfied to achieve integration (Trueswell and Hayhoe, 1993).

More recently, we examined in more detail the interactions between disparity, relative contrast and transparency in motion integration (Kwas et al., in prep.). Using an adaptation paradigm, it was shown that adapting to different levels of the three depth cues increased perceived coherence without tuning, i.e. the adaptation effect was strongest for the greatest depth, as long as there was depth in the test pattern, but was not present when there was no depth in the test pattern. Furthermore, there was a large amount of cross adaptation, i.e. adapting