ON THE RELATIONSHIP BETWEEN PATTERN AND MOVEMENT PERCEPTION IN STRABISMIC AMBLYOPIA

R. F. Hess, E. R. Howell and J. E. Kitchin
Department of Optometry, University of Melbourne. Parkville, Victoria, Australia

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Abstract—The temporal properties of pattern and movement thresholds were measured for two strabismic amblyopes with identical high spatial frequency form abnormalities and different low spatial frequency form responses. The results indicate that for the amblyope with the low frequency pattern threshold abnormality there is no movement threshold abnormality. These findings support the proposition that there is a separate movement and pattern perceptual system in the human visual system and that the amblyopic abnormality does not involve neural elements concerned with movement processing.

Keywords—strabismic amblyopia; movement perception; spatial frequency; contrast sensitivity.

INTRODUCTION

Since Enroth-Cugell and Robson (1966) first reported that ganglion cell receptive fields of the cat could be classified into two distinct types, X and Y, a mass of subsequent supportive neurophysiological (Cleland, Dubin and Levick, 1971; Fukuda, 1971; Hoffmann, Stone and Sherman, 1972; Fukuda and Stone, 1974) and histological (Hoffmann et al., 1974; Fukuda and Stone, 1974) data has accumulated. This information supports the proposition that in the cat and monkey (Dreher, Fukuda and Rodieck, 1976) there are at least two well developed and functionally separate sub-systems with radically different properties (Ikeda and Wright, 1972) and projections (Stone and Hoffmann, 1971; Cleland et al., 1971; Hoffmann and Stone 1971; Dreher et al., 1976; Hoffmann, 1972; Hoffmann and Sherman, 1974; Fukuda and Stone, 1974).

Recent psychophysical evidence (Keesey, 1971; Tolhurst, 1973; Kulikowski and Tolhurst, 1973) also suggests that there are two independent perceptual subsystems, a pattern (or form detecting system), and a movement (or flicker) detecting system. The neurophysiologically determined X and Y systems exhibit spatial and temporal properties which suggest that their psychophysical counterparts could be the pattern and movement detecting systems respectively. The X detectors exhibit sustained properties, linear centre summation, high acuity, predominately foveal distribution and cortical projection. All of these properties are consistent with contrast sensitive pattern detectors. The Y detectors exhibit transient properties, non-linear centre summation, preference for large target size, predominately paramacular distribution and project directly and indirectly to the superior colliculus and directly to the cortex; these properties are consistent with movement detectors.

The fact that these two sub-systems have been shown to maintain independence in their pathways and projections (Hoffman and Stone, 1971; Hoffmann 1972; Hoffmann and Sherman, 1974; Dreher et al., 1976) and yet share common ground in the retina (photoreceptors and possibly pre-ganglionic elements) offers a unique opportunity for differentiating between pre-ganglionic, ganglionic and post-ganglionic theories as to the site of the strabismic amblyopia abnormality. If there is a movement as well as a pattern abnormality in strabismic amblyopia, then this raises the possibility that there maybe a photoreceptor abnormality.

This hypothesis can only be validly tested for spatial stimuli for which there is strong evidence of two separate and independent systems, that is, for low spatial frequency gratings. It is only for low spatial frequencies that movement sensation can be experienced without any form information (Kulikowski and Tolhurst, 1973). For this reason, one normal and two strabismic amblyopes were chosen, for one amblyope (K.S.) there was no low spatial frequency pattern abnormality whereas for the other amblyope (J.L.), there was a low spatial frequency pattern abnormality (Hess and Howell, 1977). Since both amblyopes had approximately the same magnitude of high spatial frequency pattern abnormality, the first amblyope (K.S.) acted as a control for the second (J.L.). The contrast sensitivity abnormalities for these subjects have previously been shown to be of a primary neural origin uncontaminated by any oculomotor (Hess, 1977a), optical (Hess and Smith, 1977), field size (Hess and Howell, 1978) or eccentric fixation artifact (Hess, 1977b).

METHODS

Vertical sinewave gratings were generated on a video display using the technique and equipment previously outlined (Hess, 1977b). Gratings were drifted across the screen at constant angular velocity by summing a low frequency triangular wave with the display time base ramp and then feeding the sum via a Schmitt trigger into the gate input of the main gated sinewave function generator. The sine-wave grating of frequency 0.2 c/deg. (field size 40° x 30°) drifted across the screen equally in both directions to ensure no direction-specific adaptation.

The method of adjustment (staircase technique) was used throughout (N = 5) and the subject viewed the video dis-
play from 57 cm. The screen's mean luminance was 100 cd/m². Natural pupils and accommodation was used. The subjects were informed not to make pursuit eye-movements to follow the moving grating but to restrict eye-movements to the central 1 cm of the display. Two separate experimental runs were used: in the first, the subject was asked to set contrast thresholds for which the form of the grating could be detected; in the second run, the subject was asked to set contrast thresholds for which movement could be detected and to indicate if the form was also visible at this setting. The normal and amblyopic eye were alternately compared at each drift rate within each of these two separate runs.

RESULTS

The results for the normal and two amblyopic subjects are displayed in Figs. 1–3. In Fig. 1 for the normal subject, threshold contrast sensitivity (log scale) is plotted against drift rate (log scale). The form thresholds are seen to exhibit a peak response at about one period per sec. The decline of contrast sensitivity at high temporal frequencies is much more pronounced than the decline on the low frequency side of the peak. The movement thresholds are seen to exhibit a peak response at about 8 periods/sec. These results at 0.2 c/deg for the normal observer are in general agreement with those of Kulikowski and Tolhurst (1973) at 0.8 c/deg, although these workers found no low frequency decline in sensitivity for form detection. The S.E. of the mean for pattern thresholds was equal for normal and amblyopic eyes and equivalent to the symbol size. All subjects reported that the movement threshold was extraordinarily exact and were unable to define its upper and lower limits (<0.1 log unit). At the threshold of movement form was not discernible. These results represent evidence in the normal that two separate perceptual systems can be distinguished at least at low spatial frequencies. The general shape of the temporal curves for form and movement detection were identical for normal and amblyopic eyes. For this reason, the shape of the function which describes the normal response has been fitted to the amblyopic results.

Figure 2 is a replication of this experiment for amblyope K.S. who has only a high-medium spatial frequency abnormality. The results which are fitted by the normal curves of Fig. 1 clearly show that for this amblyope two distinct thresholds were reported and the temporal characteristics of these two thresholds are the same as for the normal observer and equal for normal and amblyopic eyes.

Figure 3 represents results from the same experiment for amblyope J.L. who has a low as well as a high frequency abnormality. The results show that the low frequency (0.2 c/deg.) form abnormality (which is approximately a factor of two in contrast threshold) is maintained throughout the form temporal response curve yet, at the drift rate for which the first separate movement threshold is established.
the degree of amblyopia disappears. This movement normality is maintained throughout the movement temporal response function.

**DISCUSSION**

The results for all subjects support the general conclusion of Kulikowski and Tolhurst (1973), that at least for low spatial frequencies (0.8 c/deg and 0.2 c/deg) there are two quite separate thresholds, a movement threshold and a form threshold, each having separate temporal properties. The results also indicate that for an amblyope with no pattern abnormality at this low spatial frequency, there is no movement abnormality. For another amblyope with the same degree of high frequency abnormality but with a significant low frequency pattern abnormality, there was also no movement abnormality. For an amblyope to have a form abnormality without movement abnormality for the same low frequency grating (0.2 c/deg) argues for normal pre-ganglionic retinal function and may indicate that the form abnormality is located in the cortex (or parvocellular layers of LGN) where X (sustained) detectors are known to project, and that there is no neural abnormality for the Y (transient) system. This result infers that at least for some strabismic amblyopes there is a neural abnormality for the photoreceptors, magnocellular layer of the LGN or Y target cells in the superior colliculus or cortex concerned with movement processing.

Such a complete dissociation of form from movement sensitivity is not unknown, as cases of more profound dissociation have been reported by Schneider (1969). Schneider has shown that superior collicular lesions impair "orientation" to visual stimulus but not "recognition" whereas visual cortex lesions impair "recognition" but not "orientation". The present results are important from two separate points of view. Firstly, they add further evidence that there are two perceptual sub-systems which are quite separate to the extent that (for at least some amblyopes) for detectors can be abnormal in the same retinal region for which movement detectors exhibit normal responses. Secondly, since neurophysiological and histological animal studies indicate that these two systems share common ground only in the retina, the present results represent indirect evidence for ganglionic or post-ganglionic (most probably supraganglionic) site of strabismic amblyopia involving only the pattern (or X cell) system in some cases.

**REFERENCES**


