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Cyclofusion and stereopsis

ANDREW E. KERTESZ
Northwestern University, Evanston, Illinois

In a recent issue of this journal, O'Shea and Crassini (1982) reported responses to the stimuli shown in Figure 1, and, based on those responses, they concluded that binocular fusion is neural in nature (p. 196). Although O'Shea and Crassini did present an interesting experiment, I have the following objections to their paper: (1) a subjective technique is used to distinguish between motor and nonmotor fusional compensation, while relevant objective data are ignored; (2) the interpretation of the data is equivocal; and (3) the results may reveal very little about the nature of cyclofusional response.

Terminology

Human fusional response has two components: a motor component in the form of compensatory vergence eye movements and a nonmotor (sensory, central, or neural) component whose magnitude is limited to the extent of Panum's fusional areas. Thus, the term vergence is used to describe the motor response, whereas the term fusion describes the subject's percept and response, which depend on both motor (vergence) and nonmotor components.

O'Shea and Crassini (1982) make reference to my papers (Kertesz, 1971, 1972, 1973a, 1973b) and claim that these papers "assert that binocular fusion is neural in nature." All of those papers addressed the nature of cyclofusional response and did not attempt to characterize the fusional response in general.

Cyclofusion (Without Depth Cues)

Objective measurements, utilizing binocular eye movement measuring devices, of cyclofusional response to stimuli devoid of depth cues have demonstrated that, in general, the response, depending on various stimulus parameters, contains both motor (cyclovergent or torsional) and nonmotor components (Crone & Everhard-Halm, 1975; Kertesz & Sullivan, 1978). Stimulus parameters exert a strong influence on the composition of the response. Nevertheless, objective data that demonstrate the existence of both components of cyclofusional response are now available. Therefore, the debate, to which O'Shea and Crassini (1982) refer, that Nagel (1868) initiated about the existence of cyclovergent eye movements should be considered settled in the light of objective data. This debate lasted so long because the difficulty of measuring torsional eye movements prompted past investigators to utilize subjective techniques to distinguish between the motor and nonmotor components. We no longer have to do that!

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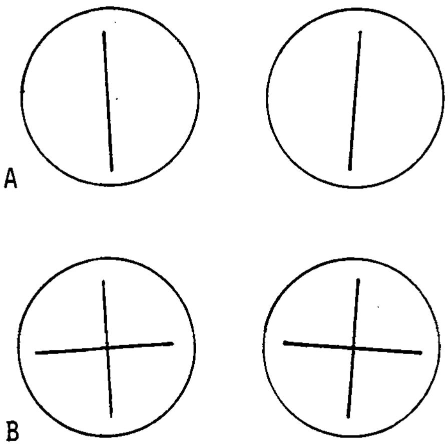

Figure 1. Dichoptic stimulus presentation of a stereogram (reproduced from O'Shea & Crassini, 1982). (A) Each monocular stimulus image contains a single initially vertical line that is rotated about its center by 4 deg in opposite directions as seen by each eye. (B) The vertical line is replaced by a cross.

Cyclofusion and Stereopsis

Interactions between the fusional and stereoptic responses may be investigated by the use of cyclofusional stimuli that contain depth cues. If a subject fixates the center of the stimulus of Figure 1A, the visual system may interpret the retinal image disparities as an indication of misalignment between the two monocular visual fields, a misalignment requiring fusional correction, or, in the case of relative horizontal disparities, as a depth cue. The combined effect of these two strategies is to provide us with a single three-dimensional percept of the space around us.

One of the important differences between the fusional and stereoptic responses is that fusion has both motor and nonmotor components but stereopsis (which responds to *relative* disparities) has a nonmotor component only.

Ellerbrock (1954) and Ogle and Ellerbrock (1946) performed experiments in which subjects fixated the center of an initially vertical line that was subsequently rotated in opposite directions as seen by each eye (Figure 1A). They suggested that if the disparity introduced by the stimulus is not too large, the response can take one of three forms:

(1) If the eyes undergo a cyclofusional movement equal to the magnitude of the orientation disparity, then a single vertical line is seen.

(2) Without any cyclofusional eye movements, the continuum of crossed and uncrossed horizontal disparities contained in the stimulus causes the line to appear tilted in space, with its top appearing farther away from the observer than its bottom.

(3) If the cyclofusional eye movements are not large enough to eliminate the entire orientation disparity between the retinal images of the stimulus but succeed only in bringing those images nearer to their corresponding meridians, then the remaining continuum of crossed and uncrossed horizontal disparities between the retinal images is used as a depth cue and is translated into a fore-and-aft tilting of the stimulus line. The amount of tilt perceived with only partial cyclofusional motor compensation is smaller than the amount of tilt perceived in Case 2, in which there is no cyclofusional compensation.

The implications in Case 3 are that the cyclofusional response results in a reduction of the orientation disparity between the retinal images of the stimulus and that only the relative horizontal disparities contained in this reduced orientation disparity serve as depth cues.

O'Shea and Crassini (1982) offer a different explanation. They hypothesize that in the event of complete cyclofusional motor compensation (Case 1), which would cause the stimuli to fall on corresponding retinal areas, the fused cross of Figure 1B would *still appear tilted* and "the impression of depth must then arise from some other mechanism (e.g., afference from the extraocular muscles mediating the cyclovergence)" (p. 195). O'Shea and Crassini do not elaborate on the implications of their hypothesis and do not point out that the hypothesis is in conflict with Ogle and Ellerbrock's (1946) work.

Ogle and Ellerbrock (1946) found only partial cyclofusional compensation, but they did not measure cyclofusional eye movements and thus were unable to distinguish between the motor and nonmotor components of the response. Instead, the amplitude of the response was inferred from the difference between the physical disparity contained in the stimulus and the portion of the physical disparity that was used as a depth cue.

Hampton and Kertesz (1980, 1982) used an objective binocular technique to monitor eye positions during the response. They found that the response contained three components: a cyclofusional motor component, a nonmotor cyclofusional component, and a stereoptic compensation in which the continuum of horizontal disparities contained within a portion of the orientation disparity was used as a depth cue. Therefore, both the stereoptic and cyclofusional mechanisms contributed to the response. Rather than consisting of torsional eye movements alone, as was suggested by Ellerbrock (1954) and Ogle and Ellerbrock (1946), the cyclofusional response is composed of small compensatory eye movements and of a substantial nonmotor contribution.

Interpretation of Results

O'Shea and Crassini's (1982) interpretation of their results is equivocal. I offer a quite different interpretation. The 8-deg orientational disparity contained in the simple stimulus of Figure 1B is beyond the range of cyclofusional compensation, but the horizontal disparities in the stimulus are within the range of stereopsis. Therefore, the vertical line is seen as being inclined and the horizontal line is seen as being diplopic. Thus, the results may reveal very little about the nature of cyclofusional response. If O'Shea and Crassini wish to convince themselves of this, they should apply a much smaller orientational disparity to their stimulus, monitor eye positions, and measure the perceived stimulus inclination and its relationship to the orientational disparity contained in it. They will find, as Hampton and Kertesz (1980, 1982) did, that cyclofusional stimuli containing depth cues that are within the range of cyclofusional amplitudes are responded to by a combination of cyclofusional and stereoptic components. If, however, one exceeds the range of cyclofusional compensation, then the visual system is left to cope with the disparity the best way it can. The differences between fusional and stereoptic responses that are germane to the topic are too numerous to outline here.

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