Stereopsis in dynamic visual noise

A NOISE signal has the useful property that convolution of the output spectrum with the reciprocal of the input spectrum gives a measure of the characteristics of the transmitting system. In visual perception it is not possible to obtain the output spectrum directly, but an observer can report on features of the 'perceptual output' of the visual system[1]. One striking characteristic which may be observed is the generation of stereoscopic depth merely by an interocular delay in transmitting binocular dynamic visual noise.

Ross[2] has recently described the effects of an interocular delay in perception of random dynamic noise (an electronic snowstorm) generated by a sophisticated computer technique. He interpreted his results as showing that a temporal rather than disparity between the two eyes may act as a signal for stereoscopic depth. The concept of stereopsis from temporal disparity is a radical one and needs to be critically examined before being fully accepted. I shall describe some observations and a theoretical viewpoint which seems to provide an explanation for dynamic noise stereopsis within the framework of stereopsis from spatial disparity.

The display used for the observations consisted of random visual noise generated by a detuned television receiver. An interocular delay of up to 100 ms may be produced by the classic technique of a neutral density filter in front of one eye[3]. Observation of the dynamic noise with a one log unit filter (creating a delay of about 30 ms at 10 trolands when fully adapted[3]) gave rise to a number of perceptual experiences which have been spontaneously confirmed by six observers. The noise exhibits a considerable depth, perhaps 10% of the viewing distance, and also a streaming motion which is leftwards in front of the point of fixation and rightwards behind fixation with the filter over the left eye. Direction of movement reverses with the filter over the right eye. The motion had the characteristics of motion in a landscape viewed from a moving train, such that points near fixation rotated slowly whereas points well in front of or behind fixation moved more quickly. Movement is leftwards in front of fixation with the filter over the left eye. Direction of movement reverses if the filter is switched to the right eye.

The range of interocular delays for depth probably depends on the density and spatial distribution of the dynamic noise. In my display depth could be perceived with as little as 5 ms delay and as much as 70 ms, the maximum obtainable. One interesting observation was that depth and in particular movement were enhanced by tracking the movement of one depth plane across the screen. Tracking also seems to enhance the unity and salience of the plane which is being tracked. In contrast tracking the conventional Pulfrich pendulum against a plain background has the effect of abolishing depth.

As a control for any peculiarities of the television noise which may have influenced the results, observers tilted their heads from vertical to horizontal. The scan rate in the transverse plane through the two eyes changes from 64 μs to 40 ms between vertical and horizontal. The plane of movement rotates to remain parallel to the two eyes,

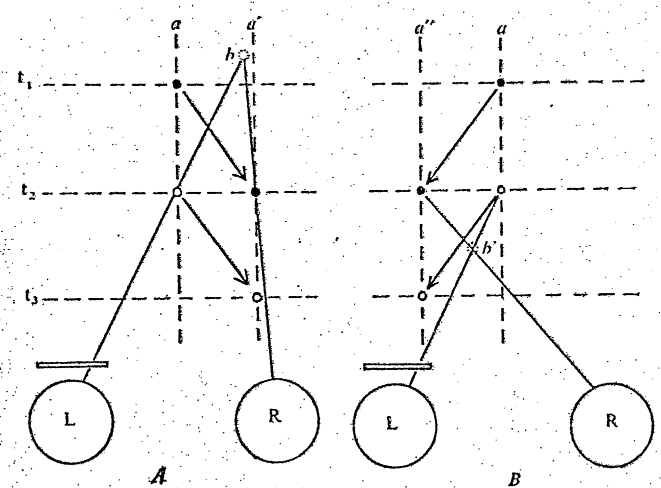

Fig. 1 *A*, Sequence of possible events at three points in time. Left and right eyes are depicted as viewing events only at t_2. A spot at point *a* is transmitted by the right eye (●) at time t_1. As a result of the interocular delay the same spot is transmitted to the left eye at time t_2 (○). If a second spot happens to appear at *a'* to the right of *a* such as to be transmitted at time t_2, a spatial disparity is produced and a spot will be perceived in a different depth plane at *b*. The monocular sequences of a spot at $a(t_1)$ followed by a spot at $a(t_2)$, and a spot at $a'(t_2)$ followed by one at $a'(t_3)$ are both preconditions for monocular apparent movement to the right, which may therefore be associated with the spot at depth *b*. *B*, reversal of both depth and movement when the second spot appears to the left of *a* at *a''* rather than the right. In a random display both sequences *A* and *B* will occur, producing both rightward movement behind the point of fixation and leftward movement in front. The distances from *a* to *a'* and *a* to *a''* will vary with a Poisson distribution depending on the density of the visual noise.

and otherwise no change in the percepts described was reported.

These observations confirm that stereopsis may be obtained by interocular delay in viewing random noise. In this situation there is no correlation between the signals from the two eyes at any instant in time. It is therefore difficult to understand what can give rise to a perception of a range of disparities in the stimulus. The model I propose is based on the assumption that the two percepts of depth and movement arise from the same operation on the dynamic noise stimulus. Thus Ross's hypothesis of depth produced by temporal disparity also implies that movement can be produced by temporal differences alone, whereas logically movement involves both temporal and spatial displacement. To resolve this difficulty, I considered the microstructure of the dynamic noise, rather than regarding it as random and therefore unpatterned. Figure 1 shows how depth and movement both arise from chance associations of points at different times in the random display. The single postulate of an association between depth and movement arising from the same pair of points is all that is required to produce the percept of a rightward-moving spot behind the plane of fixation. Such an association between the monocular movement and binocular depth is not unlikely since stationary monocular stimuli tend to be drawn to a stereoscopically defined depth[4].

It is difficult to reconcile Ross's description of a single depth plane with the dense range of depths reported by my observers.

Preliminary observations of my dynamic noise stimulus with a dark central square confirm that depth is now perceived predominantly to the rear of the plane of the card. This may be due both to gestalt figural organisation favouring an underlying as against overlying interrupted surface, and to the difficulty of making tracking eye movements with the square present.

My observations support the hypothesis that an interocular delay produces a random distribution of spatial disparities in a dynamic noise stimulus. Each disparity is associated with a certain rate of apparent movement, giving rise to the perception of moving depth planes. The observations may thus be accommodated within the conventional framework of stereoscopic theory.

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