Thresholds for dynamic visual movement

WILLIAM W. AGRESTI
University of Michigan-Dearborn, Dearborn, Michigan 48128

and

MARK S. MAYZNER
Loyola University, Chicago, Illinois 60626

The present study, employing a computer-based cathode-ray tube (CRT) display system, seeks to extend earlier findings on "dynamic visual movement." A methodology is developed that attempts to assess thresholds for various phases of "subjective visual experience," and quantitative estimates of such thresholds are examined.

Dynamic visual movement refers to a particular apparent movement phenomenon that was first reported in 1970 (Mayzner & Tresselt, 1970). The effect is produced by using a computer-driven cathode-ray tube (CRT) display system to generate characters on the screen in a complex spatiotemporal arrangement. The original study used 20 letter Os positioned next to each other to form a line at the center of the display surface. The timing and sequencing of the individual letter presentations was such that it produced an unexpected visual experience. Subjects reported seeing four letter Os in smooth motion across the screen.

The present experiment was designed to explore that "display timing" that appears critical to the production of dynamic visual movement. The objective was to assess three thresholds in the subjective experience of individuals who are presented with complex visual stimuli, in which the display consists of 36 letter Xs that, with the proper timing, can produce dynamic visual movement. However, the timing is varied by the experimenter so that four subjective visual experiences can be distinguished: (1) *Pure sequentiality.* The presentation time is so long (500 msec) that each letter X appears in sequence. (2) *Transient phase.* Here the individual presentation times of the letters are less than those above, so that more than one X appears to be present on the screen at any one instant but dynamic visual movement does not occur. (3) *Dynamic visual movement.* A number of Xs appear to be in motion across the screen, the number depending on the ordering used. (4) *Simultaneity.* All 36 Xs appear to be present on the screen simultaneously.

It is important to note that these four distinct subjective visual experiences arise from the same display: Only the presentation times of the individual letters change. Only one letter X is being displayed at any

given time. However, because of the very short presentation times (as low as 1 msec) attainable with the computer-driven display, the subjective experience is not always that of sequential presentation of the letters.

The first phase above is labeled pure sequentiality to indicate that the subjective experience is in complete agreement with the actual sequential method of generating presentations. The individual presentation times at this phase are long enough so that the letters, which are generated one at a time, also appear to have been generated that way. In the other phases, such is not the case. As the presentation times grow successively shorter, Phases 2, 3, and 4 are reached in turn.

The experiment seeks to identify those critical presentation times when the subjective visual experience changes from one phase to another. The thresholds are labeled A, B, and C for identification purposes as follows: (1) Pure sequentiality, A, (2) transient phase, B, (3) dynamic visual movement, C, (4) simultaneity. Thresholds B and C are of special interest, providing upper and lower bounds on the dynamic visual movement phenomenon.

Underlying this study is the continuing interest in the operation of the human visual system. It is intended that, by subjecting that system to such complex stimuli, more evidence will be obtained on the sophisticated processing of the information into various perceptual organizations.

METHOD

The five subjects who volunteered for the experiment were all graduate students. A VR-14 CRT display driven by a PDP-8/e computer presented the stimuli. The surface of the display was coated with an ultrashort persistence phosphor. The laboratory equipment and environment are described elsewhere (Mayzner, 1968, 1975).

The stimuli consisted of 36 letter Xs arrayed next to each other, forming a straight line across the middle of the display surface. Display luminance was measured at 1 mL and the subject was seated 2 ft in front of the display screen. The 36 Xs

Table 1
Display Orderings

Ordering	Order of Presentation
3	1,4,7,10,...,31,34,2,4,8,11,...,32,35,3,6,9,12,...,33,36
6	1,7,13,...,31,2,8,14,...,32,3,9,15,...,33,4,10,16,...,34,5,11,17,...,35,6,12,18,...,36
12	1,13,25,2,14,26,3,15,27,4,16,28,5,17,29,6,18,30,7,19,31,8,20,32,9,21,33,10,22,34,11,23,35,12,24,36
18	1,19,2,20,3,21,4,22,5,23,6,24,7,25,8,26,9,27,10,28,11,29,12,30,13,31,14,32,15,33,16,34,17,35,18,36

Note—Ordering refers to the number of moving Xs.

were presented one at a time under four different orderings given in Table 1. These particular orderings were chosen because they promote dynamic visual movement with 3, 6, 12, and 18 moving Xs, respectively. The individual presentation time (or on-time) of each letter was varied by the experimenter. The time between successive letter presentations (the off-time) was zero. Thus, the total display time for each trial was the individual letter on-time multiplied by 36.

Before each session, the experimenter explained to each subject the four visual experiences of interest: (1) pure sequentiality, one X at a time on the screen; (2) transient phase, more than one X at a time but no smooth motion; (3) dynamic visual movement, 3, 6, 12, or 18 Xs in smooth motion across the screen; and (4) simultaneity, all 36 Xs appearing at one time.

The on-times were changed and the subject was asked to indicate when his subjective experience was altered. The experimenter recorded the on-time for the first occurrence of each phase. On-times were changed in two different ways: (1) "down" direction, beginning with an obviously pure sequential display in which each letter's on-time is 500 msec, reduce the on-times successively until 1 msec; and (2) "up" direction, beginning with 1 msec/letter, increase the on-times until the subject indicates pure sequentiality has been reached.

RESULTS

Table 2 gives the mean value of the individual letter on-times at which each threshold was reached. The results are given for the different orderings and two directions.

Threshold B is of special importance because it gives the upper temporal bound for dynamic visual

Table 2
Mean Values Over All Subjects for On-Time (in Milliseconds)
of Each X at Three Thresholds

Ordering	Threshold	Direction		
		Down	Up	Average*
3	A	160.67	169.33	165.00
	B	88.33	104.67	96.50
	C	2.93	5.67	4.30
6	A	128.67	134.00	131.34
	B	36.00	51.83	43.92
	C	1.93	3.60	2.77
12	A	133.33	132.67	133.00
	B	16.67	24.17	20.42
	C	1.33	4.57	2.95
18	A	126.66	111.33	119.00
	B	11.50	17.33	14.42
	C	1.33	4.63	2.98

Average over both directions.

movement. The values for B in the "up" direction are consistently higher than those for "down." For example, with six moving Xs, Threshold B appears as 51.83 msec and 36.00 msec for up and down, respectively. This result agrees with our expectation that the threshold should be viewed as an interval of time over which a change in perceptual organization occurs. Further, higher values for the up direction agree with the "intuition" that, as the times are increased (up direction), the subject experiences the smooth motion of dynamic visual movement. That perception is repeatedly reinforced so the subject will abandon it only at the last possible time.

With decreasing on-times, however, the subject passes through the transient phase. A shorter on-time will be required before the subject is willing to announce that the smooth dynamic visual movement has been attained for the first time.

As the number of Xs in motion increases, the time for Threshold B decreases. While the value is 96.50 msec for 3 moving Xs, it decreases to 14.42 msec for 18 moving Xs. We can consider an on-time in this range, say 80 msec, and suggest what may be an explanation for this decrease. At 80 msec dynamic visual movement obtained for three Xs. Each X traverses a relatively long path very slowly. With 18 Xs, however, no such smooth motion is reported at 80 msec. The path (from Table 1) is only two Xs in length. New Xs are being posted on the screen with little opportunity to reinforce the motion of earlier Xs. With 18 Xs, smooth motion characteristic of dynamic visual movement is detectable only in a narrow range of presentation times.

DISCUSSION

In the first account of dynamic visual movement (Mayzner & Tresselt, 1970), the interval of time between the presentation of adjacent Xs within a group was 35 msec. A recent study (Agresti & Mayzner, 1978) suggests that this interval may be as high as 315 msec and still promote the movement effect. To establish this time interval for the present experiment, recall the order of presentation from Table 1. With six moving Xs, for example, one temporal grouping is 1, 7, 13, 19, 25, 31, meaning that the leftmost X was displayed first; then (after five other Xs) the X in the second position was displayed. The interval between displaying the adjacent letters was five times the individual letter on-time. Both earlier studies cited above suggest that this interval is critical to the perception of dynamic visual movement.

Table 3 lists this time interval for the present experiment.

Table 3
Time Interval (in Milliseconds) Between Presentation of
Adjacent Xs Within a Group at Threshold B

Ordering	Intervening Stimuli*	Threshold B**	Time Interval
3	2	96.50	193.00
6	5	43.92	219.60
12	11	20.42	224.62
18	17	14.42	245.14

*Number of stimuli temporally intervening.
**Threshold B average letter on-time in milliseconds.

The values, varying from 193 to 245 msec, are well within the range mentioned above. Perhaps the most appropriate way to express the upper limit of dynamic visual movement is to use this time interval and not the on-time alone.

A more general outcome of the experiment should not be slighted. The same display, differing only in individual presentation times of the stimuli, elicit reports of four different perceptual organizations by the subject. Furthermore, the changes in state occur at times that exhibit a pattern that suggests that there are highly regular and systematic processing mechanisms at work.

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