Lateral visual masking: Supraretinal effects when viewing linear arrays with unlimited viewing time*†

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Linear letter arrays of varying lengths were presented monocularly, binocularly, and dichoptically in order to provide locus information concerning previous findings that recognition of letters in such an array follows a U-shaped function over positions. With unlimited viewing time and constant fixation, U-shaped serial position curves were generated under all conditions of viewing. It was concluded that some supraretinal lateral masking effect is involved.

The perception of closely placed visual materials has received considerable attention and has been found to be influenced by a variety of conditions of viewing. Of particular interest to us is the fact that the recognition of symbols in an array is often described as a U-shaped function of distance from a fixation point. In view of increased interest in immediate memory processes, most recent multisymbol recognition work has utilized tachistoscopic (brief display) conditions of viewing (e.g., Estes & Wolford, 1971; Shaw, 1969). In an earlier study in this series (Townsend, Taylor, & Brown, 1971), we were interested in showing that the U-shaped function was not dependent upon time-constrained encoding or processing mechanisms. Accordingly, Ss viewed linear arrays of letters with unlimited viewing time. Recognition of letters was found to be a U-shaped function of distance from a fixation point. Since the data could not be accounted for in terms of retinal locus effects or memory variables, we concluded that some form of lateral masking effect, the disruption of encoding processes due to adjacent contours, was involved. Since these effects could arise from either retinal or central processes, the studies reported herein were designed to provide locus information concerning this phenomenon.

METHOD

Observers

In order to control for eye dominance, two left-eye dominant and two right-eye dominant Os were used. Eye dominance was determined by the simple expedient of the displacement of a near object when focusing on a distant object with either the left or right eye. All were familiar with this research project.

Apparatus and Procedure

Each stimulus was a linear array of one, five, six, seven, or nine letters constructed by a CDC 6500 computer random-number generator under the constraint of sampling without replacement. The letters used were consonants, including the letter Y.

Each stimulus was presented on a Tektronix Type 602 display unit by a LINC-8 (Digital Equipment Corp.) computer under one of three experimental conditions: binocular, monocular, or dichoptic. Since difference display equipment was used by Townsend, Taylor, and Brown (1971) in their lateral masking study, a replication was performed in the binocular condition where each eye simultaneously received identical letter arrays.

In addition, monocular and dichoptic conditions were used in this study. In the monocular condition, a nine-letter array was presented either to O's left or to his right eye. In the dichoptic condition, some part of the nine-letter array was presented to the one eye and the remainder to the other eye. If the lateral masking effect is not retinal in locus, then the characteristic U-shaped recognition function obtained by Townsend, Taylor, and Brown (1971) should occur under all three conditions used here. If the effect is retinal in nature, then lateral masking should occur only in the monocular and binocular conditions and it should not occur in the dichoptic condition, where the entire nine-letter array was never presented to one eye and was "seen" in its entirety, therefore only at higher processing levels.

For all the stimulus conditions set forth above, a solid partition, separating the display into left- and right-eye fields, extended from the display to the O's head restraint. A clear Plexiglas screen, edge-lit with a 28-V red lamp, was placed in front of the display unit to provide two fixation points which were positioned so that only one was seen by each eye. The points appeared as 3-mm-diam red dots which were illuminated during the entire test session. The letter arrays were always presented to the right of the fixation point. The visual angle of the fixation point and nine-letter array was 3 deg 10 min, each letter being about 20 min in extent. An array luminance of 0.16 fL, measured by a Gamma Scientific Telephotometer, Model 2020, was selected as that which all Os agreed produced characters which were clearly identifiable.

The stimuli in the binocular condition were identical random nine-letter arrays presented to the same retinal location in both eyes. In addition to the nine-letter arrays, two other types of arrays served as binocular control conditions. These were: (1) retinal location control—an array where only one of Positions 5-9 in the array contained a letter, and (2) length of array control—linear arrays containing only five, six, or seven letters. The former control served as an indicator of visual acuity for a given retinal location. The latter control was included to control for the fact that in the dichoptic condition, arrays of five, six, or seven letters were presented to only one eye.

The stimuli in the monocular condition were nine-letter arrays constructed as above. They were presented to O's right or left eye in a counterbalanced order. The nonstimulated eye saw only the fixation point.

Table 1 contains 10 types of dichoptic arrays which were used and which satisfy the conditions that the two eyes "see" different arrays of different lengths or different parts of the array but the entire array is "seen" at higher levels of processing. There were two classes of arrays in the dichoptic condition: continuous (DC), and discontinuous (DD). In either eye, the former has continuous, or adjacent, elements. The latter, on the other hand, has blank space(s) between letters for a given eye. It was hypothesized that due to the spreadout elements, DD arrays should produce less lateral masking than DC arrays if the effects were retinal in locus.

All Os participated in the same sequence of experimental conditions: binocular, monocular, and dichoptic.

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Table 1
Types of Dichoptic Arrays

Type	Class	Position at Which Letter Was Present								
		1	2	3	4	5	6	7	8	9
1	DC	L	L	L	L	R	R	R	R	R
2		L	L	L	R	R	R	R	R	R
3		L	L	R	R	R	R	R	R	R
4		R	R	R	R	L	L	L	L	L
5		R	R	R	L	L	L	L	L	L
6		R	R	L	L	L	L	L	L	L
7	DD	L	R	L	R	L	R	L	R	L
8		R	R	L	R	R	R	L	R	R
9		R	L	R	L	R	L	R	L	R
10		L	L	R	L	L	L	R	L	L

L = left eye, R = right eye, DC = continuous or adjacent elements in a given eye, DD = discontinuous or nonadjacent elements in a given eye.

A session lasted approximately 1 h, but could be terminated early if O reported severe eye strain.

Days 1-5 of the binocular condition (Days 1-8) served as practice sessions in which O viewed one-, five-, and nine-letter arrays, with one- and five-letter arrays occurring approximately every 5th and 10th trial, respectively. Days 6-8 were the test days of this condition. Each O viewed one-, nine-, and one of five-, six-, or seven-letter arrays, again in semirandom order. A session contained 80 array presentations.

The sessions of the monocular condition, containing 60 trials each, took placed on Days 9-12. All sessions were used as test data. Only nine-letter arrays were presented to O's right or left eye. Presentation order was counterbalanced over Os, eye dominance, and sessions.

In the dichoptic condition (Days 13-20), O viewed 60 nine-letter arrays per session, during which the 10 types of arrays were randomly presented. Days 13-17 served as practice sessions.

After 5 min of dark adaptation, each O was individually tested in a light- and sound-shielded room. E communicated with O by means of an intercom. O was instructed to be seated at the viewing apparatus, keep his head against the restraint, and always look at the fixation point during each trial. With practice, maintaining fixation became a relatively easy task. If O could not maintain fixation during the trial, the data for that trial were not used.

O signaled the beginning of a trial by saying "ready" when the red dot was fixated. E was thus assured that on each trial the stimuli would always fall to the right of the fixation point and on the same retinal location. O's task was to report verbally the letter(s) in the array as they were identified (e.g., not to hold them in memory) without moving his eyes from the fixation point. O was encouraged to use a left-to-right report order. He knew there were duplicate letters in the array (but could report the same letter more than once) and was free to change his report during the trial. It should be emphasized that O was under no time constraint in viewing the array; a trial usually lasted less than 30 sec. O replied "finished" or "that's all" to complete his report.

RESULTS

For each letter position in the array, the percent correct recognition (CRP) was computed.

In the binocular condition, mean CRP scores, based on four Os and Days 6-8, for one-, five-, six-, seven-, and nine-letter arrays are summarized in Fig. 1a. Comparison between the positions of the nine-letter array and position occupied by single-letter retinal location controls illustrates that decreased recognition at peripheral locations in the nine-letter array is not a function of visual acuity alone, as is noted by the latter having greater CRP scores than the former. These data are highly similar to our previous data (Townsend, Taylor, & Brown, 1971). Figure 1a also illustrates that as the length of the linear array increases from five to nine letters, CRP scores decrease. This fact implies that increased array length leads to greater amounts of lateral masking.

Figure 1b illustrates the mean CRP scores obtained in the monocular (over four Os and Days 9-12) condition. Mean CRP scores, when plotted against letter position, again yield a U-shaped function similar to that obtained in the binocular condition. No difference was apparent, upon inspection, of O's dominant and nondominant eye with respect to mean CRP scores in the monocular condition.

The data from the two classes of array in the dichoptic conditions are also summarized in Fig. 1b. The data can again be described by a U-shaped recognition function similar to that obtained both in the binocular and monocular conditions.

DISCUSSION

The U-shaped function describing CRP scores for linear arrays was obtained, regardless of the method of presentation. Woodrow's (1938) discussion of relative position in an array, Woodworth and Schlosberg's (1954, p. 104) demonstration of tachistoscopic rate exposures not being a necessary condition for generation of a U-shaped function, and Townsend, Taylor, and Brown's (1971) finding that inserting a blank space into a linear array increases CRP scores lead the present authors to the position that recognition of elements in a linear array is under the influence of a lateral masking, or interference, mechanism. Reduction of array length and inserting a blank into the array (analogous to Woodrow's spreading

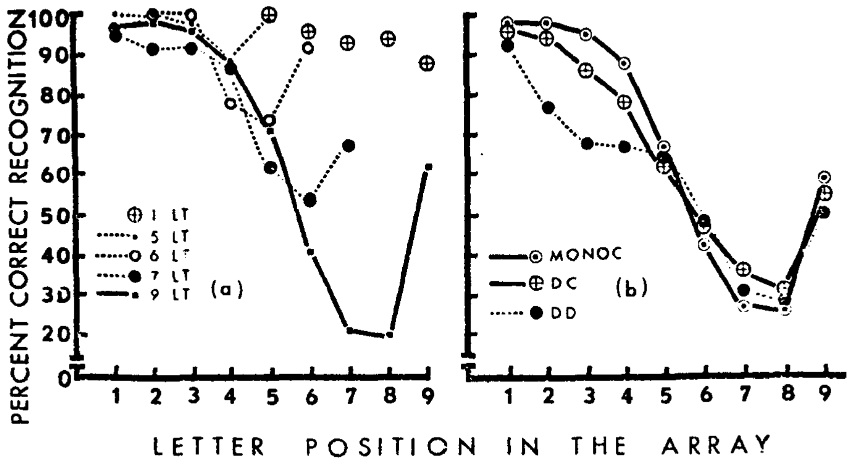

Fig. 1. (a) Recognition performance under the binocular conditions with varying length arrays and with single-letter arrays in Positions 5-9 (LT = number of letters in the array). (b) Recognition performance in the monocular and dichoptic conditions.

out the array) serve to reduce the amount of masking between and by adjacent letters and increase CRP scores.

The data presented here show small differences in the effect as a function of the three methods of presentation. The largest of these differences is the relatively poor recognition in the first four positions under the DD condition. Reports from the Os indicated some difficulty in maintaining fixation, particularly in the early sessions of the dichoptic condition, and as a consequence, in seeing a continuous linear array formed from the two sets of noncontiguous dichoptic arrays. That is to say, it is subjectively more difficult for the O to see a continuous linear array when the dichoptic information was alternate letter positions in each eye than when the information was continuous for each eye, even though the total stimulus information for each eye was the same in both the DC and DD conditions. Since the DD condition was designed to produce physically less lateral masking than the DC condition, it is difficult to explain fully the poorer recognition performance of the DD condition in terms of a lateral masking mechanism.

The overwhelming outcome is the very similar results obtained under all three conditions. Schiller (1965) has noted, using a traditional masking paradigm, that masking by patterns, as contrasted with light flashes, occurs at levels where the two monocular fields interact. We conclude, therefore, that the effects found here, whatever the details of the mechanism involved, can arise at supraretinal processing levels of the visual system.

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