Lateral masking for letters with unlimited viewing time*

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Linear arrays of 1, 8, and 9 letters were exposed while S read off the items of the letter sequence while maintaining constant fixation. By this procedure, serial position effects were studied in the absence of requirements for scanning the array quickly, as in a tachistoscopic display, and for remembering a large number of items, as in a delayed whole report. Despite the absence of these requirements, typical serial position curves were generated. Serial position effects were partially ameliorated by the introduction of blank spaces into the array. Performance was influenced both in the immediate vicinity of the blank spacings, as well as extending over a large portion of the array. The data were interpreted in terms of lateral masking effects associated with adjacent elements.

Nonuniformities in performance with closely placed visual materials have long been subjects of investigation (e.g., Harcum, 1970; Wagner, 1918; Woodrow, 1936, 1937a, b, c, 1938; Woodworth & Schlosberg, 1954). Further, it is often found that a U-shaped function describes performance plotted against distance from a fixation point. There are a number of experimental variables which can be expected to influence performance in these and similar multisymbol perception tasks. Some of the more important are (1) retinal locus (distance from fovea) (e.g., Heron, 1957; Hershenson, 1969; Woodrow, 1938), (2) relative position in array (e.g., Crovitz et al, 1966; White, 1970; Woodrow, 1938), (3) luminance duration and contrast conditions (e.g., Haber & Standing, 1968; White, 1969; Woodrow, 1937b), (4) spatial separation of symbols (e.g., Gardner, 1970; Shaw, 1969; Woodrow, 1938), (5) number of symbols (e.g., Cattell, 1885; Sperling, 1960; Woodrow, 1937a), and (6) type of report, including whole report (e.g., Bryden, 1966; Wagner, 1918) and partial report or detection procedures (e.g., Estes & Taylor, 1966; Sperling, 1960). Only two of the above studies did not use horizontal linear arrays (Estes & Taylor, 1966; Gardner, 1970).

Certain psychological constructs are of theoretical interest and are related in varying degrees to each of the above experimental variables. Those of most current interest are probably (1) perceptual acuity—related theoretically to contrast and the duplicity theory of vision; (2) immediate memory—especially in whole report, effects due to postencoding storage; (3) lateral masking—as used here, the disruption of encoding processes due to adjacent contours and possibly related to metacontrast effects not caused by contrast summation (we occasionally use the term lateral interference to refer operationally to effects associated with closeness of letters in an array); (4) availability and decay factors—related to persistence and/or the presence in the visual system of briefly displayed input; and (5) encoding process—how the symbols are scanned or translated for use by acoustic-verbal channels.

Stemming, perhaps, from the early interest in a kind of estimate of instantaneous span of conscious perception and later to immediate memory studies attempting to limit rehearsal and sequential presentation factors, a preponderance of experiments with multisymbol displays have taken place under tachistoscopic (brief display) conditions, usually with simultaneous display of the symbols. Although such procedures are indispensable for many purposes, it appears that very short durations also allow for the action and interaction of several of the theoretical factors just mentioned. Too, the demonstration given by Woodworth and Schlosberg (1954, p. 104) suggests that tachistoscopic-rate exposures are not necessary to demonstrate U-shaped performance.

The present studies were designed to eliminate or control some of the above factors while obtaining spatial characteristics of perception with linear arrays. In the first experiment, Ss viewed a horizontal linear array of nine letters. Unlimited viewing time was used, and letters were read in a left-to-right sequence from a constant fixation point to the left of the display. This procedure eliminates the effects of rapidly decaying traces of icons (e.g., Shaw, 1969; White, 1969). Experiment 1 also included trials with only one letter placed in Position 6, 8, or 9 as a control for retinal position. Experiment 2 examined the effect of placing a blank space at strategic locations in the arrays to examine interference effects under conditions similar to other studies in which results were explained with notions apparently dependent on time-constrained encoding or processing mechanisms (Estes & Wolford, 1969; Shaw, 1969).

Among recent experiments of most immediate interest for comparison are those of Shaw (1969) and Estes and Wolford (1969), both of tachistoscopic design. Like the Estes and Wolford study and unlike Shaw, the present experiments included means for analyzing retinal locus, but with a different method. Like the Shaw study and unlike Estes and Wolford, the present experiments allowed for comparison of a preletter blank with postletter blank for the same letter position in the otherwise identical array. However, the present experiments did not include conditions to unconfound order of processing from retinal locus and relative position (as did Estes and Wolford) or the use of nonsymbolic material in place of blank spaces (as did Shaw); neither of these conditions was deemed critical for the purposes of the experiments.

EXPERIMENT 1

Method

Subjects. Two senior undergraduates, participating as part of a laboratory course experience, and the second author were Ss. All were males having normal or corrected-to-normal vision. All were familiar with the purposes of the study.

Apparatus. Stimuli were projected on a closed-circuit Panasonic TV system: Camera Model WV-220P, Monitor TR-900IM masked to a 4 x 6 in. aperture, and Video Distributor (Shiba Electric Co.) DA-25. A modified welder's mask served as a head restraint and was affixed to a viewing booth holding the TV monitor. Communication between S and E was via intercom.

Stimulus materials. Random nine-letter sequences, with no duplicate letters, were generated, using a CDC 6500 computer random number generator. Only consonants, including the letter Y, were used. Five sequences, each starting with the same letter of the alphabet, were selected from a total of 1,000 generated

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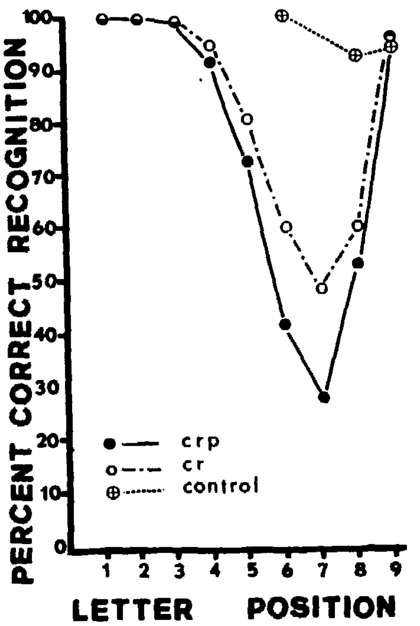

Fig. 1. Performance as a function of letter position for two accuracy measures and control trials.

randomly, thus yielding 105 stimulus sequences. Stimuli were typed on 4 x 6 in. plain white file cards, using an IBM Prestige Elite 72 uppercase typeface. Each card had one nine-letter sequence. In addition, 63 cards having only one letter in Position 6, 8, or 9 were generated and employed in the control condition for retinal locus, making a total of 168 stimulus cards. A small black rectangular (1 x 1 mm) fixation point was placed on the TV monitor to the left of the nine-letter sequence, with the complete array to the right of the fixation point. The total visual angle of the fixation point and letter sequence was 3 deg 5 sec, each letter being about 20 min in extent. Pre- and postexposure intensity was 8.50 fL; stimulus intensity was 7.88 fL, as measured by a Gamma Scientific telephotometer, Model 2020.

Procedure. Each S was tested individually for 84 trials in one session per day. There were seven test sessions following one practice session. The practice session was intended to train S to maintain fixation. He was also trained to report if his eyes left the fixation point and always to report the first letter in the sequence first. Trials on which the first letter was incorrectly reported were eliminated from analysis, as were trials where 10 letters were reported. Trials for each session were in random order. Eighty-four trials represented one-half of the 168 total stimulus cards chosen; the next session presented the remaining 84 trials in random order. When S was fixated, he was presented the stimulus array from which he then reported the letters in the sequence at his own pace. Instructions were given to attempt to report in a left-to-right order and to perform with maximum accuracy. S was told that there were no vowels or duplicates in each sequence and that he could change his answer during the trial, which lasted from 2 to 10 sec. It was also emphasized that he should not memorize the list and report it back but rather to identify each letter, report it, and then go on to the next letter.

Results

Figure 1 shows performance as a function of position for two measures of accuracy. The lower curve presents both correct letter recognition and correct positioning of the letter (CRP) and the middle curve presents only correct letter recognition (CR); performance in the control condition when one letter was presented in Position 6, 8, or 9 is also presented, fixation being maintained as for the other displays.

Analyses of variance of the arcsine transformations of both CRP and CR percentages were used to evaluate the data statistically. For this purpose, Ss were considered to be a random factor, and sessions and position effects, the repeated measures variables, were considered fixed. For CRP, performance improved over sessions ($F = 10.31$, $df = 6,12$, $p \leq .01$), and recognition was markedly sensitive to position ($F = 164.25$, $df = 8,16$, $p \leq .001$). In addition, the Sessions by Position interaction was significant ($F = 2.63$, $df = 48,96$, $p \leq .01$). For CR, the same ffects were observed with sessions ($F = 12.66$, $df = 6,12$, $p \leq .01$), position ($F = 78.07$, $df = 8,16$, $p \leq .01$), and their interaction ($F = 2.05$, $df = 48.96$, $p \leq .01$), all significant. In order to find the recognition order of the array for positions, a Newman-Keuls analysis was used to compare all pairwise differences for significance (Winer, 1962). For both CRP and CR, all positions were significantly different ($p \leq .05$) except for the difference between Positions 1 and 2 and Positions 4 and 9. The significant interaction between position and sessions can be accounted for in terms of a shift from Position 6 as the location of poorest accuracy early in testing to Position 7 as the least accurate position late in testing.

F tests showed that the control items were better recognized in Positions 6 and 8 than were the corresponding items in the same positions in the nine-letter sequences ($F = 17.54$, $df = 2,24$, $p \leq .01$).

The average number of trials that had to be thrown out was about 1 trial in 84 per S.

Discussion

It appears from Fig. 1 and the position main effect that the bowed curve typically found with short display durations is also found with unlimited viewing times. Further, the control results argue against much of the obtained performance decrement being due to retinal locus, performance being greater than 90% for the most extreme positions. It is possible that Ss were covertly making eye movements during the control trials, but it seems unlikely that they would have resorted to this maneuver on the easiest trials rather than on the most difficult. Too, introspections of the Ss were that training effectively prevented them from making such movements. It is also unlikely that Ss deviated from their instructions to read the letters rather than learn them since this would have conflicted with the maximal accuracy instructions. Hence, these results seem to imply that some kind of lateral interference, independent of persistence, decay, and memory effects, is sufficient to yield the position curves obtained.

The significant sessions main effect is demonstrated by an improvement in performance on Positions 5, 6, and 7. The small CRP and CR differences, of course, show that if a letter was correctly recognized, it was likely to be correctly placed in the report sequence.

EXPERIMENT 2

The second experiment was run in order to further investigate lateral interference and specifically the effect of placing a blank space in the letter sequence under nontachistoscopic conditions.

Method

Subjects and apparatus. Same as in Experiment 1.

Stimulus materials. Eighty-four pairs of random eight-letter sequences were selected from 1,000 randomly generated sequences. Eight sequences, each starting with the same letter, were used. The pairs were identical except for the location of a blank space, Position 6 or 8, and the other position, 8 or 6, filled by a letter. They were typed and presented in the same manner as in Experiment 1. No single-letter stimulus cards were used.

Procedure. Same as in Experiment 1, except that each S was tested for four sessions of 84 trials. Also, Ss were required to correctly

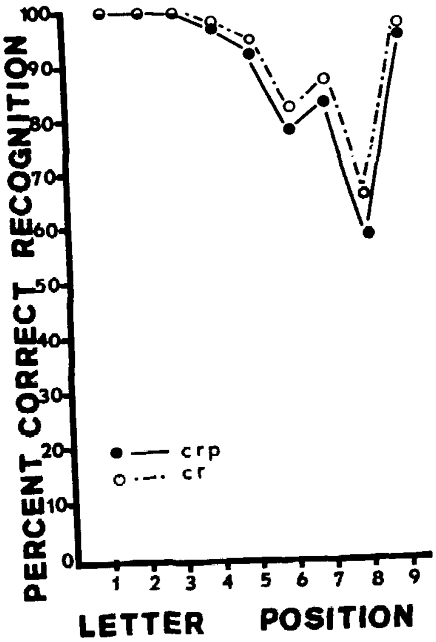

Fig. 2. Performance as a function of letter position with blank in Position 6 or Position 8.

identify the blank position. Experiment 2 followed Experiment 1 for all Ss.

Results

Figure 2 shows the mean CRP and CR measures by position. The scores for Positions 6 and 8 are for those trials on which the blank was in the other (8,6) position. An analysis of variance of the Ss by Sessions by Position design was computed under the assumption that Ss were a random factor and both repeated measures variables were fixed. The results, based upon an arcsine transformation of percentages, yielded significant sessions ($F = 9.2$, $df = 3,6$, $p \leqslant .01$) and position ($F = 67.94$, $df = 8,16$, $p \leqslant .01$) main effects, but no interaction ($F = .70$, $df = 24,48$) for the CRP measure. For CR, the pattern of significance was identical with the sessions ($F = 5.36$, $df = 3,6$, $p \leqslant .05$) and position ($F = 46.00$, $df = 8,16$, $p \leqslant .01$) effects, being significant and the interaction being negligible ($F = .67$, $df = 24,48$).

The rank order of CRP means by position was 1, 2, 3, 4, 9, 5, 7, 6, and 8. Newman-Keuls tests on pairwise differences showed that only the differences between Positions 1 and 2 and between Positions 4 and 9 were nonsignificant ($p \geqslant .05$). It is worth noting that these position effects are very similar to those obtained in the first study. The only change was in Position 7. In terms of CRP, the outcomes for Position 7 were 27.6% and 82.3% for Experiment 1 and Experiment 2, respectively.

The data concerning CRP accuracy relative to the location of the blank in Position 6 or 8 are summarized in Table 1. On all trials the blank itself was correctly located. The difference between having a blank precede (CRP = 72%) or follow (CRP = 93%) Position 7 is of particular interest. This asymmetry is highly significant according to a simple Z test based on the approximately 1,000 trials in Experiment 2. This is true despite the improvement for both blank positions.

The number of trials that had to be thrown out because Ss gave more than nine answers or failed to identify the letter in Position 1 correctly was less than 1 in 84 trials per S.

Discussion

The analysis of variance results for Experiment 2 are in general explicable in the same fashion as for Experiment 1.

The main result of interest, of course, appears in Fig. 2 and Table 1, namely the remarkable improvement in performance, especially in Position 7 but also showing up on the other positions. A small portion of this improvement might be due to greater position-information accuracy from the positioning of the blank and from the averaged preasymptotic data in Experiment 1. However, the closeness of the CRP and CR measures and the fact that the last session in Experiment 1 gave values on Positions 1, 2, 3, and 4 equal to those in Experiment 2, but values on Positions 5, 6, 7, and 8 *considerably lower*, suggest that diminution of lateral masking effects must have been much the more profound, especially for the rightmost positions. In addition to the improvement in positions adjacent to the blank, the asymmetry associated with having a blank precede or follow *a position has recently proved* of interest and generated speculation concerning its cause (Estes & Wolford, 1969; Shaw, 1969).

Shaw posits a model that assumes two mechanisms. One is a character finder that "processes the area within a processing path at a constant rate, which is independent of the number and nature of the visual objects within the path [1969, p. 265]." The other is a character reader which actually encodes the letter as soon as the finder *inputs the letter to it, stopping the* encoding process on a letter as soon as another is input. The interpretation of the blank-space results is that the character finder, discovering no character in the blank position, allows more time for the reader to spend processing the letter preceding the blank. The effect on the letter following the blank is not quite so clear; one possibility is that with the blank present more trials contain fairly complete processing of the preceding letter and thus entail less inertia or disengagement time for the character reader *when* the letter following the blank is input.[1] Estes and Wolford (1969) put forth no formal model but suggest that spaces may function as a signal to a read-out response mechanism.

Although the workings of the latter mechanisms are not entirely clear to us, they seem to be unnecessary to explain the present results, *processing* time being *essentially* unlimited and entirely at S's disposal. Further, in the present experiments the control condition indicated that retinal location was of little importance within the confines of this array. These findings, taken together, suggest *that* lateral masking may be taking place and that similar effects might also be operating in tachistoscopic exposures, although one may expect the time constraints to bring in *additional processing* factors. To be sure, Shaw's data showed no lateral interference from a black square used in place of a blank, and his unblanked arrays exhibited monotonic decreasing performance rather than a U-shaped function; thus, masking may not have been as salient a factor in his study. Alternatively, his results may be due to the fact that his data were limited to the first six positions. In any event, certain other facts from past studies also seem *difficult to explain except in* terms of spatial masking. For example, Woodrow (1937b) found that the decrement in performance, when six letters were presented instead of two, was less when the letters were dimly illuminated than when brightly illuminated, a result more parsimoniously explained by lateral interference than by more complex processing mechanisms or even by masking associated with contrast *summation effects.*[2]

Table 1
Recognition Rate (CRP) Relative *to the* Blank Space Position

Position of Blank	Position Recognized 5	7	9
6	97	72	93
8	87	93	97

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NOTES

1. This explanation is for the present results; Shaw found *no* improvement in recognition for letters immediately following a blank.

2. For example, in a whole report task with "normal" illumination (13.0 fc) the percent correct with four letters spread over about 6 deg 13 min was 67.8; with six letters spread over about 2 deg 44 min it was 58.9; but with "dim" illumination (3.1 fc) the percent correct in both cases was practically the *same*, namely, 44.3 for four letters and 44.2 for six letters. Immediate memory limitations cannot provide a complete explanation since the same effect was found with two *to* four letters. Woodrow suggests an "inhibition" hypothesis which has the kinds of effects we would expect from lateral masking, expecially as discussed in his 1938 paper. In the 1937b paper, he discusses a *shift* of attention mechanism as an alternative possibility.

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