Retinal locus and the letter-span error function

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The effect of retinal locus on the letter-span error function was investigated by requiring Ss to fixate at the left, middle, or right of lines of letters presented for 100 msec. Stimulus presentations consisted of lines of eight letters presented across the visual field, and lines of four letters presented alternately in the left and right visual hemifields. Locus of fixation and relative letter position were found to be significantly related to whether or not a letter was correctly localized. A significant interaction between locus of fixation and letter position was observed.

When lines of letters are presented briefly across S's visual field, accuracy of letter report has been found to depend on the relative position that the letter occupies within the line and not its absolute retinal locus (Bryden, 1966; Crovitz & Schiffman, 1965; Mathewson, Miller, & Crovitz, 1968). The letter-span error function is usually bow shaped; letters at the end of the line being better reported than letters nearest fixation. The similarity between this error function and that typically found in serial learning tasks has led some writers to suggest that processes allied with learning and short-term memory operate to determine the shape of the error function, perceptual factors playing a secondary role (Crovitz & Schiffman, 1965; Crovitz, Schiffman, Lipscomb, Posnick, Rees, Schaub, & Tripp, 1966).

The shape of the letter-span error function is relatively unaffected by the spacing between letters (Crovitz & Schiffman, 1965); by exposure duration (Bryden, 1966; Mathewson, Miller, & Crovitz, 1968); and by locus of stimulus information—whether stimuli are presented bilaterally or unilaterally about the fixation point (Crovitz & Schiffman, 1965; White, 1969). Dorff, Mirsky, and Mishkin (1965) have also shown that little difference exists between the error function for normal Ss and for patients whose temporal lobes have been removed.

Recently, White (1969) has shown that randomizing unilateral and bilateral stimulus presentations *within* trial blocks brings a substantial decrease in errors for letters nearest fixation. The error function was markedly bimodal. It was argued that one reason why previous researchers had found smooth bow-shaped error curves was

that stimulus presentations had tended to be either all bilateral (full-field) or all unilateral (half-field) within an experimental run. Preexposure attentional set may have contributed to the shape of the error function in these cases. If, for example, S is aware that each stimulus trial is going to be bilateral, he may unwittingly shift his locus of attention to the left of the visual field in order to facilitate "reading" the line of letters.

The present experiment was designed to assess in greater detail the role of locus of attention (retinal locus) upon the letter-span error function. Here S was required to fixate at three different loci in the visual field: at the extreme left, in the middle, and at the extreme right. The stimulus population was restricted to eight letters, and S was made thoroughly familiar with the letters used. This was done in order that guessing strategies and errors of confusion might be minimized.

METHOD

Subjects

Five right-handed undergraduate students served as Ss in this experiment. All had had previous tachistoscopic experience.

Materials

Stimulus cards consisted of 5 x 7 in. off-white cards upon which were mounted the capital English letters D, F, G, L, N, R, S, and Z (Standardgraph stencil 203/7, pen 56). The letters appeared 0.33 deg high, and approximately 0.28 deg wide.

Thirty-six stimulus cards were prepared so that on 12 cards eight letters were spaced across the card (bilateral presentations), on 12 cards four letters were spaced to the right of center, and on 12, four letters were spaced to the left of center (unilateral presentations). Letters were assigned to positions using tables of random permutations. When viewed in the tachistoscope, a bilateral array of letters subtended a visual angle of 5.73 deg.

A second set of 36 cards was prepared so that on 12 a small fixation mark was drawn just to the left of where the left-most letter of a bilateral display would appear. On 12 cards this mark was drawn between where the two middle letters of a bilateral display would appear, and on 12 this mark was drawn just to the right of where the right-most letter of a bilateral display

would appear. The fixation mark was a star subtending 0.15 deg.

A three-field tachistoscope was used to present the stimuli. the luminance of adaptation, cue, and stimulus fields was matched at 1.5 fL. The exposures were controlled by a solid-state 5-decade counter.

Procedures

The two sets of cards were arranged for presentation in such a way that each set of fixation cards (left, center, right) was associated with four bilateral, four left unilateral, and four right unilateral cards. The 36 fixation cards were randomized with the proviso that not more than two similar fixation loci consecutively succeeded each other. Each of the three sets of 12 stimulus cards was then randomized and associated with a set of fixation cards.

The Ss viewed an homogeneously illuminated adaptation field and when prepared, pressed a microswitch that started the cue-stimulus exposure sequence. The fixation cue card was exposed for 1 sec, and immediately following the offset of this exposure the stimulus card was exposed for 100 msec.

Ss were instructed to shift their focus of attention (eyes) to the fixation mark (star) when it appeared and remain there until the stimulus card was exposed. Immediately following stimulus exposure, Ss wrote down the letters they had seen in the position they occupied in the display on a checksheet. A card showing the eight stimulus letters was available to S throughout the session. Six practice trials preceded the experimental trials. Scoring was based on the correct localization of letters.

RESULTS

An analysis of variance (two Presentation Conditions by eight Letter Positions by three Fixation Loci by five Ss) was performed on the data, which gave the following results. Presentation condition was significant at the 0.1% level ($F = 90.80$, $df = 1,4$). 61.2% of letters shown in unilateral presentations and 28.2% of letters shown in bilateral presentations were correctly localized. These percentages corresponded to mean numbers of letters correctly localized per display of 2.45 and 2.26, respectively.

Fig. 1. Errors of localization by letter position for bilateral and unilateral stimulus presentations as a function of locus of fixation. (a) Locus of fixation to the left of Letter Position 1. (b) Fixation midway between Letter Positions 4 and 5. (c) Fixation to the right of Letter Position 8.

Letter position was significant at the 0.1% level ($F = 10.20$, $df = 7, 28$). Letters in Positions 1 and 8, at the end of the displays were best reported (70%, 54.2% of total shown), followed by letters occupying Positions 5, 4, and 2 (49.2%, 40.8%, 40.8%). Letters occupying Positions 7, 6, and 3 were poorest reported (36.7%, 35.0%, 30.8%). Letters in Positions 2, 3, 6, and 7 probably suffered most through spatial masking effects.

Locus of fixation was significant at the 1% level ($F = 10.68$, $df = 2, 8$). The interactions of Presentation by Letter Position and Presentation by Locus of Fixation were significant at the 0.1% and 0.5% levels ($F = 5.19$, $df = 7, 28$; $F = 12.03$, $df = 2, 8$). The importance of locus of fixation may best be seen from considering the Presentation by Fixation interaction. For unilaterally presented lines, letters were best reported when fixation was centered (75.0%); next when fixation was to the left (58.1%), and poorest when fixation was to the right (50.6%). For bilaterally presented lines, letters were best reported when fixation was to the left (33.1%); next when fixation was centered (28.7%), and poorest when fixation was to the right of the visual field (22.6%). Taken together, these results suggest that letters nearest fixation are generally reported better than letters farthest from fixation, and also that letters shown to the right of fixation—in the RVF—are better reported than letters shown to the left of fixation.

Of major importance was the interaction between Letter Position and Locus of Fixation; this was significant at the 0.1% level ($F = 102.50$, $df = 14, 56$). The interactions of Letter Position by Fixation for the three loci are plotted in Fig. 1. Here, Letter Position 1 refers to the extreme left, and Letter Position 8 to the extreme right letters of a bilateral display. For the results shown in Fig. 1a, locus of fixation was to the left of Letter Position 1; for Fig. 1b midway between Letter Positions 4 and 5; for Fig. 1c, to the right of Letter Position 8. The results are plotted for bilateral (unbroken graphs) and unilateral (broken graphs) presentations in each case.

In this experiment, the analysis of data was based on the correct localization of letters. The correct identification of a letter, irrespective of its serial positioning,

was not used as a criterion because it was obviously possible for S to score 100% correct "identifications" on any bilateral trial. A plot of identification scores was made, however, to see if the error functions were peculiar to the method of scoring. For the bilateral condition, 53.1% of the total letters shown were correctly identified; in this condition there were 46.9% errors of omission and 0% errors of confusion. For the unilateral condition, 78.8% of letters shown were correctly identified; there were 11.4% errors of omission and 9.8% errors of confusion (reported letter not shown). For bilateral presentations errors of omission were nearly double errors of serial positioning. The plots of identification scores by letter position for each locus of fixation did not appreciably depart from those shown in Fig. 1 for localization scores.

DISCUSSION

It was clear that errors within the letter span were related to locus of fixation. When S fixated at the left or at the right of a line of letters, errors were generally related to the absolute position of the letter from fixation. This is demonstrated in the bilateral results of Fig. 1a and 1c. For right fixation (Fig. 1c) a slight bow-shaped error function was observed. Letters occupying Positions 7 and 8, nearest fixation, were best localized followed by letters occupying Position 1, farthest from fixation. The discrepancy in the results for Letter Positions 8 and 1 between left and right fixation conditions was probably due to the fact that even though both occupied similar locus positions, when fixation was at the right, letters in Position 1 tended to be the first reported; when fixation was at the left letters in Position 8 tended to be the last reported. When fixation was centered, the error function was bimodal; letters appearing at the left of the visual

field and nearest fixation being relatively better reported (Fig. 1b). Again, letters in Position 1 were generally the first reported.

When line of letters were presented unilaterally, error magnitude was still determined by locus of information. In these cases, the shape of the error function was bow or inverted-V shaped; the exception being for letters presented to the right of fixation when fixation was centered (Fig. 1b). It will be recalled that errors of serial positioning were relatively high for unilateral presentations; this, and the high localization errors for letters occupying Positions 2, 3, 6, and 7, was traceable to the problem of letters in Position 2 being localized in Letter Position 3, and vice versa; letters in Position 6 being localized in Letter Position 7, and vice versa.

Crovitz and Schiffman's notion that retinal locus is unimportant needs reappraisal in the light of these results. They have suggested: "One possibility is that scanning occurs in a left-to-right order, from Position 1 to Position 8; that the task is fundamentally one of immediate memory in the face of rapidly decaying traces; and that both primacy and recency in the scanning order facilitate recall . . . the reportability of a letter depends almost exclusively upon its relative position within the string of letters of which it is a member [1965, p. 223]." This reasoning should have predicted a bow-shaped error function for the letter span when fixation was at the left. The observed function was almost monotonically increasing.

Scanning order may yet, however, be an important component of the error function. Letters appearing to the right of fixation were generally better reported than letters appearing to the left of fixation. Letters at the left of displays were also the first to be reported. These results offer support to the idea of a postexposural directional scanning

mechanism which sequentially operates on the stored information trace, proposed by Heron (1957) and Bryden (1967).

The letter-span error functions observed in this experiment appeared to be a composite function of retinal locus, spatial masking, and sequential scanning/memory factors. Overall, letters near fixation were better reported than letters far from fixation. Letters not close to fixation and not at the end of displays were relatively poorly reported; the effect of spatial masking on the visual input may account for this. It may well be, however, that the sequential processing of the stimulus trace is inhibited at a central scanning level (Bryden, 1967); and that this inhibition is directed at the letters in the middle of displays (the central traces of a trace system)—hence the bow-shaped error functions commonly observed.

It is noted that Winnick, Luria, and Zukor (1967) in an indirectly related

study, found no differences in sensitivity for letters in six letter positions along the visual meridian. This result is at variance with those presented here. Hershenson (1969), however, in a very recent experiment, has found a close association between retinal locus and errors within the letter span. It might be feasible to make use of nonalphabetic symbols in order to minimize the suggested operation of directional trace scanning.

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NOTE

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