Effect of direction of sequential presentation ıd redundancy on short-term recognition memory*

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Short-term recognition memory was tested by presenting six letters, one after the ther, followed by a target letter and having S indicate whether or not the target matched ne of the six letters. Recognition memory for a letter was better when it was embedded ı a six-letter word, rather than a nonword, and when it was included in a sequence resented left-to-right, rather than right-to-left (Experiment 1). Reducing the resentation rate from 4/sec to 2.5/sec largely eliminated the left-to-right effect Experiment 2). The effect of direction of presentation was greater for redundant Experiment 1) than for nonredundant sequences (Experiment 3) and was greater for Ss /ho more frequently formed a word out of the sequence (Experiments 1 and 2), but was o greater for words than nonwords (Experiments 1 and 2) and no greater for letter than or line-figure sequences (Experiment 3). These findings suggest that the left-to-right ffect depends as much, or more, on "peripheral" processes (e.g., eye movements) as on central" processes (e.g., reading).

When a set of items is presented achistoscopically across the visual field, Ss ypically report more accurately the lements to the left of the fixation point han the elements to the right, leading everal investigators, most notably Heron 1957), to postulate a postexposural ırocess in which traces are "scanned" əft-to-right (see White's 1969 review). 4cFarland (1970) presented three letters, ıne after the other, and found the uccession threshold to be lower when the ırder was left-to-right than when it was ight-to-left, which suggests that analysis nd integration in form perception proceed nore rapidly in a left-to-right direction. Vhen Harcum and Friedman (1963) ıresented sequentially a series of 10 filled nd unfilled circles, however, accuracy of eport was no greater for series presented eft-to-right than for those presented ight-to-left.

The present study provides yet another est of whether information is taken in nore efficiently in a left-to-right than in a ight-to-left manner. The S first saw a equence of letters, which unfolded either eft-to-right or right-to-left, and then saw a arget letter, which he had to classify as to vhether or not it had appeared in the equence. The present study provides a nore stringent test of the left-to-right ːffect than does the typical tachistoscopic tudy, because the item-recognition ırocedure required S merely to indicate vhether the target letter had been present, rather than to give a full report, which might be biased by a preferred direction (i.e., left-to-right) of report.

The present study also examined why information is taken in more efficiently in a left-to-right manner. Any superiority in performance on left-to-right (vs right-to-left) almost certainly would be based on S's extensive experience in reading left-to-right, but the actual mechanisms or processes that are polarized left-to-right need not be the same as those that organize letters into words in reading. The question posed, then, is whether the left-to-right effect depends more on "central" or higher-order cognitive processes than on "peripheral" processes, such as more efficient left-to-right eye movements. If central processes related to reading are involved, then the effect of direction of presentation ought to be greater for more English-like material, such as word vs nonword sequences (Experiments 1 and 2) and letter vs line-figure sequences (Experiment 3).

Experiments 1 and 2 also were intended to replicate, using better apparatus and procedure, Krueger's (1969) finding of better recognition memory for a letter embedded in a briefly presented word rather than in a nonword. Deese and Kaufman (1957), Lachman and Tuttle (1965), and Craik (1968) also have found better short-term or immediate memory for redundant material, and Reicher (1969) found that a letter presented tachistoscopically was identified more accurately if it was part of a word than if it was part of a nonsense item or by itself.

EXPERIMENT 1

Method

Apparatus. A PDP-4 computer controlled the presentation of illuminated capital letters on a Fairchild Type 737A display scope, which has a fast decay phosphor (1.5 microsec to 10% of maximum brightness), and clocked the response time (RT). Each capital letter was .5 cm wide and .7 cm high; .9 cm separated letters. The illuminated letters were moderately bright and produced no discernible afterimage. The S sat alone, unrestrained, 2-2.5 ft from the display scope in a dimly lit room.

Procedure. A left-to-right presentation of letters was preceded by a left dash and followed by a right dash, which remained on when the target letter appeared to its right. Right-to-left sequences were preceded by the right dash and followed by the left dash, to whose left the target letter appeared. The initial dash appeared for .8 sec, allowing S to set his gaze, after which the first letter appeared for .25 sec, followed immediately by the second letter for .25 sec, and so on for all six letters. The presentation rate thus was 4/sec. After the sixth letter the second dash appeared alone for .75 sec before the presentation of the target letter. The S was to press a right ("yes") button to indicate that the target letter had been present in the immediately preceding string of six letters, and a left ("no") button to indicate it had not. A 1-sec pause intervened between S's response, which extinguished the target letter, and the onset of the dash for the next trial.

The S was told to respond as quickly as possible, but not at the expense of accuracy, and was told his RT would be recorded. The S was told to scan along with the left-to-right or right-to-left unfolding of the six-letter sequence, rather than to fixate some point on the display scope. The S was told that the target letter would appear once or not at all ("catch" trials) in the six-letter sequence. When S pressed the incorrect button, the word WRONG appeared on the screen for 2 sec. The S received 6 to 12 practice trials.

Direction of presentation did not affect the *spatial* order of the letters. The word BEYOND, for example, was presented in the *temporal* order BEYOND for left-to-right and DNOYEB for right-to-left.

To ensure that S always knew the direction of a forthcoming display, 18 trials in a row had the same direction. After each block of 18 trials, a 2-sec message informed S of the change in direction. Half the Ss began with a left-to-right block, and half with a right-to-left block.

Display materials. All six letters in a sequence were different, and they formed a word or a nonword. Half the words were common words which occur 30 times or

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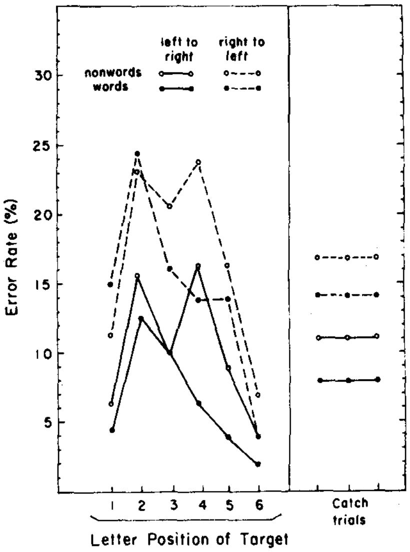

Fig. 1. Experiment 1: Error rate (%) by (temporal) letter position of target, for words and nonwords, and left-to-right and right-to-left presentations. (Three points are shown for each condition for catch trials, reflecting their greater frequency. N = 20.)

more per million words of printed English, according to Thorndike and Lorge (1944), and half were rare words, which occur once per million words. From each set of words, a set of nonwords was created by permuting the letters at each letter position randomly. Thus, the nonwords retained the distributional redundancy, but not the sequential redundancy, of the words (for further details, see Krueger, 1969). Word trials were intermixed randomly with nonword trials. No word or nonword appeared twice during the session for a particular S.

Experimental design. Each S received all conditions and thus served as his own control. All possible combinations of four types of displays (common, rare words, and the two sets of corresponding nonwords), two directions (left-to-right, right-to-left), and nine target locations (once each in the six letter positions, plus three "catch" sequences in which the target letter did not appear) constituted a basic set of 72 conditions (4 x 2 x 9 = 72). The 72 conditions were ordered randomly for each S, except that 18 sequences in a row were presented in one direction. Four replications of the basic set of 72 conditions yielded 288 trials per S.

Data analysis. Two-tailed t tests were performed in all cases, except where otherwise specified. RTs for incorrect responses were removed before geometric means were taken across the four replications for each of the 72 conditions for each S. All further averaging on RT, both within and across Ss, was arithmetic.

Subjects. Twenty Harvard University students served as paid Ss.

Results

As Fig. 1 reveals, error rate was significantly lower for left-to-right than for right-to-left, both for words ($p < .001$) and for nonwords ($p < .001$). The shorter RT for left-to-right (see Fig. 2) was not significant for words or for nonwords, and for words and nonwords together attained only marginal significance on a one-tailed t test ($p < .10$). Likewise, the lower error rate for words (vs nonwords) was significant, both for left-to-right ($p < .02$) and right-to-left sequences ($p < .05$), but the shorter RT for words was not significant for left-to-right or right-to-left, and for left-to-right and right-to-left together attained only marginal significance on a one-tailed test ($p < .10$). Among words, differences on error rate and RT between common and rare words were slight and not significant.

One striking result was the lack of interaction between direction of presentation and redundancy; the combined effect of left-to-right (vs right-to-left) and words (vs nonwords) was about equal to the sum of their separate effects. For example, left-to-right and right-to-left differed on error rate nearly as much on nonwords (6.4%) as on words (7.2%).

A second striking result was that direction of presentation had a greater effect than redundancy. Presenting letters left-to-right (vs right-to-left) reduced errors by 7% (8.7% vs 15.5%) and RT by 25 msec (781 vs 806 msec), whereas presenting sequences forming words (vs nonwords) reduced errors by 3% (10.5% vs 13.6%) and RT by 15 msec (786 vs 801 msec).

When questioned after the session, Ss indicated that on left-to-right they tended to try to see if the sequences formed a word, whereas on right-to-left they tended to concentrate on the individual letters, using such devices as saying each letter aloud as it appeared. The last 10 Ss, when asked specifically how often they had tried to make a word out of the six letters, reported doing so on about 60% of the left-to-right and 30% of the right-to-left sequences. To see what effect S's strategy had on his left-to-right vs right-to-left performance, the 10 Ss were divided into two groups according to how often they reported trying to make a word out of the left-to-right sequences. The left-to-right effect was larger, but not significantly so, for the five Ss who were high word-encoders (reported frequency: 75% or more) than for the five Ss who were low

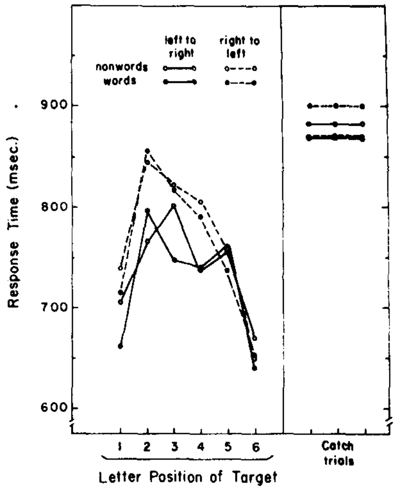

Fig. 2. Experiment 1: Response time by (temporal) letter position of target, for words and nonwords, and left-to-right and right-to-left presentations. (Three points are shown for each condition for catch trials, reflecting their greater frequency. N = 20.)

word-encoders (reported frequency: less than 75%), especially on word trials, where the difference in error rate between left-to-right and right-to-left was 9.4% for high word-encoders and 4.4% for low word-encoders.

For left-to-right as well as right-to-left, as Figs. 1 and 2 reveal, error rate and RT were lowest for the last letter (recency effect). Errors and RT also dipped for the first letter (primacy effect). Other investigators (e.g., Corballis, 1967; Morin, DeRosa, & Stultz, 1967; Norman & Waugh, 1968) also have found a recency effect in short-term recognition memory.

EXPERIMENT 2

Experiment 2 replicated Experiment 1, except that the presentation rate was reduced from 4/sec to 2.5/sec, and the interval between the sixth letter and the target letter was reduced from .75 to .5 sec. Reducing the presentation rate to 2.5/sec made it very easy for S to scan along with the unfolding of the letters and was intended to eliminate a "peripheral" explanation of the left-to-right effect based on more efficient left-to-right eye movements. In addition, to determine whether being set to form words would increase the left-to-right effect, as is suggested by the tendency in Experiment 1 for the left-to-right effect to be greater for Ss who more frequently tried to make out a word, the 10 Ss in Experiment 2a were told to try to make words out of the sequences, whereas the 10 Ss in Experiment 2b were told that, although some sequences formed real words, they were to concentrate their attention on the

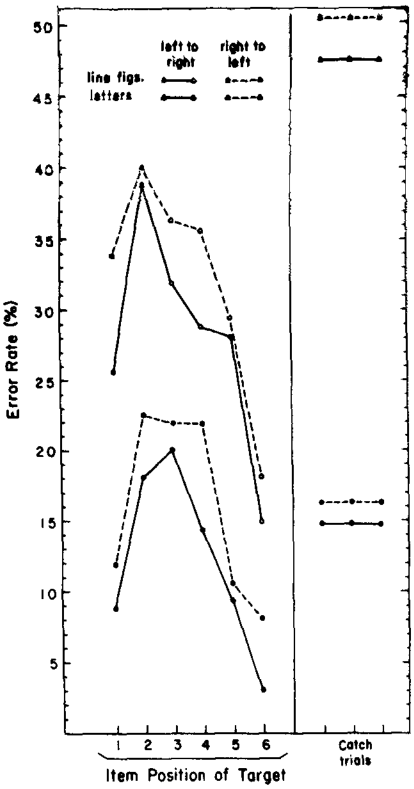

Fig. 3. Experiment 3: Error rate (%) by (temporal) item position of target, for letter and line-figure sequences, and left-to-right and right-to-left presentation. (Three points are shown for each condition for catch trials, reflecting their greater frequency. N = 20.)

individual letters. All Ss were Harvard University students and were paid.

Results

Reducing the presentation rate to 2.5/sec produced a significant decrease in error rate for Experiments 2a and 2b, as compared with Experiment 1 ($p < .05$). It also largely eliminated the difference between left-to-right and right-to-left found in Experiment 1, but not the difference between word and nonword sequences. No RT difference on left-to-right vs right-to-left was significant, and the only significant reduction in error rate for left-to-right (vs right-to-left) was for words in Experiment 2a ($p < .05$). On the other hand, there were significant reductions in error rate for words (vs nonwords) for both left-to-right (4.9% vs 10.3%, $p < .005$) and right-to-left sequences (8.5% vs 11.5%, $p < .05$) in Experiment 2a and both left-to-right (6.1% vs 9.0%, $p < .02$) and right-to-left (6.4% vs 10.4%, $p < .001$) in Experiment 2b.

Error rate was lower for words than for nonwords by nearly as much in Experiment 2b (6.3% vs 9.7%), where Ss had been told to attend to the individual letters, as in Experiment 2a (6.7% vs 10.9%). The instructions on whether or not to form words seemed to have had little effect on Ss because after the session Ss in Experiment 2b reported making out a word on 37% of the left-to-right and on 11% of the right-to-left sequences, compared with 55% and 26%, respectively, in Experiment 2a. The frequency with which S made a word out of the sequence did not affect performance in Experiment 2a, but in Experiment 2b, where Ss had been instructed not to form words, the five high word-encoders (reported frequency: 50% or more) performed significantly more accurately on left-to-right (vs right-to-left) than did the five low word-encoders ($p < .02$).

On one-tailed t tests, RT was significantly shorter for words than for nonwords for both the left-to-right (814 vs 852 msec, $p < .05$) and right-to-left sequences (805 vs 844 msec, $p < .025$) in Experiment 2a and right-to-left sequences (789 vs 810 msec, $p < .05$) in Experiment 2b, but was longer, though not significantly so, for words on left-to-right sequences (809 vs 797 msec) in Experiment 2b.

The error rate was significantly lower for common words than for rare words in Experiment 2b (5.0% vs 7.5%, $p < .05$) but not in Experiment 2a (6.8% vs 6.5%). No difference on RT between common and rare words was significant.

EXPERIMENT 3

In Experiment 1 the nonwords had the same letter distributions as the words. Experiment 3 tested whether the left-to-right effect persists even when all redundancy, both sequential and distributional, is eliminated from the letter sequences. Experiment 3 also examined the effect of direction of presentation on nonredundant sequences of line figures.

Method

The basic method was the same as in Experiment 1. To form the 210 six-letter sequences which were sampled at random (without replacement) during the session, 14 each of the first 15 letters of the alphabet (A through O) were distributed randomly in each letter position, with the constraint that no letter appear twice in one sequence. Target letters on catch trials were drawn from the same set, A through O.

To form the line-figure sequences, each letter in a sequence was replaced by a particular line figure. Each line figure contained two to five lines, and was .6 cm wide and .6 cm high, with .8 cm between adjacent line figures. The five-line figure was a square with a diagonal through it. All 15 line figures possessed the bottom horizontal line in common.

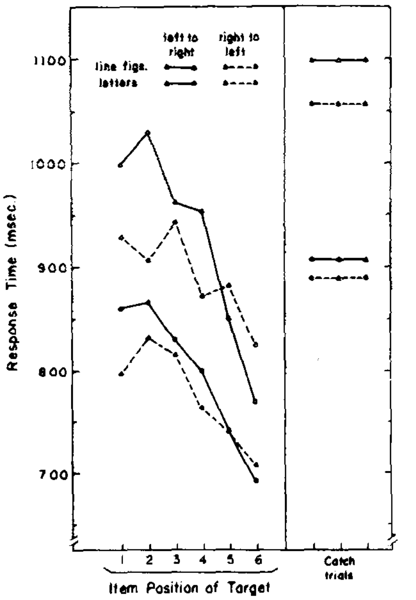

Fig. 4. Experiment 3: Response time by (temporal) item position of target, for letter and line-figure sequences, and left-to-right and right-to-left presentation. (Three points are shown for each condition for catch trials, reflecting their greater frequency. N = 20.)

Four replications of a basic set of 72 conditions yielded 288 trials in all. The 72 conditions represented all possible combinations of two repetitions each of two types of displays (letters, line figures), two directions of presentation (left-to-right, right-to-left), and nine target locations (once each in the six element positions, plus three "catch" sequences in which the target did not appear) ($2 \times 2 \times 2 \times 9 = 72$). Eighteen trials in a row contained a particular type and direction of display.

Subjects. Twenty Harvard University students served as paid Ss.

Results

For letter sequences, as Fig. 3 shows, error rate was significantly lower for left-to-right than for right-to-left ($p < .02$). For line figures, too, error rate was significantly lower for left-to-right ($p < .02$). The difference between left-to-right and right-to-left was slightly larger for line-figure (4%) than for letter sequences (3%).

Unlike error rate, RT was higher for left-to-right than for right-to-left, which, though not significant for letters and line figures considered separately, was significant for the two together ($p < .02$).

Further, whereas both a strong primacy effect and a strong recency effect are evident on error rate (Fig. 3), on RT the recency effect predominates and the primacy effect hardly exists (Fig. 4).

What effect did the elimination of redundancy in letter sequences have? Whereas Ss in Experiment 1 reported that they tried to form words on 60% of the left-to-right and 30% of the right-to-left sequences, Ss in the present experiment reported doing so on only 3% of the left-to-right and 1% of the right-to-left letter sequences. The decrease of 6.4% in errors for left-to-right vs right-to-left (10.4% vs 16.8%) for nonwords in Experiment 1 is significantly larger on a one-tailed test than the 3.1% decrease (13.1% vs 16.2%) for the letter sequences in the present experiment ($p < .05$). Similarly, for left-to-right (vs right-to-left) RT was significantly shorter on a one-tailed test for nonwords in Experiment 1 than the letter sequences in the present experiment ($p < .05$). Thus, left-to-right presentation aided recognition memory to a greater extent for redundant than for nonredundant material.

GENERAL DISCUSSION

With the present procedure, which involved memory search for a target letter presented after a sequence of letters, error rate proved more sensitive than RT to the effects of redundancy and direction of presentation. Krueger (1969), on the other hand, found that with visual search, where the target letter is presented before rather than after the word or nonword, RT was much more sensitive than error rate to the effects of redundancy.

Some findings in the present study indicate that the left-to-right effect (i.e., the lower error rate for left-to-right relative to right-to-left) depends somewhat on "central" or higher-order cognitive processes. Thus, in Experiments 1 and 2 the left-to-right effect was larger for Ss who were high word-encoders than for Ss who less frequently made a word out of the letter sequences. Further, a greater left-to-right effect was found for the redundant-letter sequences of Experiment 1 than for the nonredundant-letter sequences of Experiment 2.

More impressive, however, are the findings that indicate that higher-order cognitive processes related to reading are not crucial for the occurrence of the left-to-right effect. The reduction in error rate for left-to-right (vs right-to-left) was as large for nonwords as for words (Experiment 1), and as large for line-figure as for letter sequences (Experiment 3). That the left-to-right effect is due not simply to S's reading a sequence as though it were a word also is indicated by the finding (Experiment 2) that reducing the rate of presentation eliminated the superiority of performance on left-to-right (vs right-to-left) but not that on words (vs nonwords). The reduced rate did not inhibit those higher-order organizational processes involved in reading but did undercut or short-circuit those processes responsible for the left-to-right effect. The overall evidence, then, suggests that the left-to-right effect depends as much or more on "peripheral" or lower-level processes as on "central" or higher-order cognitive processes.

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