Effects of spaces on report from tachistoscopically presented letter strings*

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The introduction of spaces into tachistoscopically presented strings of letters produced substantial increases in reportability of letters adjacent to the spaces. As in the detection experiment of Shaw (1969), a space had a greater effect on a letter preceding than on a letter following it in the instructed read-out order. However, a similar asymmetry appeared on the central-peripheral dimension in the visual field. Position of a letter in the read-out order and number of adjacent characters interacted strongly with the central-peripheral gradient.

Using a forced-choice detection procedure (Estes & Taylor, 1964, 1966), Shaw (1969) has shown interesting asymmetries in the effects of spaces upon tachistoscopically presented strings of letters. In Shaw's basic experiment, the S was presented in the control condition with a row of 10 letters with the fixation point at the left. When a comparison was made between, for example, detection of a signal at Position 6 in a solid string with detection in a comparable string which had blank spaces in place of letters immediately to the left or right of the signal, a large facilitation of detection of Position 6 was observed in the latter condition but none in the former. The relationship was reversed when similar displays were used with the fixation point at the right.

The interpretation suggested by Shaw is that the S processes information from the strings of letters by a serial scan, proceeding from the fixation point, with the processing mechanism taking a constant amount of time per character in a solid string but lingering for some additional time on a letter preceding a blank space. On the assumption that the amount of information extracted from a briefly presented character is a function of the amount of processing time, this hypothesis would account nicely for the observed asymmetries.

It should be noted, however, that in Shaw's experiment the position of a space on the left or right side of a signal letter relative to the presumed processing order was confounded with spatial position relative to the fovea in the visual field. That is, when the fixation point was at the left end of the string, a space at the right of the signal letter followed the letter in the presumed processing order and was also on the peripheral side of the letter

relative to the fixation point and its foveal representation. Similarly, when the fixation point was on the right, a space at the left of the signal letter followed it in the presumed processing order but again was on the peripheral side of the letter relative to the fixation point. Thus, the possibility is open that the asymmetries observed by Shaw might be interpreted in terms of some model based upon central-peripheral gradients in the visual field rather than in terms of relative positions in a serial processing order.

Our purpose in this study was to circumvent this confounding by varying the locations of spaces on either side of a signal element relative to the fixation point independently of their positions in the processing order. To this end, we used the same types of displays as those in Shaw's study, with the fixation point at either the left or the right of the display, but also we instructed and trained Ss to attempt to process and read out information in either a left-right or a right-left order and combined the two types of read-out orthogonally with the two positions of the fixation point. In order to gain additional information as to how well the Ss were able to conform to instructions to read out in a prescribed direction, we utilized a report procedure rather than the detection procedure of Shaw's study.

EXPERIMENT

Design

Each S received 10 replications of the basic design. One S-replication of the design utilized 36 stimulus cards. The cards within a replication varied in the number of letters present and the position of the letters. The positions were determined by assuming a scale of 18 type spaces (pica, 10/in.) numbered from -9 to +9, with the fixation point occupying the half space between -1 and +1. The arrangements of the letters in the displays of any one replication conform to the cell entries in the rows of either the upper or lower half of Table 1.

Subjects and Apparatus

Seventeen Ss were paid \$4.00 each for 2 h of participation in the experiment. The Ss were from the staff at Rockefeller University or were persons who had responded to a newspaper ad. A Scientific Prototype three-channel tachistoscope was used in the presentation of the stimulus cards. The scope was modified by the addition of a rapid card changer¹ mounted on Channel 1.

Procedure

A trial began with 8 sec of exposure to a blank field of .96 fL of luminance. At the end of the 8 sec, a field of the same luminance appeared for 3 sec containing a black dot (period in pica type) in the center of the field. The display was then presented for 200 msec at a luminance of 1.86 fL.

An ordered random sample of nine consonants (excluding C, D, and M) was drawn without replacement for each replication, and the 12 displays falling in any one position relative to the fixation point, e.g., displays having the leftmost letter at Position 1, were obtained by deleting letters from the basic nine-letter control display or by interchanging the letters in the positions adjacent to a space. Corresponding to a display having spaces at adjacent Positions *i* and *j*, there was a companion display which was identical except that the letters in Positions *i*-1 and *j*+1 were interchanged; and corresponding to each of these, there was a nine-letter and a seven-letter display with the same letters in Positions *i*-1 and *j*+1, but with the spaces filled by the appropriate letters from the basic nine-letter sequence for that replication. The set of 12 displays so generated was duplicated exactly to obtain the displays with leftmost letters at -9, and the sets of 6 with leftmost letters at -6 and -3 were obtained similarly. All of the displays occupied the same horizontal axis as the fixation point. A nine-element display subtended a visual angle of approximately 1.5 deg.

The 10 Ss of Condition L were instructed to report as many letters as possible after each display presentation in a left-to-right order. They were urged always to be correct on the leftmost letter of each display. They were given 8 sec in which to make their report. They were instructed to report a letter even if they were not sure of its exact position but thought that it had been in the display. The importance of correctly reporting the leftmost letter was stressed throughout the course of the experiment.

For each S the cards for the 10 replications of the design were shuffled together to form the displays

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Table 1
Percentages of Correct Reports for Letter Positions for Each Read-Out Order (Data for Protocols with Correct Initial Letter)

Position Relative to Fixation Point																			
-9	-8	-7	-6	-5	-4	-3	-2	-1	•	1	2	3	4	5	6	7	8	9	
Left to Right Read-Out																			
										100	72	46	23	16	14	9	9	21	
										100	74	44	18	15	19	25			
										100	94			34	19	7	5	24	
										100	74	39	25	35			9	15	
100	22	18	11	13	20	17	26	48											
100	34	25	16	14	25	47													
100	51			34	29	18	19	34											
100	21	18	15	17			50	57											
						100	73	48		38	20	20	11	6	21				
						100	73	54		38	31	18	32						
						100	89				55	34	12	11	26				
		100	29	22		22	25	30		30	25	39							
		100	31	26		18	29	35		52									
		100	28	28		23	34				41	50							
Right to Left Read-Out																			
										35	10	7	8	14	20	41	48	100	
										42	7	6	17	29	69	100			
										23	16			40	35	35	34	100	
										26	14	4	13	15			76	100	
18	6	4	4	9	23	46	63	100											
29	9	3	16	20	74	100													
12	7			39	40	40		100											
19	1	4	3	9			88	100											
						32	13	8		17	17	35	50	34	100				
						41	14	13		21	33	76	100						
						32	17			41	32		39	51	100				
		18	6	2		9	12	38		46	65	100							
		28	2	7		21	27	78		100									
		23	5	4		10	5				87	100							

for a single sequence of 360 trials. An experimental session lasted approximately 2 h, with pretraining on a set of 10 practice cards preceding data collection on the experimental series.

The procedure for Condition R was the same as that for Condition L, except that the Ss were asked to report the letters in a right-to-left order and were urged always to get the rightmost letter correct. The exposure duration was increased to 250 msec owing to the increased difficulty of the task. Of the seven Ss started, two were discarded for their inability to perform properly in the experiment.

RESULTS

The basic data in terms of percentage of correct reports for each letter position in each type of display are presented separately for the left and right read-out orders in Table 1. These data represent only the protocols for which the leftmost letter was reported correctly in Condition L or the rightmost letter in Condition R. The protocols excluded, presumably including the preponderance of the instances in which Ss failed to conform to the instructed read-out order, range from 3.2% of the protocols with initial letters at Position 1 to 17.5% of those with initial letters at Position -9 for Condition L and from 11% of the protocols with initial letters at Position 1 to 12.3% of those with

initial letters at Position 9 for Condition R. All other analyses presented in this report are based on the full set of data for each condition with no protocols excluded.

It is clear from inspection of Table 1 that the insertion of spaces in the letter strings exerts substantial effects upon the accuracy of report of letters adjacent to the spaces and also that these effects are by no means uniform in magnitude over the various conditions. In order to bring out the way in which these effects depend upon the positions of spaces and adjacent letters relative to the fixation point or relative to the instructed read-out order, the percentages of correct reports at positions adjacent to spaces are presented in Table 2, together with differences between these and corresponding values for letters in the same positions without adjacent spaces, the data being pooled over all of the displays of a given type. Thus, the values in the top row indicate that 52.6% of the letters in

positions immediately preceding a space in the instructed read-out order were correct, as compared to 52.6 - 21.1 = 31.5% of the letters in the corresponding positions of the nine-letter control strings. Similarly, the third row indicates that 46.6% of reports were correct on letters immediately central to a space (regardless of the read-out order), compared to 28.1% in the corresponding position of the nine-element control strings.

In every instance the effect of a space is to increase the accuracy of report at adjacent positions. However, it is difficult to know just what basis of comparison to use in order to determine whether the effects differ with respect to the positions of the letters and spaces in either the read-out order or the central-peripheral dimension. In terms of the absolute differences between proportions correct at positions adjacent to spaces and corresponding positions in the control strings, one

Table 2
Percentages of Correct Reports at Positions Adjacent to Spaces, Compared to Control Values

Direction	Position	Percentage Correct	Difference from Control (9)	Difference/Maximum Difference
Read-Out Order	Before Space	52.6	21.1	.31
	After Space	23.2	9.1	.12
Central-Peripheral	Before Space	46.6	18.5	.26
	After Space	29.2	11.7	.14

would conclude that the effect of a space is much greater on the letter preceding than on the letter following the space in the read-out order and that the effect is much greater on the letter central than on the letter peripheral to a space in the central-peripheral dimension. Also, the asymmetry in the effect of a space is nearly as great in the central-peripheral dimension as in the read-out order.

If, instead, we convert the differences between the proportions correct at positions adjacent to spaces and the corresponding control string values to proportions of the control values, we obtain proportions of .67, .64, .66, and .67 for the four rows of Table 2, reading from top to bottom. This result would suggest little asymmetry on either dimension. If we conceive that effect of a space upon proportion of correct responding is described by a mathematical operator of the type which is often found to approximate the effect of a reinforcing event in a learning model (e.g., Bush & Mosteller, 1955; Estes, 1950), then the difference between an experimental and a control proportion should be converted instead to a proportion of the difference between the control value and unity. When this is done, we obtain the proportions shown in the right-hand column of Table 2. The results of this transformation agree with the absolute differences in indicating a distinct asymmetry in the effect of spaces, but with the degree of asymmetry only slightly greater with respect to the read-out order than with respect to the central-peripheral direction in the visual field.

Although the experiment was designed with a view only to determining asymmetries of effects of spaces, some subsidiary results are available bearing upon the ways in which reportability of a letter at a particular position depends upon position in the read-out order, distance from the fixation point, and number of adjacent letters.

In order to provide some information regarding report as a function of position in the display relative to the fixation point, the average percentages of correct reports presented in Table 3 have been computed for data pooled over the different display types and read-out conditions, and with position in the display folded relative to left-right direction from the fixation point. Means are presented only for cells for which at least six determinations are available and in all cases the values arising from Conditions L and R have been equally weighted.

It is apparent that for letters which fall in the initial position in the instructed read-out order there is only

Table 3
Percentages of Correct Reports for Letters in First, Second, or Terminal Position in Read-Out Order

Position in Read-Out Order	Position in Display								
	1	2	3	4	5	6	7	8	9
Initial	92.2		90.3			88.8			81.6
Second		66.5			35.0			31.2	
Terminal	42.0	40.2				22.5			19.8

a relatively small decrement in reportability as a function of distance from the fixation point in the visual field. For letters falling in the second position in the read-out order, represented in the second row of Table 3, the decrement function is very much steeper. That the difference between the shallow function for initial letters and the steep decline over position for second letters is largely due to the addition of a second neighboring element in the latter case is evident if one, for example, compares the mean value of 66.5% correct reports for all second letters at Position 2 with the values of 93% and 86%, which obtain for Conditions L and R, respectively, for second letters in displays which have spaces at Positions 3 and 4 or -3 and -4.

That relative position in the read-out order is a still stronger determiner of reportability is shown clearly by the third row in Table 3. Even when the letter is in the position adjacent to the fixation point and has only one neighboring element, there are only 42% correct reports on the average if the letter falls in the terminal position in the instructed read-out order.

DISCUSSION

Clearly, spatial position, number of adjacent letters, and position in the instructed read-out order all have appreciable effects upon reportability. Under our experimental conditions, the latter two variables exert considerably stronger effects than position in the visual field per se. The insertion of spaces within a string of letters by deleting letters from the corresponding control strings produces major increases in reportability of letters adjacent to the space under all circumstances tested.

The questions of symmetry or asymmetry of the effects of a space on letters which precede or follow it in the instructed read-out order or which fall on the central or peripheral side relative to the fixation point are difficult to answer in the absence of any unequivocal rationale for quantifying the effects. When the effects are measured in terms of absolute increases in percentage of correct reports over values obtained from corresponding positions in control strings, or when these

differences are expressed as percentages of the maximum possible effect, strong asymmetries appear, with the asymmetry being slightly greater relative to position in the read-out order than to a central-to-peripheral axis through the fixation point.

This last result suggests that the confounding of position in the read-out order with position relative to the fixation point in the visual field might be a factor of importance also with the detection procedure used by Shaw (1969). As alternatives to Shaw's hypothesis that spaces exert their effects by perturbing a serial scanning process, it may be desirable to explore the possibility that spaces function, rather, as attenuators of lateral masking effects of neighboring characters. On this conception, the asymmetries would arise from a gradient of susceptibility to masking either in the central-peripheral dimension or in the read-out order, or in both. On the basis of his finding that solid rectangles adjacent to signal letters mimicked the effects of spaces, Shaw concluded that a masking interpretation is implausible. However, his argument is not decisive, for masking may operate at the level of feature extraction (Rumelhart, 1970); and either a space or a rectangle adjacent to a letter serves to increase its separation from characters having confusable features. In any event, it seems at present that the formulation of a model embodying any of these ideas had best wait upon further empirical exploration of the way in which the three independent variables under examination in this study exert their combined effects under both detection and report procedures.

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NOTE

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