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Effects of bars and blanks on recognition of words and nonwords embedded in a row of letters*

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Solid bars or blank spaces placed before, after, or on both sides of a pronounceable four-letter string embedded in a longer string of letters facilitated recognition of the embedded string. This effect was equal whether bar or blanks were used, and whether the embedded string was a word or a pronounceable nonword. The effect of bars or blanks on pronounceable strings was interpreted in terms of a multiletter processing operation.

In the chapter on reading in his historic book, Woodworth (1938) displayed the following letter groups

o
bom
sbomk
asbomku
easbomkut
geasbomkutc
wgeasbomkutcz
dwgeasbomkutczh
idwgeasbomkutczhv
xidwgeasbomkutczhvp
fxidwgeasbomkutczhvpn
rfxidwgeasbomkutczhvpnj
yrfxidwgeasbomkutczhvpnjl

and pointed out that if the reader would fixate on the center o in a line, he would see the end letters more clearly than other letters near the ends. Woodworth called this phenomenon "interference of adjacent letters" and said that end letters received less interference.

More recent investigations (e.g., Estes & Wolford, 1971; Shaw, 1969; Stuart, 1971; Taylor & Brown, 1972; Townsend, Taylor, & Brown, 1971), using several different paradigms, have indicated the following facts about this interference of adjacent letters: (1) the neural locus is not in the retina (Taylor & Brown, 1971); (2) an adjacent contour does not necessarily cause interference, i.e., an adjacent solid black rectangle (a bar) in place of a letter does not produce interference under certain conditions (Shaw, 1969); (3) in terms of proportion correct, there is appreciably more interference from an adjacent letter on the far side of a letter from the focusing mark than on the near (Estes & Wolford, 1971; Shaw, 1969; Stuart, 1971; Townsend, Taylor, & Brown, 1971); (4) a letter not adjacent to a given letter interferes with the given letter much less than does an adjacent letter (Shaw, 1969); and (5) letters in a vertical display also show interference from adjacent letters (Stuart, 1971).

The experiments to be reported investigated the effects of a bar or a blank on recognition of a word or pronounceable nonword in a row of letters. The recent data of Reicher (1969) and Wheeler (1970), showing a word context effect, suggest the possibility that a letter in a word is processed differently from a letter presented by itself or presented in a context of letters not together composing a word. In view of this possibility, it is of interest to study the similarities and differences in the effects of a blank or bar on recognition of a letter and on recognition of a word or word-like group of letters.

A natural hope for one interested in analyzing visual processing is that it will be possible to decompose the transformation from the retinal mosaic to an overt response into a series of information-processing operations. The facilitation of recognition of a single letter by a bar or blank can be interpreted in this framework as an improvement in the performance of a single-letter processing operation. Shaw (1969), for example, suggested that a bar or blank in the proper relationship to a signal letter increases the duration for the signal letter of a serial read-out operation which is applied to only one letter at a time. This view is compatible with a number of facts, but is only one of several possible identifications of a single-letter processing operation facilitated by the presence of a bar or blank in place of a letter. If it is true that a bar or blank facilitates a read-out operation, then it probably is an operation performed on only one letter at a time: Shaw (1969) found that a blank or bar separated from the signal letter by a background letter did not appreciably or consistently improve recognition accuracy.

The word context effect, at present, can be interpreted in a number of ways (cf. Wheeler, 1970). Common to the current interpretations, however, is the assumption that at some stage in the processing of the letters of a word the processing of one letter affects and is affected by the processing of other letters. For the view that visual processing is a series of operations, this means that the processing of a word entails a multiletter processing operation.

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Table 1
Examples of Each Display Condition in Experiment I

Control	V N X B O L D X N X
Preblank	V B O L D X N X
Prebar	V ▬ B O L D X N X
Postblank	V N X B O L D X
Postbar	V N X B O L D ▬ X
Double Blank	V B O L D X
Double Bar	V ▬ B O L D ▬ X

The possibility arises, therefore, of demonstrating a facilitation of word recognition by a bar or blank affecting a multiletter operation. Since a multiletter operation did not appear to be involved in the letter recognition experiments of Shaw (1969), a result of this kind would indicate that more than one information processing operation can be facilitated by the presence of a bar or blank. To perform this demonstration, the displays must be constructed such that an obtained difference cannot be easily attributed to the known effect of a bar or blank on what appears to be a single-letter processing operation.

In the experiments of Shaw (1969), the S was instructed to begin each trial looking at a focusing dot, to "read" a briefly presented single row of consonants appearing just to the right of the focusing dot position, and to report which one of several possible signal letters was the one that had appeared somewhere in the row. Requiring a near perfect report of the letter nearest the focusing dot appeared to force the S to begin each trial with his eyes fixated near the focusing dot and to force him to begin his "reading" with the leftmost letter.

The experiments of Shaw and LaBerge (1971) provide strong support for the view that the instruction to "read" a display along a simple path influences the order in which some operation is applied to each location in a representation of the display. The experiments of Shaw (1969) show that a blank or a bar that immediately follows the signal letter in the instructed "reading" path greatly facilitates the processing of the signal letter. Under the conditions of these experiments, a bar or blank separated from the signal letter by one background letter did not make an appreciable change in the accuracy level from that of a row of letters having no bar or blank. A bar or blank immediately before the signal letter in the "reading" order also did not change the signal recognition accuracy.

The present Experiment I used the same paradigm as the letter recognition experiments of Shaw (1969), which controlled the important variable of "reading" order, but differed in that there were 12 four-letter signal words rather than 2 or 3 signal letters. These signal words all began with B and ended with D. The Ss were quite familiar with the set of signal words and, therefore, were not able to improve their response selections on the basis of a correct recognition of the first or last letters of a signal word. Therefore, to the extent tha the spacing, visual angles, type style, etc., of Experiment I are similar enough to the conditions of Shaw (1969), in which a bar or blank separated by one or more letters from a signal letter did not systematically have a large effect on signal-letter accuracy, a facilitation of signal-word recognition accuracy is not to be expected under the conditions of Experiment I; instead, accuracy for bar or blank displays should be equal to accuracy on control displays.

On the other hand, the experiments of Reicher (1969) and Wheeler (1970) suggest the existence of a multiletter operation not important in signal-letter recognition experiments, and this operation may be faciliated by a bar or blank under the conditions of Experiment I and produce superior performance for bar and blank conditions.

EXPERIMENT I

Method

Subjects

Four employees of the Rockefeller University served as paid Ss. No S wore contact lenses.

Stimuli

The stimuli of any session were 252 35-mm slides of black capital block letters on a transparent background. These slides were made by photographing a row of black block capital letters typed on a white paper with IBM Directory type. The distance between letters was the width of a letter. There were 36 slides in each of seven conditions. The 36 slides for a condition were all combinations of a letter selected from the set H, T, V and a signal word selected from the set BALD, BAND, BARD, BAWD, BEAD, BEND, BIND, BOLD, BOND, BLED, BRED and placed in a row of Ns and Xs. An example from each of the seven stimulus conditions is given in Table 1. The leftmost letter in a display is called the verification letter and was always H, T, or V. The signal word in a display always occupied the 4th through 7th letter positions. The two arrangements of the background letters, X and N, are illustrated in the examples V N X B O L D X N X and V X N B O L D N X X. A randomly chosen half of the 36 slides of a condition had the first background pattern, and the other half had the second. The slide from each condition having a particular verification letter and a particular signal word had the same background arrangement. The visual angle subtended by the verification letter and the last letter of the signal word was 1.4 deg, the angle subtended by the entire row of letters, 2.1 deg.

The seven conditions illustrated in Table 1 are named: control, postblank, preblank, prebar, postbar, double blank, and double bar. In the postblank condition, for example, a blank space appeared immediately to the right of the signal word. The distance between the signal word and the next background letter to the right was equal to the width of two missing between-letter spaces plus three spaces each having the width of one letter. In the prebar condition, for example, the solid black rectangle appeared immediately to the left of the signal word and was made by filling in two background letters and the space between them before photographing. Thus, for example, the distance between the signal and the closest background letter to the left on a prebar slide is the same as the distance between the signal and the closest letter to the left on a preblank slide, and the width of a rectangle is less than the width of a blank space by twice the distance between letters. The background blank and the solid black rectangle in the other conditions were constructed in the same manner.

Procedure

The slides were presented in a Scientific Prototype Model GB autotachistoscope. Each trial began when the S fixated on a small black focusing dot in the middle of the left side of Field B. When the S was ready, he pushed a footpedal and one of the 252 slides, randomly arranged in eight slide trays, was immediately presented in Field I for the number of milliseconds used for that S. Field B then returned at the offset of Field I. The leftmost letter, the verification letter, of the horizontal array presented in Field I appeared just to the right of the position of the focusing dot. Field I had an intensity of 1.4 fL; Field B had an intensity of 1.2 fL.

The instructions required the S to "read" the display from left to right, to say the verification letter, and then to say the signal word. The instructions emphasized that the S should begin each trial fixated on or immediately to the right of the focusing dot and should maintain a near-perfect accuracy on the verification report. He was told that trials on which verification errors were made would not be counted in the analysis and that he should say "mistrial" if he failed to see the verification letter. ("Mistrials" were rare.)

Each S had 5-7 practice sessions. During the practice sessions, the S was given feedback each trial on the verification and signal responses. During the course of the practice sessions, the task was slowly made more difficult by lowering the stimulus duration from 200 msec to a final duration chosen separately for each S at which his signal responses over all conditions were about 40% correct. The final duration used for each S during the practice sessions was used for the first few data-collection sessions. These durations were 20, 24, 14, and 30 msec for Ss E, M, P, and H, respectively. During the course of the data-collection sessions, each S's duration was lowered by 2 msec when he had improved with practice.

There were 20 sessions of data collection for each S, except for P, who was able to participate in only 18 sessions. Each session began with 3 min of dark adaptation and 15 warm-up trials. After the warm-up, the S saw each of the 252 slides at his own pace. There was a brief rest between each slide tray. Sessions lasted about 30 min.

Results

For Ss E, M, and H, there were 720 trials for each of the stimulus conditions. For P, there were 648 trials. Mistrials varied across Ss from 1.3% to 2.9%. For each S, the proportion of verification errors for each condition for trials that were not mistrials is presented in Table 2. These verification error proportions indicate that Ss did fixate near the focusing dot at the onset of each presentation. Table 3 shows for each S the proportion of correct signal responses for each condition for all trials except mistrials and trials with the wrong verification response. To compute a confidence interval for each S about his control proportion, the control trials for each S were assumed to be binomial trials with a different probability correct for each S. The 95% confidence intervals are shown in Table 3.

An obvious feature of these data is that blanks and bars have similar facilitating effects. For each S, the double-blank and the double-bar proportions were above the control confidence interval. The pre and post conditions were not above the control confidence interval for every S but were above if they were not in the confidence interval. If, for a S, the preblank (postblank) proportion was above the control proportion, then the prebar (postbar) proportion was also. While the pattern of facilitative effects for each S is the same for blank conditions and bar conditions, over all Ss the blank space was significantly more facilitative than the bar (sign test, .01 level).

Table 4 shows for each S the two middle letters of the word most frequently given as a wrong response to each signal word and the proportion of error trials on which this most frequent error word was the response to the signal word. It is obvious that Ss had some knowledge of the correct middle letters on a significant percent of the signal error trials. Note, for example, that for each S the most frequent errors to BIRD, BIND, and BOND were BIND, BIRD, and BOLD, respectively. For each signal word, there were 11 possible wrong responses, and on the average 6 of the wrong responses had no letters in

Table 2
Verification Error Proportions for Each Condition and Each Subject of Experiment I

	H	M	E	P
Control	.04	.01	.01	.09
Preblank	.03	.02	.01	.07
Prebar	.05	.01	.02	.10
Postblank	.02	.02	.03	.06
Postbar	.03	.02	.03	.08
Double Blank	.04	.03	.01	.10
Double Bar	.05	.03	.02	.08

Table 3
Proportion of Correct Signal Responses for Each Condition and Each Subject of Experiment I

	H	M	E	P
Control	.41	.56	.46	.30
Preblank	.59	.59	.54	.40
Prebar	.52	.58	.51	.37
Postblank	.58	.62	.49	.30
Postbar	.53	.60	.44	.30
Double Blank	.68	.66	.57	.39
Double Bar	.60	.64	.54	.36
Control Confidence Interval	(.37, .45)	(.52, .60)	(.42, .50)	(.26, .34)

Table 4
Most Frequent Error for Each Stimulus and the Proportion of the Error Responses in Experiment I

Stimulus	E	M	H	P
BALD	LE .34	OL .31	AR .22	AR .34
BAND	AW .35	AW .44	AR .55	AR .34
BARD	AN .26	AW .42	AN .34	AW .30
BAWD	AN .30	AR .21	AN .38	AR .38
BEAD	LE .32	EN .23	EN .27	LE .24
BEND	EA .37	EA .30	RE .33	EA .19
BIND	IR .71	IR .76	IR .44	IR .35
BIRD	IN .66	IN .45	IN .58	IN .44
BOLD	LE .34	ON .31	IN .23	ON .38
BOND	OL .53	OL .62	OL .33	OL .27
BLED	OL .42	OL .47	OL .26	AL .37
BRED	EA .34	IR .20	EN .26	AR .15

Table 5
Conditions of Experiment II

	▬▬▬ (bar above D A L B)
Over Bar	V N X X N D A L B N X N X
Control	V N X X N D A L B N X N X
Double Bar	V N ▬▬▬ D A L B ▬▬▬ X
Double Blank	V N D A L B X

common with the signal. However, only 1 of the 48 entries in Table 4 (stimulus BOLD, S H) has no middle letter in common with the presented signal word. Further, the signal word and the most frequent error have the same second letter 33 times out of 40 possibilities (BRED and BLED can have no wrong responses with the same second letter). If it is assumed that on error trials every error word is equally likely to be the response, then the expected number of signal responses having a second letter matching the presented signal is 6.55.

Discussion

The salient result of Experiment I is that for each S, the double-blank and double-bar conditions are above the control confidence interval. This is not what is expected on the basis of the signal-letter data under the assumption that the letters of a word are processed like four adjacent signal letters. Shaw (1969) found a significant effect, consistent across Ss, only for the conditions having a bar or blank immediately after the signal letter in the reading order, whereas the last letter of the present signal words could not be useful in selecting a response.

Experiment II is a replication of the double-blank/double-bar effect under somewhat different conditions and is a test of two questions immediately provoked by this effect: (1) Is it necessary that the signal group of letters be a word? (2) Is it sufficient that the region of the display containing the signal group of letters be clearly delimited?

To test the first question, two sets of signals were generated by selecting eight words from the signals of Experiment I and then switching the first and last letters of these eight words to make eight pronounceable nonwords that had the same pairs of middle letters. A double-blank/double-bar effect that was equal for each set of eight signals would show that the signal group need not be a word and also need not have been frequently experienced as an ordered string before the experiment.

To test the second question, Experiment II included a condition with displays which contained above the entire signal group a black bar like the ones used in Experiment I. If a marker of this kind does not change the level of accuracy from the control level, then certain notions of "focusing of attention" are disconfirmed and distance from the signal group to the closest adjacent letters is indicated as the critical variable.

EXPERIMENT II

Method

Subjects

Four undergraduates of the University of Illinois served as paid Ss. No S wore contact lenses.

Stimuli

The stimuli were 35-mm slides of black capital block letters on a clear background. A slide was made by photographing with high-contrast copy film a row of letters made with a Varitype Headliner. The Headliner style used was New Gothic reversed. The space between letters was about two-thirds the width of a letter.

There were 64 slides in each of the four conditions. The 64 slides of a condition consisted of two identical sets of 32 slides each. The 32 distinct slides of a condition were all possible combinations of a verification letter selected from the set T, V, and a signal word or pronounceable nonword selected from the set BEAD, BEND, BOND, BOLD, BALD, BAND, BLED, BRED, DEAB, DENB, DONB, DOLB, DALB, DANB, DLEB, and DREB and placed in a row of Ns and Xs. The eight pronounceable nonwords were generated by reversing the first and last letters of the eight words. Half of the 32 slides of each condition had NXXN – – – – NXNX as the background, and the other half had NXNX – – – – NXXN as the background. If a signal word had the first background in one condition, then it had the first background in the other conditions and the signal formed by switching the positions of the B and the D in the word also had the same background.

An example from each of the four stimulus conditions is given in Table 5. Each example has V as the verification letter, DALB as the signal, and NXNX – – – – NXNX as the background. The four conditions are: over bar, control, double bar, and double blank. The signal occupies Letter Positions 6 through 9 and the control slides contain 13 letters. The bars in the double-bar-condition slides were made by covering the three adjacent Headliner letters on each side of the signal with a white rectangle the height of a letter and photographing the modified Headliner strip surrounded by a black paper mask to produce a negative with black bars around the signal. The procedure for producing negatives for the double-blank condition was the same, except that the three letters on each side of the signal were covered with black paper. To produce an over-bar slide, a white rectangle, the height of a Headliner letter and the width of the signal, was placed on the black mask above the signal at a distance equal to the distance in the row between letters. The row of letters on a negative was mounted in the center of a 35-mm slide and subtended 2.6 deg when viewed in the tachistoscope. The angle subtended by the verification letter and the last letter of the signal was 1.8 deg.

Procedure

The slides were presented in a Scientific Prototype Model GB autotachistoscope. The trial sequence was the same as in Experiment I, except that instead of a slide containing a focusing dot, a slide containing two small vertical bars was presented in the B field. The position of the two bars was such that the gap between them occupied the position of the verification letter of the stimulus array – one bar above this position and one bar below. Both Field 1, containing the stimulus row, and Field B, containing the focusing gap, had an intensity of 2.8 fL.

The instructions were the same as in Experiment I except for the minor differences that the focusing gap replaced the focusing dot in the instruction emphasizing that the S begin each trial fixated on the focusing dot, that H was dropped from the verification letter set, and that the set of possible signals was changed to the set for Experiment II. The S was told that he was to report the signal as a unit, not by letter; there appeared to be no difficulty in pronouncing the nonwords.

A series of at least five practice sessions with feedback preceded the experimental sessions. The intent of the practice sessions was to make each S's performance on the task stable and to determine an exposure duration appropriate for each S.

In the first practice sessions, S was given a verbal description of all the stimuli he would see and was shown 66 slides for 2 sec each. Starting at 200 msec, the stimulus exposure duration was gradually reduced within the practice sessions until the S's signal performance in the control condition appeared to be stable at 40%-50% correct. The exposure durations in milliseconds, determined for each S by the above procedure and used throughout the experimental sessions, were 15, 31, 13, and 10 for Ss M, V, and L, respectively. The number of practice sessions required for Ss M, V, L, and C were 5, 6, 10, and 6, respectively.

Each experimental session began with a period of several minutes of dark adaptation followed by presentation of a practice tray chosen randomly from the eight slide trays containing the 256 slides of the experiment in a random order. Next, the eight trays were presented in a random order, with the contraint that the tray used for practice was presented last. There was a brief rest between each slide tray. No feedback was given during the experimental sessions.

There were eight experimental sessions for each S. Sessions lasted about 30 min. To be sure that Ss did not learn the order of slides in each tray, the order was changed from the order of the practice sessions to a new order for the experimental sessions, and for the last four experimental sessions the slides in each tray were presented from last to first by advancing through the trays in reverse.

Results

For each S, there were 512 trials for each condition. Mistrials per S varied from 0.0% to 1.6%. The proportion of verification errors for trials that were not mistrials for Ss M, V, L, and C were .04, .01, .00, and .06, respectively. Apparently, these Ss also consistently fixated near the focusing bars. Table 6 presents for each S the proportion of correct signal responses for each condition for trials that had the correct verification response.

There is no indication that the over-bar condition is different from the control condition. Except in the case of C, the differences between the control condition and the double-blank or the double-bar conditions are large. To gauge the size of the effects of blanks and bars, a 95% confidence interval was computed for each S's control proportion; these intervals are given in Table 6. As in Experiment I, for each S the double-blank and the double-bar conditions were greater than the control confidence interval.

Table 6
Proportion of Correct Signal Responses for Each Condition and Each Subject of Experiment II

S	Control	Over Bar	Double Blank	Double Bar	Control Confidence Interval
M	.44	.45	.68	.65	.40, .48
V	.48	.53	.74	.76	.44, .52
L	.51	.50	.79	.77	.47, .55
C	.55	.55	.69	.62	.50, .60

Table 7
Proportion of Correct Signal Responses for Words and Nonwords of Experiment II

		Control	Over Bar	Blanks	Bars
M	Word	.42	.48	.65	.69
	Nonword	.50	.40	.72	.60
V	Word	.52	.48	.74	.73
	Nonword	.54	.49	.74	.80
L	Word	.52	.50	.80	.77
	Nonword	.48	.52	.78	.76
C	Word	.60	.58	.74	.61
	Nonword	.51	.51	.66	.62
Average	Word	.50	.51	.73	.70
	Nonword	.48	.51	.72	.70

In Table 7, the proportions of Table 6 are given for trials on which a word was the signal and trials on which a nonword was the signal. The pronounceable nonwords of this study produced virtually the same recognition performance as the words in all conditions, and the blanks and bars had the same effect on nonwords as on words.

The analysis of the most frequent errors for each signal in Experiment I indicated that error responses were similar to the correct response. In the present experiment, each signal was not presented often enough to provide a stable estimate of the most frequent error for each signal. Instead, errors for each S for each condition were divided into three categories: (1) errors matching the signal presented in the two middle letters, (2) errors matching the signal in first and last letters (either B, D or D, B), and (3) errors not matching the signal in either of these ways. The proportion of each S's errors in each of these categories is presented in Table 8 for each condition. The error proportions for responses having a correct middle and for having correct ends are in every case higher than the chance probabilities based on the assumption that every error is equally likely. In fact, a chi-square test is significant at far beyond the .001 level for the three proportions of each condition and S.

Probably the statistic showing the greatest amount of partial knowledge of the signal is the one presented in Table 9. Here, the errors having the end letters reversed from the signal are divided into those matching the middle letters of the signal and those not matching. The chance probability of matching in this case is 1/8 and is greatly under the observed proportions in every case.

A facilitative effect of bars and blanks on signal words is not evidence for the existence of a multiletter processing operation unless the facilitation entails an improvement of recognition accuracy for letters separated from a bar or blank by at least one letter. The evidence presented so far has shown that bars and blanks

Table 8
Separation of Errors into Categories of Partial Correctness for Experiment II

	Chance	M	V	L	C
Control					
$\hat{p}$ (Correct Middle/Error)	.067	.25	.14	.12	.16
$\hat{p}$ (Correct Ends/Error)	.467	.52	.63	.66	.51
$\hat{p}$ (Wrong Parts/Error)	.467	.23	.23	.22	.33
Over Bar					
$\hat{p}$ (Correct Middle/Error)	.067	.24	.13	.16	.19
$\hat{p}$ (Correct Ends/Error)	.467	.53	.61	.58	.56
$\hat{p}$ (Wrong Parts/Error)	.467	.23	.25	.26	.25
Blanks					
$\hat{p}$ (Correct Middle/Error)	.067	.40	.21	.22	.31
$\hat{p}$ (Correct Ends/Error)	.467	.51	.69	.67	.53
$\hat{p}$ (Wrong Parts/Error)	.467	.09	.10	.10	.16
Bars					
$\hat{p}$ (Correct Middle/Error)	.067	.26	.18	.21	.31
$\hat{p}$ (Correct Ends/Error)	.467	.56	.67	.61	.50
$\hat{p}$ (Wrong Parts/Error)	.467	.17	.15	.18	.19

facilitate recognition of signal words or a certain type of nonword signal. But in Experiment II, unlike Experiment I, the observed variation in signal recognition accuracy might be caused solely by variation in accuracy for end letters of the signal. To test for changes in accuracy on the middle letters of the signal, a response was counted correct if and only if the middle pair of letters was correct. The proportions correct in this sense are presented in Table 10 for word-signal trials, nonword-signal trials, and for word and nonword trials combined. A 95% confidence interval was computed for each S's control, combined proportion, and in each case the limits are the proportions ±.04. For each S for the combined proportions, the blanks proportion and the bars proportion are appreciably greater than the control confidence interval, and the over-bar proportion is in the interval. In summary, the proportions correct on the middle letters show the same pattern as the proportions correct on the whole signal.

DISCUSSION

Removal of Adjacent Letters Facilitates

Recognition accuracy for the signal group of letters when it had blanks or bars on both sides was appreciably better than when both sides had letters. The analogous result has not been tested in the case of a signal letter, but seems a natural extrapolation from the experiments of Shaw (1969), which found for all Ss facilitating effects of a single bar or blank on the far side of the signal letter from the focusing mark and the lack of effect of a single bar or blank on the near side. An important difference between the processing of a signal group of letters in the present Experiment I and the processing of a signal letter in previous experiments was that for a signal group the effect of a single bar or blank was not consistent across Ss.

Table 9
$\hat{p}$ (Correct Middle/Wrong Ends) for Each Condition and Subject of Experiment II

	Control	Over Bar	Blanks	Bars
M	.52	.51	.82	.61
V	.38	.34	.68	.54
L	.36	.38	.69	.53
C	.33	.44	.66	.61
Chance	.125	.125	.125	.125

Equivalence of bars and blanks

Blanks and bars had a nearly identical effect on recognition of the signal group in both of the present experiments, as was true in the previous experiments on letter recognition. Unpublished data (Shaw, in preparation) have further tested the equivalence of bars and blanks in an experiment like the present ones but having new conditions. Accuracy for displays having a bar on both sides of a signal word was equal to accuracy for displays having a blank (bar) on the left of the signal and a bar (blank) on the right.

This equivalence is a very interesting constraint on theories of visual recognition, and it is especially interesting for theories based on the concept of lateral inhibition (cf. Ratliff, 1965). What is definitely not expected on the basis of current lateral-inhibition theories, which make performance for one location solely a function of the light intensities stimulating it and surrounding locations over time, is the equivalent effect of a moderate-intensity area and a near-zero-intensity area on an adjacent location, as found in the present experiments. The present experiments show that adjacent characters, or perhaps only character-like patterns, decrease recognition accuracy for a character and that removing these adjacent characters can improve performance whether

Table 10
$\hat{p}$ (Correct Middle Pair of Letters) for Each Condition and Subject of Experiment II

		Control	Over Bar	Blanks	Bars
M	Word	.60	.61	.81	.77
	Nonword	.56	.57	.81	.71
	Combined	.58	.59	.81	.74
V	Word	.58	.60	.79	.79
	Nonword	.53	.58	.80	.82
	Combined	.56	.59	.80	.81
L	Word	.56	.60	.85	.84
	Nonword	.58	.55	.83	.79
	Combined	.57	.58	.84	.82
C	Word	.63	.65	.80	.72
	Nonword	.61	.63	.71	.75
	Combined	.63	.64	.76	.74

the adjacent location is now empty and illuminated or is filled with a zero-intensity object having contours. A solid rectangle has an effect quite different from that of a character. While the equivalence of bars and blanks as markers appears to be obvious intuitively to the nonscientist, it is not within the scope of current lateral-inhibition theories, which are based on experiments not using recognition accuracy as the dependent variable.

It is well known that a bright character on a black background is equivalent in recognition accuracy to a dark character on a bright background if the contrast ratios of character to background intensity are adjusted properly. This fact may seem related to the equivalence of bars and blanks, but it probably isn't. The equivalence of a bright character and a dark character probably arises from the fact that the magnitude of the spatial rate of change of intensity at the contour can be made the same in the two cases and this characteristic is used in the representation of the character. Despite the fact that bar and blanks differ not only in intensity but also in having and not having contours, they are the same, apparently, in not being treated as a character by some processing operation or, perhaps, in not having character features.

Partial Processing

Analysis of the error responses showed that words and nonword signals did not act in the present paradigm as unitary objects which were recognized or completely missed. An experiment reported by Bricker and Chapanis (1953), for example, also found that error responses tended to contain the same letters as the stimuli, which were five-letter pronounceable nonwords. Thus, a theory assuming a processing algorithm which takes the input pattern as data and determines the appropriate category of experience by testing for various familiar visual objects must also assume that the algorithm computes and stores more than just the probable visual object, at least for some stimuli in some situations. In the present experiments, probable letter components of the signal group were stored sometimes.

Existence of a Multiletter Processing Operation

The present experiments suggest that a multiletter processing operation that is facilitated by bars and blanks exists. This inference is based on the assumption that the signal-letter experiments of Shaw (1969) show the effects of bars and blanks on a single-letter operation and the fact that the present results show effects of bars and blanks not readily interpreted in terms of this operation. The relevant results are the following: (1) bar and blank conditions were appreciably better than the control condition in Experiment I, and in this experiment bars and blanks were never adjacent to a letter useful in selecting a correct response. This contrasts with the signal-letter experiments, in which replacing letters with a bar or blank facilitated recognition reliably only for an adjacent letter. (2) In Experiment II, the proportions correct on the middle pair of letters were appreciably higher for the double-bar and double-blank conditions than for the control, and these letters were not adjacent to a bar or blank. (3) In contrast to the signal-letter experiments where a preblank or a prebar did not facilitate recognition for any S, in Experiment 1 a preblank or prebar appeared to facilitate signal group recognition for two or three of the four Ss.

Equivalence of Words and Certain Nonwords

The only major difference between the present experiments and the experiments of Shaw (1969) is the use in the present experiments of pronounceable signal groups of letters. Results 1 through 3 above indicate that the effect of a bar or blank on a word or nonword is not what would be expected on the basis of the effect on each of the several letters if some of the letters had not been frequently experienced together in an order. But accuracy for words was equal to accuracy for certain pronounceable words in all conditions having the same middle letters as the words. Thus, it seems that bars and blanks affected pronounceable nonwords like words either because the nonwords were pronounceable or because the nonwords contained the same frequent English letter pairs for middle letters.

Distance Between the Signal and the Background

In Experiment II, accuracy for a signal with a bar over it delimiting the signal location was about the same as accuracy for the control condition. A similar result was found in an unpublished experiment which found the following conditions to be equivalent: a bar under the signal word, a bar over the signal word, a bar over and a bar under the signal word, and the control no-bar condition. These results point to the distance between the signal and background letters as the critical variable for the bar/blank effect.

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