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Do small visual angles produce a word superiority effect or differential lateral masking?

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Purcell, Stanovich, and Spector (1978) report that recognition of the center letter of the words APE, ARE, ACE, and AGE is superior to recognition of the same targets in the nonwords formed by the context letters V_H. Since a small set of predesignated targets was used and there was complete certainty about the location of the target letter, these results pose serious problems for three otherwise viable accounts for why word superiority effects (WSEs) are obtained in a variety of other paradigms. This series of experiments explores the possibility that the word advantages reported by Purcell et al. have nothing to do with the lexical properties of the A_E display or the general phenomenon of word superiority, but they result from a fortuitous case of differential lateral masking. This reinterpretation is supported by five experiments. Experiments 1 and 2 show that the A_E word advantages are anomalous in that the magnitude of the WSE obtained with these particular words is not contingent upon the presence of a patterned mask. Experiment 3 provides direct evidence for differential lateral masking by showing that digit recognition is poorer in the V_H than in the A_E frame. Experiments 4 and 5 show that the WSE obtained under these conditions does not generalize to a new set of words and nonwords that produce the same amount of lateral masking. It was concluded that a genuine WSE does not occur under the conditions tested by Purcell et al., and that, therefore, the WSE has not been shown to depend on visual angle.

Letter recognition is usually better when a target is presented in a word compared with when it is presented either alone or in a sequence of orthographically irregular letters. Reicher's (1969) contribution to our understanding of this word superiority effect (WSE) was to control for response biases by forcing subjects to choose between two alternatives that did not change the lexical status of the test display. That is, on word trials both alternatives would form a word, whereas the incorrect alternative on nonword trials would always form another nonword. Since word advantages occur with this control, it is clear that the WSE involves more than a simple bias to respond with a letter name that forms a word in the surrounding context.

Subsequent tests of various hypotheses concerning the locus of the WSE have often sought to determine the necessary and sufficient conditions for its occurrence. Of special interest to this discussion is a series of experiments reported by Purcell, Stanovich, and Spector (1978). In their first two experiments, these investigators obtained word advantages when (1) a fixed set of predesignated targets was used throughout the experimental session, (2) the target location was fixated and known in advance of stimulus presentation, and (3) the type of context, in this case word or consonant trigram, was randomly varied from trial to trial. In a final experiment the WSE was erased when these same conditions were preserved, but the visual angle and interletter spacing were increased. The pattern of results is provocative since the appearance of word advantages under the conditions described is inconsistent with three of the competing hypotheses concerning the locus of the WSE, while its disappearance in the third experiment suggests that the WSE, under these conditions, may be restricted to foveally presented material.

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Implications for the Perceptual Inference Model

The presence of word advantages with a small set of predesignated targets is most damaging to Massaro's perceptual inference model. Since the two target alternatives in Reicher's (1969) procedure were presented after the test display, Massaro (1973; Thompson & Massaro, 1973) has argued that the perceptual recognition process may have been guided by inferences, drawn from knowledge of orthographic

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redundancy, and operating on letter-size units. As an example, suppose the word SPOT is presented and the subject detects sufficient visual features for the perceptual recognition process to synthesize S, O, and T but does not permit discrimination between P and D as candidates for the second position. According to the inference model, P will be synthesized since D is not legal. If the alternatives P and H are presented, the observer will, of course, correctly choose P. However, if the orthographically irregular anagram TPSO has been presented, either P or D may be synthesized as the complete percept in the second position, since neither is legal. When D is synthesized, and the alternatives P and H are subsequently presented, the observer can do no better than chance performance, since the model assumes that the features used in perceptual synthesis are not available to the conceptual recognition process that is responsible for selecting the final verbal classification.

As a test of the perceptual inference model, Massaro (1973, Experiment 2) required a forced choice between pairs from a set of targets (viz., P, R, C, and G) that was used throughout the experimental session. The target letter always appeared in the center position of three-letter displays. On word trials the adjacent context letters were always A and E; on nonword trials the adjacent context letters were always V and H. Under these conditions, Massaro reasoned that knowledge of the alternatives would be incorporated into perceptual processing, thus eliminating the effects of redundancy. The results supported this analysis, since the word-nonword conditions did not differ from each other at any of the eight processing intervals tested. Similar findings were reported at about the same time by Bjork and Estes (1973) and Estes, Bjork, and Skaar (1974). Although the word advantages reported by Purcell et al. (1978) do not rule out the possibility that perceptual inference may contribute to the WSE found under certain circumstances, their results certainly do question the generality of the perceptual inference model.

Implications for Strategy Models

The presence of word advantages under conditions in which context type randomly varies is most damaging to a position advocated by Carr, Lehmkuhle, Kottas, Astor-Stetson, and Arnold (1976) that emphasizes the importance of subject-controlled attention-allocation processes in the WSE. This view argues that readers have learned to maximize efficiency by allocating more attention to the beginnings and ends of words than to the center positions. Consequently, performance on the initial and terminal letters should be better on word displays than on nonword displays, as long as the subject is expecting words and has engaged the normal reading strategy. Carr et al. (1976) tested the attention-allocation model by introducing two modifications into the paradigm developed by Massaro (1973). First, context type was blocked instead of randomized. This would permit subjects to adopt different allocation strategies on the word and nonword displays. Second, the words POT, ROT, COT, GOT, TAP, TAR, TAC, and TAG (together with appropriate nonword controls) were added to Massaro's materials so that the position of the target letter could be varied across trials. A WSE was obtained in the first and last positions, but not in the center. This is consistent with the view that subjects pay more attention to the outside letters when they are expecting words, and it also provides two reasons for Massaro's failure to obtain a WSE; namely, subjects did not know when to adopt a word-processing strategy, and only the center position was tested.

An earlier report by Johnston and McClelland (1974) also supports the view that subject-controlled strategies are critical to obtaining the WSE. In the first experiment, all of the stimuli were four-letter words; in the second experiment, they were unpronounceable quadrigrams. In each experiment the subject's strategy was directly manipulated through instructions. For half of the trial blocks, subjects were instructed to fixate the middle of the display and try to see the whole stimulus. On the remaining trials, subjects were told the position of the target letter and were further instructed to fixate that position and try to see only the letter that appeared there. Instructing subjects to pay attention to the whole stimulus, rather than to just the target letter, produced better performance with word stimuli (Experiment 1), but worse performance with unrelated letters (Experiment 2). Combining the data from both experiments leads to the inference that the WSE occurs when subjects allocate their attention across all letters of the display, but that nonwords produce better performance when subjects fixate and attend to only the target position.

The word advantages reported by Purcell et al. (1978) do not rule out the possibility that strategies may still contribute to the WSE found in some studies. However, these results certainly call into question whether any support for strategies can be drawn from the experiment by Carr et al. (1976). These investigators conclude that there were two critical differences between their experiment and that of Massaro (1973), namely, the blocked presentation of the words and nonwords that permitted the subjects to use a word-processing strategy and the variation in target location, which permitted them to test for word advantages at the ends, as well as the middle, of the displays. However, the true critical difference may have been that Carr et al. used small displays and Massaro used large displays. This seems reasonable, since the Purcell et al. study shows that word advantages can occur with Massaro's materials and procedure as long as the display size is small.

Implications for the Perceptual Confusion Model

The presence of word advantages when there is complete certainty about the location of the target letter is most damaging to a perceptual confusion model developed by Paap, Newsome, and Rudy (Note 1) to specify the conditions that should produce a WSE when predesignated targets are used.[1] This model starts with the premise originally advanced by Smith (1971), namely, that letter sequences corresponding to whole words can be perceptually synthesized on the basis of fewer letter features than would be necessary to perceive the constituent letters presented in isolation. If whole words can be perceived on the basis of fewer criterial features, then subjects will have more accurate information about the letters in a word than about the letters in a nonword. The importance of perceptual confusions in the predesignated-targets paradigm arises from the further assumption that the advantages of a word match should be much greater for the recognition of the context letters than for that of the target letter. The logic of this assumption is as follows. When the subject searches on every trial for the same small set of targets, it is likely that the letter units corresponding to the targets will have their criteria lowered to the point at which they may be activated on the basis of very little evidence. This means that there is a very good chance that the input from the target location will activate the corresponding letter unit. However, lowering the criterion for the target units will also increase the probability that the input from a context letter will activate one of the incorrect target units. Assuming that word matches override incompatible or ambiguous matches at the level of individual letter units, it therefore follows that the occurrence of a word match is more likely to correct the errant matching of context-letter input than of target-letter input. This, in turn, makes it less likely that a context letter will be mistaken for a target when the target is embedded in a word as compared with in a nonword.

As an example, consider an experiment that used the predesignated target set M, N, P, and R and a trial on which the word NICK is presented. If the subject knows that the target will occur in the first position, then his decision will be based only on the evidence concerning the identity of the character located in the specified target location. In this example all four potential targets form a word in the following context. Consequently, there is no way for the perceptual recognition process to take advantage of lexical knowledge to further reduce the number of viable alternatives. Accordingly, performance should be the same as in the nonword NJCK, for which, once again, the recognition process must find the best match between the visual features detected in the first position and the four potential targets.

The situation is quite different when the target can occur in any position. In this case, the input from each location must be considered a potential target, and occasionally the input from a context letter may look just as much (or more) like one of the incorrect targets than the input from the target location looks like itself. For example, suppose that when NICK is presented, N, I, and C are unambiguously synthesized in the first three positions, but the partial information extracted from the last position supports either K or R. (Support for an incorrect target, R in this case, should occur often, since the model assumes that predesignating the targets leads to a reduction in the number of criterial features necessary to activate those letter units.) Since NICR is a nonword, the only potential word match is NICK. If the word NICK is activated, the evidence from the word match will support N in the initial position, and the subject will correctly respond that N was the target. In contrast, when a nonword such as NJCK is presented, the context NJC__ does not form a word with either K or R and either letter could be synthesized. When R is synthesized, the subject will have to choose between the N seen in the first position and the R seen in the last position. On these trials the subject will have only a 50% chance of being correct. Performance will be lower with nonwords than with words to the extent that this type of confusion occurs more often with the nonwords.

The first experiment reported by Paap et al. (Note 1) used the predesignated targets M, N, P, and R embedded in either four-letter words or consonant strings formed from randomly replacing the vowels of the 80 words with consonants. On half the trials the target location was fixated and known in advance of stimulus presentation; on the other half fixation was centered and target location was unknown. As predicted by the perceptual confusion model, planned comparisons on the significant Context Type by Cuing interaction showed that word advantages occur under conditions of positional uncertainty, but not when target location is known in advance. In a subsequent analysis both the words and nonwords were partitioned into sets whose context letters were either highly confusable with the incorrect targets or contained low levels of visual similarity. The perceptual confusion account of the WSE was further supported, since under conditions of positional uncertainty a significant WSE occurred with the highly confusable items, but not with those of low confusability. Furthermore, the results show that the location cue facilitated performance on the highly confusable nonwords, while having very little effect on either type of word or the nonwords of low confusability.

Since the results show that word advantages can be eliminated when subjects are given a location precue and permitted to fixate the target location, the perceptual confusion model seems to neatly account for the fact that Carr et al. (1976) obtained a WSE with predesignated targets and positional uncertainty, while Massaro (1973) failed to obtain a WSE with predesignated targets and positional certainty. The failure of Estes and his associates (Bjork & Estes, 1973; Estes et al., 1974) to find a WSE with predesignated targets and positional uncertainty suggests some important limitations for the perceptual confusion model. Since Estes always had subjects searching for only two potential targets, R and L, there were fewer potential confusions than when four targets are used. For example, the four targets and four-letter displays used in our experiments provided nine potential confusions, whereas the two targets and four-letter displays used by Estes provided only three possible confusions per trial.

In summary, we feel that the perceptual confusion model definitely specifies an important determinant of the WSE in experiments using predesignated targets and may account for all of the word advantages reported in this paradigm. The model's ability to account for all of the data is more seriously questioned by the finding that word advantages occur when the opportunity for confusion is eliminated (Purcell et al., 1978) than by the occasional failure to find word advantages when some confusions are possible (Estes et al., 1974).

Evaluation of the Size-Contingent More-Features Model

In summary, it is evident that the WSE obtained by Purcell et al. (1978) cannot be predicted from the models advocated by Carr et al. (1976), Massaro (1973), and Paap et al. (Note 1). Accordingly, it is necessary to bring the specific details of this important finding into sharp focus. In their first experiment, Purcell et al. used the same words and nonwords as Massaro (1973, Experiment 2). However, the stimuli subtended a horizontal extent of only .53 deg, compared with 3.33 deg in Massaro's study. Purcell et al. feel that it was the unusually large size of Massaro's stimuli, rather than his controls for perceptual inference, that produced the equivalence between words and nonwords. This hypothesis is suggested by their observation that, when inference is controlled through the use of predesignated targets, advantages of words over nonwords are found with stimuli subtending 1.0 deg or less (Carr et al., 1976; Smith & Haviland, 1972; Spector & Purcell, 1977), but not with larger displays (Bjork & Estes, 1973; Estes, 1975; Estes et al., 1974; Massaro, 1973). In their introduction, Purcell et al. suggest that this correlation between the WSE and retinal size should be consistent with a size-contingent more-features model. The more-features notion was first discussed by Wheeler (1970); it assumes that words actually contain more information than individual letters. This information may be in the form of supraletter features that correspond to word envelopes, word length, or the distinctive configuration of certain letter groups. Under the further assumption that units of larger than letter size are processed in parallel with letter units, it is clear that this additional information could account for the WSE even when inferential processes have been controlled. Purcell et al. extend the basic more-features model by hypothesizing that supraletter features will be automatically processed "only when the visual display subtends a fairly small visual angle" (1978, p. 7).

Although we would certainly agree that extremely large displays would have to be processed letter by letter and that the use of abnormally large intercharacter spaces (such as those used by Purcell et al. 1978, in Experiment 3) would destroy the effectiveness of shape cues, it is not clear why the automatic extraction of supraletter features should be precluded by normally spaced stimuli in the range of 1.0 to 5.0 deg. Gross features such as overall configuration and length should certainly be perceptible within this range.

Purcell et al. (1978) also discuss a possible interaction between retinal position and backward masking in the WSE. First, they note that a patterned mask seems to be necessary to obtain a WSE (Johnston & McClelland, 1973; Massaro & Klitzke, 1979). Next, they review several studies that show that masking effects are significantly greater when retinal locus is changed from .0 to about 1.7 deg. This suggests that the outside letters of the larger word displays may be more effectively masked than the center letters. This may be very important when the target letter is in the center and the context letters are on the outside, since, under these conditions, the context letters may be rendered nonfunctional, while the central target letter may still be seen with reasonable clarity. This gives a plausible account of the size-contingent WSE reported by Purcell et al., but it would seem to limit the importance of retinal size to those experiments in which the subject always fixates the target position. If the target can occur in parafoveal, as well as in foveal, vision, then one might expect the opposite result. The basic premise of this argument is that the discriminability advantage of supraletter features such as shape and length over the more detailed features necessary to recognize individual letters should increase as the visual input is degraded. Assuming that the target is not always foveally fixated, this analysis suggests that as masking effectiveness is increased by using larger displays, the subject may be forced to rely more on the supraletter features than on the less discriminable infraletter features. Consequently, the WSE would be greater for large displays than for small displays.

To this point we have simply argued that there does not seem to be a compelling reason to assume that supraletter features will be automatically processed only when the component letters are in foveal vision, but we have not addressed the facts of the matter, namely, that Purcell et al. (1978) produced large word advantages with small stimuli and no advantages with large material. Purcell et al. suggested that the WSE could be attributed to the automatic extraction of supraletter features. But, considering the particular materials in question, what are the supraletter features that permit a subject to discriminate APE from ARE and ACE from AGE? An alternative explanation for the WSE observed with small stimuli is differential lateral masking. The A_E frame may interfere less with the perception of the target letter than does the V_H frame. If such differential lateral masking existed, the effects would be more apparent when the letters were close together than when they were farther apart. This follows since separation is one of the important determinants of the magnitude of lateral masking (Bouma, 1970). This would explain the absence of the WSE in both Massaro's (1973) original report and in Experiment 3 of Purcell et al., since in both cases the separation between adjacent letters was about .7 deg. In contrast with this rather large interletter spacing, the context letters of the small displays used in the first two experiments of Purcell et al. nearly touch the target letter. These points of minimal separation are difficult to measure, but they are probably less than .03 deg.

The implications for a lateral masking reinterpretation of these results is obvious since this explanation rests simply on the differences in visual structure between the A_E and V_H frames. It becomes only a fortuitous coincidence that the target letters formed words in the context of the less effective mask and nonwords in the context of the more effective mask. With this reinterpretation in mind, we decided to replicate the results of Purcell et al.'s (1978) first experiment with our tachistoscope (Experiment 1) and show that the word advantages obtained with these materials do not require a patterned mask as do those observed by others (Experiment 2), that the V_H context can laterally mask a set of target digits more effectively than the A_E context (Experiment 3), and, finally, that the WSE found under the conditions imposed by Purcell et al. with the A_E and V_H contexts does not generalize to another set of materials (Experiments 4 and 5).

EXPERIMENT 1

The first experiment was very similar to Experiment 1 of the Purcell et al. (1978) series, with the following modifications. First, our mask was somewhat different, since the mask used by Purcell et al. is not described in sufficient detail to permit a precise reconstruction. Our mask consisted of a series of three overprinted Xs and Os that coincided with the spatial locations of the test displays. The mask characters were typed with the same element used to type the test letters and, consequently, were approximately the same size and had the same stroke width as the test letters. Purcell et al.'s mask also consisted of overprinted Xs and Os, but they covered a width and height that was almost twice that of the three-letter displays. It is not clear whether the size and stroke width of the characters in their mask were the same as that of the letters used in their test displays. Second, it was not possible for us to adjust the test and masking field to the same intensities used by Purcell et al. Accordingly, instead of setting the masking field to about two-thirds the intensity of the test field, we simply set both fields to the same intensity. Third, the fixation point appeared only during the 1-sec interval just prior to the onset of the test display, rather than being continually illuminated. In all other respects we attempted to replicate the materials, event timing, and procedures as faithfully as possible. The purpose of this first experiment was simply to determine if the word advantages that Purcell et al. report with their small displays could be replicated with the minor changes indicated above.

Method

Subjects. Fifteen introductory psychology students from New Mexico State University served as subjects.

Materials and Apparatus. The stimulus set consisted of the words ACE, AGE, APE, and ARE and the nonwords VCH, VGH, VPH, and VRH. The uppercase letters of the IBM Pica Prestige typing element were used to type each display. No additional spaces were inserted between the letters. The test displays were presented via an Iconix tachistoscope at a viewing distance of 88.9 cm. Since the maximum horizontal extent of the three-letter displays was about 7 mm, the displays subtended a visual angle of .45 deg. Since we used the same typing element and viewing distance as Purcell et al. (1978), it is not clear why their reported visual angle was slightly greater (.53 deg) than ours. The mask consisted of three overprinted Xs and Os that were typed with the same element and in the same positions as the test displays.

Procedure. Each trial was initiated by a 1-sec warning tone. Immediately following the warning signal, a fixation point was presented for 1 sec just below the center position of the upcoming test display. The duration of the test field was set at 30 msec, and that of the mask field at 1,000 msec. The asynchrony in onset (SOA) of the test display and mask was adjusted during the practice trials so that each subject had an overall error rate of about 25%.

Subjects were instructed to look directly at the fixation point and to report only the center letter of each test display. The subjects were forced to choose between the four targets C, G, P, and R and were required to guess if they were not sure what letter they had seen. The displays were presented in random order with the restriction that each display appear three times in a block of 24 trials. Feedback was provided during the three blocks of practice trials, but not during the six blocks of experimental trials. If the subject's performance level appreciably drifted from the desired 25% error rate, the SOA was adjusted so as to bring him back to that performance level. Adjustments were made only at the conclusion of a block of 24 trials, so that an equal number of words and nonwords were always presented at a given SOA.

Results and Discussion

For each subject, the percentage of errors was computed for each of the two context types. Across subjects, the mean percent errors for the A_E words and V_H nonwords were 23.1% and 33.1%, respectively. An analysis of variance with context type as a within-subjects factor indicated that the effect of context type was significant [$F(1,14) = 21.54$, $p < .001$]. Thirteen of the 15 subjects displayed superior performance with the A_E word displays, 1 subject performed equally on the two context types, and another did better on the V_H nonwords. Clearly, the WSE reported by Purcell et al. (1978) under similar conditions has been replicated. In fact, the 10% word advantage observed in this experiment was somewhat larger than the 7.5% advantage obtained by Purcell et al.

Although Purcell et al. (1978) do not report the magnitude of the WSE for each individual target, we feel such an analysis is mandatory when general processes concerning language stimuli are tested from an extremely small sample of words. Large, but idiosyncratic, effects nested within a single stimulus could cause the appearance of a systematic effect when none exists or even obscure a smaller but more general effect that produces the opposite outcome. Furthermore, an analysis of the individual targets would seem to be especially profitable in this experiment, since the more-features and differential masking hypotheses do not predict the same type of Context Type by Target Letter interaction.

If the word advantages are due to the processing of supraletter features, then the advantages of any given word over its control should be determined by the likelihood that supraletter features have been abstracted and stored and are utilized in the recognition of that word. It seems reasonable to assume that this should occur most often with words of high natural language frequency. Based on the Kučera and Francis (1967) frequency count presented in Table 1,

Table 1
Natural Language Frequency of Word Sets

Experiments 1 and 2			Experiment 4		
	T-L	K-F		T-L	K-F
ACE	3	15	ODE	6	0
AGE	AA	227	ORE	18	3
APE	6	3	ONE	AA	3292
ARE	AA	4393	OWE	A	10

Note—*T-L = Thorndike-Lorge (1944) occurrences per million; A = at least 50 per million and less than 100 per million; AA = 100 or more per million. K-F = Kučera and Francis (1967) occurrences in corpus of 1,014,232 words of text.*

Table 2
Mean Percentage of Errors for Each Target in Each Type of Context

Context Letters	Target Letters or Digits			
	Experiment 1			
	C	G	P	R
A_E	34.8	27.4	15.2	14.8
V_H	37.4	40.7	34.8	19.6
Difference	+ 2.6	+13.3*	+19.6†	+4.8
	Experiment 2			
	C	G	P	R
A_E	21.8	27.4	15.9	26.2
V_H	42.5	21.4	29.0	35.3
Difference	+20.7†	− 6.0	+13.1†	+9.1*
	Experiment 3			
	3	6	8	9
A_E	19.0	22.2	37.3	22.2
V_H	23.0	31.7	44.4	23.8
Difference	+ 4.0	+ 9.5	+ 7.1	+1.6
	Experiment 4			
	D	R	N	W
O_E	25.0	18.5	27.3	40.7
C_F	17.1	25.9	37.0	34.7
Difference	− 7.9*	+ 7.4	+ 9.7	−6.0
	Experiment 5			
	3	6	8	9
O_E	16.7	40.5	23.0	22.2
C_F	20.6	45.2	25.4	23.0
Difference	+ 3.9	+ 4.7	+ 2.4	+ .8

*$p < .05$. †$p < .01$.

it is evident that the magnitude of the WSE should be greatest for ARE, with AGE producing somewhat larger advantages than either ACE or APE. Failure to observe this pattern of interaction would not seriously weaken the more-features hypothesis since other factors, such as the relative distinctiveness of the supraletter features, are also involved. However, if a consistent relationship were found between the magnitude of the WSE and word frequency, it would be consistent with the expectations of the more-features model, but difficult to explain from the view of differential masking.

The first and second lines of Table 2 show the average percentage of errors for each of the target letters in the V_H and A_E contexts, respectively. The difference scores on the third line can be thought of as the magnitude of the WSE for each target letter, with a plus sign indicating more errors on nonwords than on words. An analysis of variance with context type and target letter as within-subjects factors shows the previously discussed significant main effect of context type and a significant main effect of target letter [$F(3,42) = 8.65$, $p < .01$], but a nonsignificant interaction between context type and target letter [$F(3,42) = 2.24$, $p > .05$]. Despite the lack of a significant interaction, a series of planned linear contrasts was performed to test for a WSE with each individual target letter. The 19.6% and 13.3% advantages for APE and AGE were significant [ts(14) = 4.13 and 2.60, ps < .01 and .05, respectively]. The 4.8% and 2.6% advantages for ARE and ACE were nonsignificant ($p > .05$ in both cases). One must treat these differences cautiously, but from the more-features point of view, they suggest that the availability of supraletter features is different across the stimulus set and that this availability is the opposite from what one might expect on the basis of natural language frequency.

Table 3 contains the confusion matrices for the A_E and V_H context types. The first four rows of each matrix show the distribution of incorrect responses for each display; the last row of each matrix shows the same information collapsed across the four target letters. The confusion matrices offer myriad opportunities for post hoc explanations of the large word advantages found with ACE and APE. Rather than engage in this type of speculation, we would like to simply focus on the overall distribution of incorrect responses. Since 47.4% of all incorrect responses were "R," it is apparent that there may have been a sizable response bias, despite the fact that all target letters were equiprobable. This response bias may have been abetted by the fact that the overprinted Xs and Os of the mask may look more "R-like" than any other target. The bias toward R seems to have been somewhat stronger in the V_H context than in the A_E context. This would be consistent with the view that the V_H context is a more effective masker and, consequently, is more likely to degrade the percept of the target letter to the point at which the subject is just guessing and likely to use a response bias.

Table 3
Confusion Matrices for the Two Context Types: Experiment 1

Display Presented	Incorrect Response Alternatives			
	C	G	P	R
ACE		.63	.08	.29
AGE	.27		.20	.53
APE	.10	.10		.80
ARE	.08	.22	.70	
All A_E	.11	.29	.20	.40
VCH		.44	.11	.45
VGH	.25		.04	.71
VPH	.06	.25		.69
VRH	.09	.49	.42	
All V_H	.11	.26	.10	.53

Note—Entries are proportions of the total number of incorrect responses that were made to the indicated display; for example, .63 of errors to ACE were "G" responses.

EXPERIMENT 2

We have suggested that the main effect of context type observed in the first experiment may have nothing to do with the lexical or orthographic properties of the word displays, but rather, that the A_E context interferes less with the perceptibility of the target letter than does the V_H context. A basic assumption of the differential masking hypothesis is that large lateral masking effects can co-occur under conditions of backward pattern masking. However, Weisstein (1968) has suggested that the same neural mechanism is responsible for lateral and backward masking, and that, consequently, interference caused by lateral masking may be overwhelmed in the presence of a strong backward mask. Accepting this possibility, Johnston and McClelland (1973) have argued that lateral masking may be inconsequential when a backward mask is used. If this is true, it would be folly to suggest that differential lateral masking could be responsible for word advantages as large as 10%.

Fortunately, a recent experiment by Massaro and Klitzke (1979) seems to justify our assumption that lateral masking effects are independent from backward masking effects. Letters alone, words, nonwords, and letters embedded in dollar signs were utilized as test displays in the postcue paradigm first developed by Reicher (1969). The test display was followed by a masking stimulus at any of several different SOAs and on some trials by no mask at all. The effect of lateral masking, uncontaminated by the contribution of lexical context, can be assessed for each masking condition by directly comparing the nonword and letter-alone conditions. No consistent letter advantages are apparent at the four shortest SOAs. However, letter superiority effects of 6%, 8%, 8%, and 9% emerge at SOAs of 128, 163, 203 msec, and the no-mask condition, respectively. Thus, significant lateral masking effects were observed when the backward mask was presented at SOAs comparable to those used in Experiment 1. Most of the subjects in Experiment 1 maintained an SOA of about 165 msec. In addition, Massaro and Klitzke tested a mathematical model that does not require a neural tradeoff between lateral masking and backward masking. In this model lateral masking simply lowers the potential figure-ground contrast of the test letter, whereas the onset of a backward mask determines the available processing time. When the parameter that reflects lateral masking was estimated independently of the presence or delay of the backward mask, a reasonably good description of the results was obtained. More important, the fit was not significantly improved when the constraints on this parameter were removed.

Massaro and Klitzke (1979) also replicated Johnston and McClelland's (1973) finding that a patterned backward mask is necessary to produce large WSEs. This finding may be important in determining the locus of the WSE. If the primary effect of a backward mask is to control available processing time, then the relative benefits of linguistic context will depend upon whether or not the facilitation is due to an increase in the rate of processing of the target letter. If context speeds the rate of perceptual recognition, then, clearly, one would expect large benefits when processing time is limited and smaller effects when it is not. On the other hand, if words contain more potential information (e.g., supraletter features), then words should be superior to nonwords regardless of the masking conditions. In the Massaro and Klitzke study, the magnitude of the WSE can be measured by directly comparing performance on word displays with that on nonwords. The largest WSE of 12% occurred at an SOA of 73 msec and monotonically declined as processing time increased to the no-mask level of 4%. Massaro and Klitzke conclude that this interaction is most consistent with the view that the WSE is due to an enhancement in the rate of processing of the test letter, rather than to an increase in the amount of potential information in the display.

Depending upon one's perspective, the Masking by Context interaction just described can be viewed as either consistent or inconsistent with the size-contingent more-features model. Purcell et al. (1978) have suggested that the automatic extraction of supraletter features may be responsible for the word advantages reported in two studies using predesignated targets and displays as large as 1.0 deg (Carr et al., 1976; Smith & Haviland, 1972). The WSE reported by Carr et al. was a robust 12%. Supraletter features should have been salient in the Massaro and Klitzke (in press) materials, since the four-letter displays subtended about 1.5 deg, appeared to have reasonably normal spacing (a space was about .38 of the width of a small letter), and were printed in lowercase. Accordingly, there should have been large word advantages in the no-mask condition. Thus, the 4% WSE obtained suggests that supraletter features play a modest role at best in the Reicher (1969) postcue paradigm, even when the display sizes are in the range in which one might expect these features to be automatically extracted. However, one could also argue that there is a fairly sharp boundary somewhere between 1.0 and 1.5 deg and that the component letters in the Massaro and Klitzke study were too far into the periphery to permit the automatic extraction of supraletter features and, consequently, that no word advantages were to be expected in the no-mask condition.

In any event, the previous investigations of backward masking lead to the following predictions when the APE, ARE, ACE, and AGE materials are tested without a patterned mask. First, if the WSE found with these stimuli is essentially the same phemonenon as the WSE reported in the Reicher (1969) postcue paradigm, then we would expect the magnitude of the word advantage to be significantly attenuated in the no-mask condition. Alternatively, if the WSE found with A_E words is due to either differential lateral masking or the availability of supraletter features, then the magnitude of the word advantage in the no-mask condition should be about the same as that in the mask condition.

Method

Subjects. Fourteen introductory psychology students from New Mexico State University served as subjects.

Materials and Procedure. The second experiment used the same materials and apparatus, with the exception that a plain white mask replaced the overprinted pattern of Xs and Os used in the first experiment. The design and procedure were identical to that of Experiment 1, with the exception that stimulus duration (mean = 19.0 msec), rather than SOA, was used to adjust performance to the desired 25% error rate. The white postexposure field always immediately followed the offset of the test display.

Results and Discussion

Across subjects, the mean percentage of errors for the A_E words and the V_H nonwords were 22.8% and 32.0%, respectively. Twelve of the 14 subjects displayed superior performance with the words, and 2 with the nonwords. The 9.2% difference observed in this experiment is nearly identical to the 10.0% difference obtained in Experiment 1. Clearly, the absence of a pattern mask does not severely attenuate the advantage of A_E displays over the V_H context. Since the magnitude of the WSE was much greater in the pattern-mask condition of two previous studies (Johnston & McClelland, 1973; Massaro & Klitzke, in press), one suspects that the mechanism responsible for the word advantages in the Reicher (1969) paradigm is not the same as that producing the A_E advantages in the present experiments.

Table 2 shows the mean percentage of errors in the V_H and A_E contexts for each of the four target letters. An analysis of variance with context type and target letter as within-subjects factors showed a significant main effect of context type [$F(1,13) = 27.29$, $p < .01$] and a significant Context Type by Target Letter interaction [$F(3,39) = 4.17$, $p < .05$], but a nonsignificant main effect of target letter [$F(3,39) = 2.13$, $p > .05$]. The significant Context Type by Target Letter interaction was further analyzed with a series of planned linear contrasts that assessed the context effect for each target letter separately. The 20.7% and 13.1% advantages for ACE and APE were significant at the .01 level [$ts(13) = 16.17$ and 2.94, respectively], and the 9.1% advantage for ARE was significant at the .05 level [$t(13) = 2.18$]. The 6.0% advantage of VGH over AGE was nonsignificant. It is interesting to note that, although the overall magnitude of the WSE was almost identical in the

Table 4
Confusion Matrices for the Two Context Types: Experiment 2

Display Presented	Incorrect Response Alternatives			
	C	G	P	R
ACE		.80	.09	.11
AGE	.26		.29	.45
APE	.08	.20		.72
ARE	.12	.52	.36	
All A_E	.13	.38	.21	.29
VCH		.79	.09	.11
VGH	.22		.28	.50
VPH	.08	.47		.45
VRH	.05	.56	.39	
All V_H	.07	.52	.19	.22

Note–Entries are proportions of the total number of incorrect responses that were made to the indicated display; for example, .80 of all errors to ACE were "G" responses.

two experiments, the effects on individual targets were quite different. For example, AGE produced a significant word advantage with a pattern mask, but not without, whereas just the opposite was found for ACE and ARE. This further illustrates the danger of testing for general language effects with a small set of materials. Not only is there a great deal of variation between words, but the pattern of variation can be drastically altered by the conditions of masking.

Table 4 contains the confusion matrices for the A__E and V__H conditions of Experiment 2. The first four rows of each matrix show the distribution of incorrect responses for each display; the last row of each matrix shows the same information collapsed across the four target letters. As in Experiment 1, the pattern of confusions is sometimes surprising and not easily interpreted. For example, when G is presented, subjects are much more likely to report seeing an R than the more similar target C. With respect to overall distribution of incorrect responses, it is apparent that the heavy bias to respond "R" in Experiment 1 was replaced in Experiment 2 by a comparable bias to respond "G." The elimination of the bias toward R follows from the fact that Experiment 2 did not use the R-like mask of overprinted Xs and Os, but we have no explanation for the large number of incorrect "G" responses.

EXPERIMENT 3

If the context effects observed in Experiments 1 and 2 were due to differential lateral masking and had nothing to do with the lexical status of the test displays, then one ought to be able to produce similar effects with targets that do not form words in the A__E context. Accordingly, the targets C, G, P, and R were replaced with the digits 3, 6, 8, and 9. If the V__H frame is a more effective lateral masker than the A__E frame, then digit recognition should be poorer with the V__H displays. Digits, rather than another set of letters, were selected, since it could be argued that strings like AME or AFE are more word-like and have greater orthographic redundancy than strings like VMH or VFH.

Method

Subjects. Fourteen introductory psychology students from New Mexico State University served as subjects.

Materials and Procedure. The displays used in this experiment were the same size as those used in Experiments 1 and 2, but they consisted of A3E, A6E, A8E, A9E, V3H, V6H, V8H, and V9H. The design and procedure were identical to those used in Experiment 2.

Results and Discussion

Across subjects, the mean percentage of errors for the A__E displays and the V__H displays were 25.2% and 30.8%, respectively. An analysis of variance with context type as a within-subjects factor indicated that the effect of context type was significant [$F(1,13) = 4.99$, $p < .05$]. Ten of the 14 subjects displayed superior performance with the A__E displays, 1 subject showed no difference, and 3 subjects were better with the V__H displays. Although significant, the 5.6% context effect found in this experiment is not as great as the 10% effects found with letters. One could argue that this difference suggests that the word advantages found in the earlier experiments were a combination of the availability of supraletter features and the effects of differential lateral masking. However, one cannot rule out the possibility that the smaller magnitude of the context effect in this experiment was due to the structural differences between the digit and letter targets. Adriessen and Bouma (1976) have shown that the letter v is interfered with more than certain other letters when presented in the context x__x. Similarly, Estes, Allmeyer, and Reder (1976) have noted a special tendency for letters containing a vertical line segment to be masked more strongly by a # mask than by a $ mask. Since the critical discriminative features of P, R, C, and G are linear, whereas those of 3, 6, 8, and 9 are curvilinear, it may be that the digits are less susceptible to the adverse effects of the straight-line contours inherent in both V__H and A__E. If the overall level of lateral masking is less in the digit experiment, then it follows that the differential effects of the two context types would also be attenuated.

Table 2 shows the mean percentage of errors in the V__H and A__E contexts for each of the four target digits. An analysis of variance with context type and target digit as within-subjects factors shows the previously discussed main effect of context type, a significant main effect of target digit [$F(3,39) = 6.92$, $p < .01$], and a nonsignificant Context Type by Target Digit interaction. The planned linear contrasts on the context effect of each individual digit failed to

Table 5
Confusion Matrices for the Two Context Types: Experiment 3

Display Presented	Incorrect Response Alternatives 3	6	8	9
A3E		.25	.38	.38
A6E	.11		.79	.11
A8E	.09	.53		.38
A9E	.32	.14	.54	
All A_E	.13	.28	.36	.24
V3H		.28	.41	.31
V6H	.08		.65	.27
V8H	.23	.29		.43
V9H	.27	.50	.23	
All V_H	.16	.27	.29	.28

Note–Entries are proportions of the total number of incorrect responses that were made to the indicated display; for example, .25 of all errors to A3E were "6" responses.

show any significant differences ($p < .05$ in all cases).

Table 5 contains the confusion matrices for the A_E and V_H context conditions of Experiment 3. The first four rows of each matrix show the distribution of incorrect responses for each display; the last row of each matrix shows the same information collapsed across the four target digits. Although 36.5% of all the errors made were on displays containing the target 8, there was also a marked tendency to give "8" as an incorrect response. Simply stated, subjects rarely saw an 8 when an 8 was presented, but they frequently thought they saw an 8 when one of the other target digits was presented. Although this "8 effect" tweaks one's curiosity, it does not seem to play any special role in producing the context effect. The smaller 8 effect observed with the V_H displays was due, almost entirely, to the fact that presentation of V9H resulted in very few "8" responses. Fortuitously, one also notes that the target 9 produced the smallest context effect, namely, 1.6%. Accordingly, it would seem to be quite speculative to suggest that the context effects found in this experiment were the product of a changing response bias involving 8s.

EXPERIMENT 4

Experiment 3 offered some support for the view that the WSE observed in Experiments 1 and 2 of this report and the first two experiments of Purcell et al. (1978) may have been produced by differential lateral masking. If this hypothesis is correct, then one would not expect to find word advantages with a new set of materials that does not produce differential lateral masking. On the other hand, if part of the word advantages observed with the first set of materials was due to the extraction of supraletter features, or any other unique characteristic of words, one would expect the WSE to generalize to a new set of words. Accordingly, the purpose of this experiment was to see if the WSE could be produced under the same conditions, that is, a set of predesignated targets and locational certainty, but with a new set of words and nonwords.

Method

Subjects. Twelve introductory psychology students from New Mexico State University served as subjects.

Materials and Procedure. The stimulus set consisted of the words ODE, ORE, ONE, and OWE and the nonwords CDF, CRF, CNF, and CWF. The displays were typed with the same element, presented at the same viewing distance, and, consequently, subtended the same visual angle as those used in Experiments 1-3. Inspection of Table 1 shows that the new set of words are comparable to the old set in the Thorndike and Lorge (1944) frequency count and slightly lower on the Kučera and Francis (1967) count. Other than this change in stimulus materials, the design and procedure were identical to that used in Experiment 1.

Results and Discussion

Across subjects, the mean percentage of errors for the O_E words and the C_F nonwords were 27.9% and 28.7%. An analysis of variance with context type as a within-subjects factor indicated that the effect of context type was not significant [$F(1,11) = .19$, $p > .05$]. Clearly, the WSE did not generalize to this new set of materials.

Table 2 shows the mean percentage of errors in the O_E and C_F contexts for each of the four target letters. An analysis of variance with context type and target letter as within-subjects factors showed a significant main effect of target letter [$F(3,33) = 3.34$, $p < .05$]. Although ORE and ONE appear to have produced sizable word advantages of 7.4% and 9.7%, while ODE and ONE produced equivalent effects in the opposite direction (−7.9% and −6.0%, the Context Type by Target Letter interaction was not significant [$F(3,33) = 1.92$, $p > .05$]. The planned linear contrasts on the context effect for each individual target letter showed a significant nonword advantage of CDF over ODE [$t(11) = -2.55$, $p < .05$], but the other three contrasts were nonsignificant. The magnitude of the WSE obtained for ORE and ONE was about the same as the significant ARE advantage reported in Experiment 2 and is as large or larger than the significant advantage of CDF over ODE just noted. However, the nonsignificant word advantages obtained for ORE and ONE are probably just that, since in both cases only 7 of the 12 subjects showed a WSE.

Table 6 contains the confusion matrices for the O_E and C_F context conditions of Experiment 4. The first four rows of each matrix show the distribution of incorrect responses for each display; the last row of each matrix shows the same information collapsed across the four target letters. Again, the confusion matrices for the two context types seem to contain more similarities than differences. There was a tendency for the number of incorrect "N" responses

Table 6
Confusion Matrices for the Two Context Types: Experiment 4

Display Presented	Incorrect Response Alternatives			
	D	R	N	W
ODE		.41	.43	.17
ORE	.28		.67	.05
ONE	.36	.39		.25
OWE	.17	.31	.52	
All O_E	.19	.30	.40	.11
CDF		.38	.46	.16
CRF	.43		.46	.11
CNF	.45	.39		.16
CWF	.27	.25	.48	
All C_F	.32	.26	.32	.10

Note–Entries are proportions of the total number of incorrect responses that were made to the indicated display; for example, .41 of all errors to ODE were "R" responses.

to increase and the number of incorrect "D" responses to decrease when the targets were presented in word context. The difference could be attributed to a response bias toward the most frequent word, ONE, and away from one of the low-frequency words, ODE.

EXPERIMENT 5

Experiment 4 showed that the WSE observed in Experiments 1 and 2 does not generalize to a new set of words. However, one could argue that in this case the benefits of supraletter features were counteracted, rather than supplemented, by differential lateral masking. If the O_E frame is a more effective masker than the C_F frame, then it would still be reasonable to maintain that the extraction of supraletter features had facilitated word recognition to the same extent that differential lateral masking had produced an advantage for the C_F nonwords. If the counteraction hypothesis is true, then one should observe poorer performance in the O_E context condition when neither the O_E nor the C_F displays form words. Experiment 5 tested this possibility by replacing the target letters R, D, N, and W with the target digits 3, 6, 8, and 9.

Method

Subjects. Fourteen introductory psychology students from New Mexico State University served as subjects.

Materials and Procedure. The stimulus set consisted of the displays O3E, O6E, O8E, O9E, C3F, C6F, C8G, and C9F. Other than this change in stimulus materials, the design and procedure were identical to those used in Experiment 3.

Results and Discussion

Across subjects, the mean percentage of errors for the O_E displays and the C_F displays were 25.6% and 28.6%, respectively. An analysis of variance with context type as a within-subjects factor indicated that the effect of context type was not significant [$F(1,13) = .69$, $p > .05$]. The lack of a significant effect of context type supports the view that these two frames produce equivalent amounts of lateral masking and that the failure to find a WSE in Experiment 4 should not be attributed to differential lateral masking favoring the C_F nonwords. In fact, the nonsignificant (3.0%) trend for the O_E displays to produce fewer errors than the C_F displays argues that, if anything, differential masking should have supplemented, not counteracted, any true word advantages.

Table 2 shows the mean percentage of errors in the O_E and C_F contexts for each of the four target digits. An analysis of variance with context type and target digit as within-subjects factors showed only a significant main effect of target digit [$F(3,39) = 11.29$, $p < .01$]. This effect was primarily due to the fact that 39.6% of all errors occurred on displays containing the target 6. The planned linear contrasts on the context effect for each individual target digit showed no significant differences ($p > .05$ in all four cases).

Table 7 contains the confusion matrices for the O_E and C_F context conditions of Experiment 5. The first four rows of each matrix show the distribution of incorrect responses for each display; the last row of each matrix shows the same information collapsed across the four target digits. The confusion matrices are quite similar for the two context types. It is interesting to note that the large proportion of incorrect "8" responses observed in Experiment 3 was greater in Experiment 5. However, in this experiment it was the displays containing the digit 6, not 8, that resulted in the greatest error rate.

Table 7
Confusion Matrices for the Two Context Types: Experiment 5

Display Presented	Incorrect Response Alternatives			
	3	6	8	9
O3E		.24	.43	.33
O6E	.06		.74	.20
O8E	.45	.14		.41
O9E	.14	.07	.79	
All O_E	.16	.09	.53	.22
C3F		.27	.15	.58
C6F	.17		.72	.11
C8F	.56	.13		.31
C9F	.34	.07	.59	
All C_F	.26	.09	.43	.22

Note–Entries are proportions of the total number of incorrect responses that were made to the indicated display; for example, .24 of all errors to O3E were "6" responses.

CONCLUSIONS

In two experiments Purcell et al. (1978) obtained the WSE when (1) a fixed set of predesignated targets was used, (2) the target letter was foveally presented and its location was known in advance, and (3) the type of context randomly varied from trial to trial. The present set of experiments sought to determine if the WSE produced under these conditions should be attributed to the processing of supraletter features or, in a more general sense, to the same mechanism responsible for the WSE found in a variety of other paradigms. Although no single outcome or experiment leads to the obvious rejection of the size-contingent more-features model, our experiments have convinced us that a genuine WSE does not occur under the conditions listed above, and that it therefore follows that the WSE has not been shown to depend on visual angle.

To summarize, Experiments 1 and 2 show that the advantages of the A_E words over the V_H nonwords is not contingent upon the presence of a pattern mask. Both Johnston and McClelland (1973) and Massaro and Klitzke (1979), using Reicher's (1969) postcue paradigm, have shown that the magnitude of the WSE is much larger when a pattern mask follows the test display. Experiments 1 and 2 also illustrate that the WSE is item specific and highlight the risks involved in relying on small sets of words and nonwords. We have suggested that the word advantages found with the APE, ARE, ACE, and AGE materials may have been produced by differential lateral masking. Since digit recognition is poorer in the V_H than in the A_E frame, Experiment 3 provides some evidence for this hypothesis. Although the amount of differential lateral masking produced in Experiment 3 is not as great as the magnitude of the WSE found in Experiments 1 and 2, one cannot rule out the possibility that the amount of differential lateral masking was attenuated by the choice of the curvilinear targets 3, 6, 8, and 9. More important than the particular determinants of the WSE found with the A_E and V_H displays is the issue of whether or not word advantages can be consistently obtained with predesignated targets and positional certainty. The failure to obtain a WSE with the new set of materials tested in Experiment 4 argues that this consistency is not likely to be forthcoming.

The implications of these experiments are straightforward. If the A_E advantages are due to differential lateral masking, or some other nonlinguistic property of these particular materials, then the three general theories described in the introduction are not weakened by the fact that each of them predicts no genuine WSE under the conditions used by Purcell et al. (1978).

Although the primary focus of this paper was to explore the generality and causes of the size-contingent WSE reported by Purcell et al. (1978), we might indulge in a limited evaluation of the mechanisms responsible for the WSE, particularly in the predesignated-targets paradigm that was used in the present experiments. To begin, we can rule out, with quite a bit of confidence, the Carr et al. (1976) suggestion that randomly presenting the words and nonwords will prevent subjects from adopting a word-processing strategy that is critical for the production of the WSE. When predesignated targets have been tested under conditions of positional uncertainty, both Spector and Purcell (1977, Experiment 2) and Paap et al. (Note 1) have reported significant word advantages, even though words and nonwords were randomly mixed. Furthermore, several investigators using the Reicher (1969) postcue paradigm have also shown that it is not necessary to block the materials in order to produce an advantage of words over nonwords (Geoffrion, 1976; Reicher, 1969; Spector & Purcell, 1977, Experiment 2).

A stronger case for the importance of strategies in the WSE can be drawn from the results of Johnston and McClelland (1974). When subjects were instructed to attend only to the letter that appeared at the target position, no significant word advantages were observed. An interesting issue is to what degree this lack of a WSE was due to subjects' abandoning their word strategies, as opposed to the consequences of there being complete certainty concerning the position of the target letter. Estes (1975) has suggested that when the alternatives are postcued (as was the case in all conditions of the Johnston and McClelland study), words provide better context than nonwords since familiar or othographically regular letter patterns supply positional information that enhances the chances that input arising from the target will be attributed to its actual position in the display. If the subject knows the location of the target in advance, there should be fewer errors caused by incorrect position information, and, consequently, the WSE should be attenuated. This scenario could be viewed as a strategy, but we feel that it reflects an important, although subtle, shift in theoretical emphasis. This account of the Johnston and McClelland findings emphasizes that advance knowledge of the target location permits the subject to adopt a strategy that obviates the benefits of linguistic context. This is quite different from assuming that subjects must adopt a word-processing strategy in order to benefit from the presence of linguistic context.

Recall that Massaro's (1973) perceptual inference model assumes that orthographic redundancy is used dynamically to facilitate the rapid synthesis of letter-size perceptual units. Accordingly, this particular perceptual inference model cannot easily account for the frequently reported finding that letters embedded in words are identified better than those in orthographically regular pseudowords (Juola, Leavitt, & Choe, 1974; Manelis, 1974; McClelland, 1976; Spoehr & Smith, 1973; Paap et al., Note 1). More important, there is a growing body of literature that suggests that orthographic structure does not always contribute to the magnitude of the WSE (Johnston, 1978; Manelis, 1974; McClelland & Johnston, 1977; Paap et al., Note 1).

As discussed earlier, we feel that the perceptual confusion model offers the best account for why and when word advantages are likely to be found in the predesignated-targets paradigm. The present set of studies alleviates our greatest concern for the validity of the model. Since it now appears that the WSE reported by Purcell et al. (1978) is likely to have been caused by a nonlinguistic factor, namely, differential lateral masking, and that it does not generalize to another set of materials, there are no cases in which a genuine WSE has been observed in the predesignated-targets paradigm that cannot be accounted for by the perceptual confusion model. However, since the perceptual confusion model assumes that words can be matched on the basis of fewer criterial features than their component letters, the perceptual confusion model falls into the general class of sophisticated guessing models that Johnston (1978) has persuasively argued against. His attack rests heavily on his inability to show any effects of lexical constraint in two clever and well controlled experiments. In these experiments, word pairs for which the identity of the critical letter was only weakly constrained by lexical knowledge (e.g., DATE-GATE) were compared with pairs of matched words for which the identity of the critical letter was strongly constrained (e.g., DRIP-GRIP). The probability of correctly reporting the critical letter during free report was just as high for the weakly constrained words as for those that were highly constrained. Johnston feels that models that assume that word units can be activated on the basis of fewer features than their component letters are inconsistent with these results. There are two aspects of his experiment that suggest that this conclusion may be premature.

First, consider those trials on which the three context letters were correctly reported. The conditional probabilities of a correct critical letter report given a correct report of all three context letters are .90 and .86 for the high- and low-constraint pairs, respectively. This is an extremely high range of performance, and any significant differences due to lexical constraint may be obscured by a ceiling effect. Moreover, if one assumes that the same stimuli presented to the same subjects under the same conditions would yield performance distributions with some variability, then it would seem quite reasonable to characterize these trials as samples that have been drawn from the upper end of the distribution and reflect trials on which the level of visual information was unusually high. When the stimulus information is high, the effects of lexical constraint may be low. Massaro, Jones, Lipscomb, and Scholz (1978) have shown just such a tradeoff in a lexical decision task.

On trials on which relatively few features are detected, it may be more likely that lexical knowledge is used. However, when the subject has only partial information about the letter in each location, Johnston's (1978) operational definition of high and low constraint may not be valid. It could be that the considerable differences between his high- and low-constraint words would be severely attenuated with a measure of featural redundancy that is based on the assumption that only a portion of the features from each letter location were sampled on a given trial. We are currently investigating this possibility. If Johnston's conclusions are substantiated by further research, it would no longer be viable to assume that word matches can occur on the basis of fewer features than those required to match their component letters.

One possible alternative is a model proposed by Johnston (1978) that assumes that (1) features activate letter codes, (2) letter codes can activate word codes, (3) word codes will not be activated unless a sufficient number of features have been detected to identify each of the component letters separately, and (4) word codes are more resistant to masking than are letter codes.

The assumption that words are less susceptible to masking accounts for the fact that materials that have been shown to yield large word advantages with a pattern mask show little or no advantage with a homogeneous postexposure field. However, this assumption is not without weakness either, since, by itself, it cannot account for any of the failures to observe a WSE in the presence of a backward patterned mask (e.g., Experiment 4 of the present series or Experiment 2 of Massaro, 1973).

In summary, it may be the case that in certain paradigms a portion of the WSE could be attributed to perceptual inference based on orthographic redundancy, to longer lasting perceptual codes for words, or even to supraletter features; but at the present time, the extant literature on context effects with predesignated targets seems to be most consistent with the perceptual confusion model.

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NOTE

1. The idea that distractors may sometimes be confused with targets is, of course, not new. For example, Gardner (1973) and Gummerman (1973) have shown that this type of error may be involved in many investigations of selective perception. Furthermore, Estes (1975) has suggested that the advantages he reports for single letters over both words and nonwords may be due to the fact that confusions can occur only in multiletter displays. However, we believe that the idea that linguistic context interacts with confusability to produce the WSE found with predesignated targets and positional uncertainty is unique to our model.

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