The interaction of sentence context and perceptual analysis in word identification

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The influence of sentence context on word identification has, in some interactive models, been attributed to enhanced accuracy or speed of perceptual analysis. This view is challenged by two experiments in which contextually enhanced word identification was found only when a target's relevance to the sentence context was correlated with its presence. When this constraint was removed by using contextually relevant foils, accuracy in detecting words in normal and scrambled sentences did not differ reliably. Moreover, under conditions that constituted a negative correlation between target relevance and presence, word identification was more accurate with scrambled than with normal sentences. These results are consistent with models of sentence context effects that are based on the assumptions that (1) perceptual analysis proceeds independently of contextual analysis, and (2) the results of these analyses are integrated to determine a word's identity.

The identification of an object is more likely to be correct and can be completed more quickly when the object appears in an appropriate context than when it appears in an inappropriate context. This phenomenon has been demonstrated with a number of different classes of stimuli, including visually presented words (Ehrlich & Rayner, 1981; Sanocki et al., 1985; Stanovich & West, 1983; Tulving & Gold, 1963; Tulving, Mandler, & Bauml, 1964), pictures (Biederman, Mezzanotte, & Rabinowitz, 1982; Reinitz & Loftus, 1986; Rosch, 1975), and spoken words (Auble & Franks, 1983; Tyler & Wessels, 1983). The influence of context and expectations upon the identification of objects is so compelling that observers can be led to believe that something was seen that was not actually there (Pillsbury, 1897), or, when contextual violations occur, that their perceptual systems have gone awry (Bruner & Postman, 1949).

Results like these have encouraged the view that expectations and context can have a direct influence on the perceptual analysis of patterns. This view has been formally expressed in a number of different models of reading and pattern recognition in which contextual information is assumed to affect the amount, rate, or accuracy of perceptual information extracted from a stimulus prior to identification (Gibson & Levin, 1975; Glucksberg, Kreuz, & Rho, 1986; Goodman, 1976; Morton, 1969; Reinitz & Loftus, 1986; Rumelhart, 1977; Smith, 1971).

Two major alternative views of the influence of context on word identification have been proposed. One view assumes that separate and independent processes or mod-

ules are responsible for word identification and for interpretation of the identified word in terms of the current context (Fodor, 1983; Forster, 1979). Word identification is accomplished purely through featural analysis and without reference to the context. For example, multiple meanings of an ambiguous word are accessed through analysis of the word's features, and then the appropriate activated meaning is selected on the basis of context (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979). A less extreme modular view is that information from analysis of stimulus features and from the context are obtained independently, but are integrated in order to determine a word's identity (Massaro, 1979; Oden, 1984; Potter & Noel, 1987). According to this view, the featural support for each word and the contextual support for each interpretation of that word are integrated. The combination of orthography and meaning with the highest relative amount of evidence is then selected (Rueckl & Oden, 1986).

Modular views of context effects are supported by experiments that have demonstrated independence between contextual factors, such as amount of sentence context or congruity with the target word, and perceptual factors, such as target duration or speaking rate (Gough, Alford, & Holley-Wilcox, 1981; Miller, Green, & Schermer, 1984). More direct evidence is available from experiments involving the application of signal detection theory. The advantage of this approach is that it affords the opportunity to distinguish between potential effects of context on the *accuracy* of perceptual analysis and on *bias* in the interpretation of a stimulus.

If contextual information can be used to influence the accuracy or rate of perceptual processing, then context effects should be apparent in the sensitivity component of a signal detection analysis. On the other hand, contextually enhanced perception may be illusory, in which case the effects of context might appear in the form of a bias

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toward a particular interpretation of a stimulus. For example, the integration view (Oden, 1984; Rueckl & Oden, 1986) assumes that the contribution of context is not to enhance the amount of perceptual evidence but to raise the level of contextual evidence (and, therefore, the level of combined evidence) for the more contextually relevant candidates. This process may be manifest in the signal detection analysis as a lower criterion for those trials in which the target is judged relevant to the context.

A number of studies using signal detection analysis have found that context did not influence the accuracy of perceptual judgments, but did influence the criteria adopted by subjects in making those judgments (Hale & Johnston, 1983; Masson, 1986; Samuel, 1981; Schvaneveldt & McDonald, 1981). These results suggest that erroneous conclusions may have been drawn from analyses of experiments that did not distinguish between accuracy and criterion effects. In those studies the higher level of identification accuracy or speed induced by relevant context may have been misattributed to enhanced perceptual processing.

There is one experimental paradigm, however, in which signal detection analysis has provided evidence for the influence of sentence context on perceptual accuracy. In studies using this paradigm (Juola, Ward, & McNamara, 1982; Masson & May, 1985), subjects were required to search for a member of a conceptual category or a specific word target in a rapidly presented series of words. Detection accuracy was higher when meaningful sentences, rather than scrambled sentences (consisting of a random reordering of words from a normal sentence), were used, indicating that words were more easily perceived when they appeared in the context of a sentence. But there is reason to doubt the validity of this conclusion. Integration of independently obtained perceptual and contextual evidence could account for enhanced detection performance with normal sentence contexts in the absence of any true effect on perceptual accuracy.

On those trials when the target was not present in the context sentence, it was unrelated to the meaning of the sentence. For example, one item from Juola et al.'s (1982) study, in which subjects searched for a member of a target category, consisted of the target *food* and the sentence *The policeman carried a gun but never used it*. Consequently, when the context sentence and target were unrelated, there would be very little contextual evidence in support of the target. On the other hand, whenever the target was relevant, it was present in the sentence, so contextual evidence appropriately favored the target. The design of the materials, then, led to a confounding of presence of the target and contextual evidence in favor of the target. If we assume that contextual evidence would be greater for normal than for scrambled sentences, decisions about target presence could have been more accurate for normal sentences only because of greater contextual evidence, not because of any influence of context on the extraction of perceptual evidence. Greater contex-

tual evidence would be provided by normal sentences because, even during rapid presentation of a sentence, information about word order and perhaps syntax would be available to help the observer construct a more lucid message than could be produced from a random ordering of the words (see Forster, 1970; French, 1981; Masson, 1986).

The interpretation of sentence context effects offered here is consistent with modular and integration views, but constitutes a challenge to the interactionist position. If it could be shown that this interpretation is invalid, however, the interactive processing view would be supported. In an effort to move toward a resolution of this issue, two experiments were conducted as a test of the claim that sentence context effects may be attributed to differential accrual of contextual, rather than perceptual, evidence. In these experiments the subjects were required to search for a predesignated target word in rapidly presented normal or scrambled sentence contexts. Different sets of materials were constructed in order to demonstrate that when target presence and relevance were correlated a normal sentence advantage would be found, and to eliminate the confounding and thereby provide a valid assessment of the influence of context on detection accuracy.

EXPERIMENT 1

Three sets of sentence-target pairs were constructed. In one set, targets that were to be present in the sentences were words from the sentences, and therefore were relevant to the sentences. Targets that were to be absent were words that were irrelevant to the sentences. These items were like those used in earlier studies and were expected to replicate the detection advantage for normal sentences.

The other two sets are referred to as *critical items*. In one of these sets the target, whether present or absent, was always relevant to the sentence. In the other set the target was always irrelevant to the sentence, even when it was present (in which case the sentence contained one anomalous word). Within each set of critical items, then, target relevance and presence were uncorrelated. It was expected that if the integration or modular views were correct these conditions would not produce a detection advantage for normal sentences, because the presence of strong contextual evidence would not be sufficient grounds for determining whether the target was present. It was also predicted, on the basis of the modular and integration views, that for the first set of critical items, the strong contextual evidence provided by target relevance would be expressed in the form of a lowered decision criterion or bias. This would be especially true when normal sentences were used because the contextual evidence would be strongest in that case.

Method

Subjects. The subjects were 60 University of Victoria students enrolled in a cognitive psychology course. They participated in the

experiment as part of a laboratory project but were naive with respect to its purpose at the time of testing. Half of the subjects were assigned randomly to the normal sentence context condition and half to the scrambled context condition.

Materials. A set of 132 unrelated sentences was drawn from various sources, both fiction and nonfiction. The sentences ranged in length from 11 to 21 words, with a mean length of 14.9 words. Twelve of these items were treated as practice items, 40 were used as filler items, and the remaining 80 were critical items. For half of the sentences in the practice and filler sets, a single word from the sentence was designated as the target for that sentence. Target words appeared in positions ranging from the first word of the sentence to the second-to-last word. For the other half of the sentences in these sets, a new word, not present in or relevant to the sentence, was selected as the target.

Two targets were selected for each of the critical sentences. One, the *relevant* target, was actually present in the original sentence. The relevant targets were located in the region bounded by the eighth and second-to-last positions in the sentences. The second target for each critical sentence, the *irrelevant* target, was derived from the first target by changing one of the word's interior letters to form a new word. The substitute letter had to be of the same shape (i.e., ascender, descender, other) as the original letter (e.g., *role-rule* was allowed but *role-rose* was not). The resulting irrelevant target was not related to its sentence context. Across all kinds of sentences, targets that actually appeared in the sentences were not restricted to any particular syntactic class. Sample sentences and targets are shown in Table 1.

Procedure. Instructions and materials were presented using an Apple II+ microcomputer equipped with a clock card that allowed timing of events in milliseconds. The display device was a green video monitor. When viewed from a distance of 40 cm the width of a four-letter word subtended a visual angle of 1.2°.

The subjects were tested individually and were presented with a series of 132 trials. Half of the subjects were tested with normal sentence contexts and half were tested with scrambled versions of the same contexts. Scrambling was accomplished by randomly re-ordering the words of each sentence, maintaining capitalization of the first word of the normal sentence, and placing a period after the last word in the scrambled sequence. For contexts that contained a target word, that word retained its original ordinal position in the context.

The first 12 trials involved the practice items, and performance on these items was not recorded. The remaining 120 trials, presented in a random order, consisted of three sets of 40 trials. One set consisted of filler items, and for half of these items the target was present in the sentence. The other two sets consisted of the critical items.

Table 1
Examples of Materials Used in Experiment 1

Sentence Type	Sentence	Target	
		Relevant	Irrelevant
Filler	The entire town arrived to see the appearance of the controversial political candidate.	town	—
Filler	The sound of an approaching train woke him and he started to his feet.	—	kettle
Critical	The products of digital electronics will play an important role in your future.	role	rule
Critical	Fresh lobster could not be found so the cook decided on crab.	cook	cork

For one critical set, the relevant target word was used in the search task; for the other set, the irrelevant target word was used. Half of the sentences in each set of critical items were altered by replacing the relevant target word with the corresponding irrelevant word (e.g., *The products of digital electronics will play an important role in your future* became *The products of digital electronics will play an important rule in your future*). For these modified sentences, then, the irrelevant target actually was present in the sentence. Therefore, half of the sentences in each critical set contained the target and half did not. Assignment of groups of 20 critical sentences to the four conditions produced by the factorial combination of target type (relevant, irrelevant) and sentence type (original, modified) was counterbalanced across subjects.

Subjects in the normal sentence condition were told that on each trial they would be shown a target word, and their task was to search for that word in the sentence that was to follow. They were also told that sometimes one of the words in a sentence would not fit very well. This was in reference to the modified critical sentences. For subjects who were given scrambled sentences, the context was referred to as a series of words rather than a sentence. At the beginning of each trial the warning signal READY appeared in the center of the screen and the subject pressed either of two buttons to begin the trial. The left button was labeled YES and right was labeled NO. A blank interval of 500 msec followed the buttonpress; then the target word appeared in lowercase letters in the center of the screen and remained there for 1 sec. The screen was then blank for 500 msec and the context was presented. Words in the context were shown successively at the center of the screen and a row of 12 asterisks was inserted as the last item in each context. Each word was shown for a fixed duration and then was immediately replaced by the next word. The subjects were told to press the YES button as soon as they detected the target word, or, if they did not detect the target, to press the NO button after the context had been presented. Regardless of when a response button was pressed, the whole context was shown. After the entire context was shown and a response was obtained, a row of 12 hyphens was printed in the center of the screen and remained for 500 msec before the next trial began.

For the first four practice trials each word in the context sentence appeared for 180 msec. The duration was reduced by 50 msec following those four trials and again after the second four practice trials (the actual duration varied by a small random amount due to the refresh characteristics of the monitor). The duration for context words in the last four practice trials and in the filler and critical trials was 80 msec.

Results and Discussion

Hit and false-alarm rates were computed for the filler trials. A hit occurred when the subject correctly claimed that the search target appeared in the context. A false alarm occurred when the subject claimed that the target was in the context when, in fact, it was not. The mean hit and false-alarm rates for subjects in the normal and scrambled context conditions are shown in Table 2. Analyses of variance indicated that the hit rate was significantly higher in the normal condition [$F(1,58) = 10.57$, $MSe = 0.165$], but the false-alarm rates did not differ reliably ($F < 1$). For these and all other analyses, Type I error rate was set at .05.

The hit and false-alarm rates from filler trials were also examined using a nonparametric signal detection analysis (Grier, 1971; Pastore & Scheirer, 1974). This analysis was chosen because it does not rely on the assumptions that signal and noise distributions are normal and of equal

variance. In this analysis detection accuracy, A' , takes on the value 0.5 when hit and false-alarm rates are equal (chance performance) and 1.0 when perfect performance occurs (hit rate = 1.0 and false-alarm rate = 0.0). As in parametric signal detection analysis, the measure of criterion, B'' , takes on larger values (maximum = 1.0) when subjects set high criteria for making positive responses and smaller values (minimum = -1.0) when subjects' criteria are lower.

The mean accuracy and criterion scores for the normal and scrambled context conditions, shown in Table 2, were compared in separate analyses of variance. The analysis of A' scores indicated that subjects in the normal condition detected targets more accurately than did subjects in the scrambled condition [$F(1,58) = 6.72$, $MSe = 0.002$]. The two groups did not differ significantly on the measure of criterion ($F < 1$).

Hit and false-alarm rates were computed separately for critical trials involving relevant and irrelevant targets. For trials with relevant targets, a hit occurred when the subject correctly claimed that the target was present in the context. A false alarm occurred when the subject claimed the target was present, but the context had been modified so that the target word had been replaced by its visually similar counterpart. For trials with irrelevant targets, a hit occurred when the subject claimed the target was present in the context and the context had been modified so that the irrelevant target word had been inserted in place of the relevant word. False alarms occurred when a positive response was given but the context had not been modified.

The mean hit and false-alarm rates for the critical trials involving relevant and irrelevant targets are shown in Table 3. An analysis of variance of hit rates with target relevance and sentence context (normal, scrambled) as factors revealed that hit rates were significantly higher when relevant targets were used [$F(1,58) = 28.43$, $MSe = 0.010$]. The effect of sentence context was not reliable, but there was an interaction between this factor and target relevance [$F(1,58) = 8.66$, $MSe = 0.010$], indicating that normal sentences produced higher hit rates only when the targets were relevant. A similar analysis of false-alarm rates indicated significantly lower false-alarm rates for irrelevant targets [$F(1,58) = 37.71$, $MSe = 0.011$], no overall effect of sentence context, and an interaction between context and target relevance [$F(1,58) = 15.02$, $MSe = 0.011$]. The interaction supports the conclusion that there was a higher false-alarm rate for normal sentences, but only when relevant targets were used.

Table 2
Hit Rate, False-Alarm Rate, Accuracy (A'), and Bias (B'') for Filler Trials in Experiment 1

Context	Hit Rate		False-Alarm Rate		A'		B''	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Normal	.837	.099	.068	.066	.935	.040	.477	.488
Scrambled	.732	.146	.065	.056	.906	.046	.541	.361

Table 3
Hit Rate, False-Alarm Rate, Accuracy (A'), and Bias (B'') for Critical Trials in Experiment 1

Context	Hit Rate		False-Alarm Rate		A'		B''	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Relevant Target								
Normal	.807	.092	.358	.147	.813	.067	-.179	.274
Scrambled	.718	.129	.242	.126	.822	.073	.066	.300
Irrelevant Target								
Normal	.657	.126	.167	.146	.833	.077	.350	.392
Scrambled	.675	.119	.198	.142	.824	.081	.231	.342

The analyses of hit and false-alarm rates for critical items suggested that when relevant targets were used, the hit-rate advantage for normal sentences was balanced by a corresponding elevation in the false-alarm rate, indicating the lack of any net accuracy advantage. When irrelevant targets were used, the normal and scrambled conditions produced similar hit and false-alarm rates. This pattern was verified by applying a nonparametric signal detection analysis. The mean accuracy and criterion scores for the critical items are shown in Table 3. An analysis of variance of A' scores with target relevance and sentence context as factors yielded no significant effects ($F_s < 1$).

A similar analysis of variance of B'' scores, however, indicated that lower criteria were applied when relevant targets were used [$F(1,58) = 52.34$, $MSe = 0.069$], and that although there was no main effect of sentence context, the two factors interacted [$F(1,58) = 14.38$, $MSe = 0.069$]. Simple effects analyses based on the interaction showed that when relevant targets were used, normal context sentences produced a significantly lower mean criterion than did scrambled contexts [$F(1,58) = 10.82$, $MSe = 0.083$]. When irrelevant targets were used, normal and scrambled contexts did not produce reliably different B'' scores.

The results of Experiment 1 were consistent with the integration and modular views of sentence context effects. The detection accuracy advantage for normal sentences appeared to depend on the existence of a correlation between target relevance and presence. When the correlation was present (filler items), a clear context effect on accuracy was obtained. But when target relevance was held constant by using only relevant or only irrelevant targets in performing the signal detection analysis, varying the context did not influence accuracy. A strong effect of sentence context on decision criterion was apparent, however, when relevant targets were used, particularly in conjunction with normal sentences. This pattern of results is not consistent with the claim that accuracy of perceptual processing is influenced by contextual evidence. Although evidence from sentence context induces observers to make positive responses, this influence is just as apparent when the target is not present.

A drawback of the design of Experiment 1 was that filler and critical items were not counterbalanced, so direct

comparison across the materials is not appropriate. Furthermore, all targets used in the critical set were visually similar to one of the words in the search string, even when the target was not present in the string. This was not true of the filler items. One means of overcoming this problem is to apply additional signal detection analyses to the critical items. It is possible to combine target-present and target-absent trials in ways that produce two other contingencies between target presence and relevance.

One contingency yields a positive correlation between target presence and relevance, like that created with the filler items. This was done by using the hit rate based on relevant targets and the false-alarm rate based on irrelevant targets. From Table 3, the means of the appropriate hit and false-alarm rates for subjects given normal sentences would be .807 and .167, respectively. For those given scrambled sentences, the corresponding rates would be .718 and .198. These pairings of hit and false-alarm rates were used to produce a new A' value for each subject. The mean of the resulting A' values was .888 for subjects given normal contexts and .841 for subjects in the scrambled context condition. These two means differed significantly [$F(1,58) = 6.33$, $MSe = 0.005$], replicating the results with filler items.

The other contingency represents a negative correlation between target presence and relevance. In this case the hit rate was based on irrelevant targets and the false-alarm rate was taken from relevant targets. From Table 3, the mean hit and false-alarm rates for subjects in the normal condition would be .657 and .358, respectively. For those in the scrambled condition the means would be .675 and .242, respectively. This pairing of hit and false-alarm rates constituted a negative correlation between target relevance and presence, in the sense that irrelevant targets were present and relevant targets were not. An A' value based on this combination of hit and false-alarm rates was computed for each subject. The striking finding in this case was that the mean A' in the scrambled condition, .805, was significantly *greater* than the mean for the normal condition, .716 [$F(1,58) = 11.55$, $MSe = 0.010$].

Among the critical items in Experiment 1, then, different arrangements of hit and false-alarm rates could be used to produce different contingencies between target presence and relevance. When the contextual evidence concerning a target's presence was consistent with the target's actual status, detection accuracy was improved by providing more discriminating contextual evidence (i.e., normal sentence contexts). But when contextual evidence was contrived to be negatively correlated with a target's presence, detection accuracy was reduced when strong contextual evidence was available. Finally, when there was no correlation between target relevance and presence, there was no sentence context effect. These results demonstrate that the influence of sentence context on detection accuracy depends on the *validity* of the contextual evidence. Consequently, sentence context appears to have beneficial effects on word identification, not by improving the recruit-

ment of perceptual evidence for the word, but by taking advantage of common linguistic contingencies.

EXPERIMENT 2

In Experiment 1 alteration of the relationship between target presence and relevance was based on modification of sentence contexts. When an irrelevant target was present or a relevant one was absent, the context contained an anomalous word. Moreover, failure to obtain a detection advantage with normal sentences occurred when detection accuracy was low, relative to cases where a significant normal context advantage was observed. It is possible that either the presence of an anomalous word in the context or increased discrimination difficulty was responsible for altering the effectiveness of sentence contexts.

Experiment 2 was designed to rule out these two possibilities. Three kinds of targets were used. One set of targets consisted of a word taken from each sentence, and these words served as the only targets that were present in the contexts. No modifications were made to the original contexts. The other two sets of targets were foils. One set consisted of words that were thematically unrelated to their context sentences, but were visually similar to one word in the sentence. The irrelevance of these foils was a valid basis for claiming that they were not present. This configuration of materials constituted a positive correlation between target presence and relevance, and it was expected, therefore, that a signal detection analysis would yield an accuracy advantage for normal sentence contexts. The other set of foils consisted of words that were not visually similar to any word in their associated context sentences, but were related to the meaning of the sentences. The contextual relevance of these foils was expected to make difficult their rejection on the basis of contextual evidence alone. Instead, the subjects would have to rely on perceptual evidence. If sentence context does not enhance the extraction of perceptual evidence, then a normal sentence advantage should not be found using this set of foils. Furthermore, the lack of visual similarity between these foils and words in the contexts implies that detection performance based on relevant foils should be superior to detection accuracy observed when perceptually confusable foils are used. If obtained, this pattern of results would be complementary to that observed in Experiment 1: The normal sentence advantage would appear under conditions of relatively low detection accuracy and would be eliminated under conditions associated with higher detection accuracy.

Method

Subjects. The subjects were 74 University of Victoria undergraduate students who volunteered to participate in the study. Half were randomly assigned to the normal sentence context condition and half to the scrambled condition.

Materials. A set of 132 unrelated sentences was developed, most of which had been used in Experiment 1. The sentences were from 11 to 24 words long, with a mean length of 15.8 words. Twelve

of the sentences were used in practice trials and the remaining 120 served as critical items. For each critical sentence, three target words, ranging in length from four to eight letters, were selected. One was taken from the sentence and was used on target-present trials. These targets were never among the first three or last three words of the sentence. The other two targets were foils (i.e., they were not present in the sentence), and were selected so that one was thematically relevant to the sentence, but was not visually similar to any word in it, whereas the other was irrelevant to the sentence but was visually similar to one of the content words in the sentence. The visually similar foil was created by exchanging one letter (exterior or interior) of its counterpart in the sentence for a letter of the same shape (ascender, descender, or neither). The following are two examples of critical sentences and their targets:

The sun was dying and a blurred moon was low on the horizon.
(moon/night/moan)

He stood there at the edge of the flock while they were singing and listened to the sweet music. (edge/choir/fleck)

A scrambled version of each critical sentence was prepared according to the restrictions used in Experiment 1. In addition, six of the practice sentences were scrambled and used in the scrambled condition. The remaining six practice items were used in the normal condition.

Procedure. Experiment 2 was conducted using the same equipment as in Experiment 1, except that a hardware modification was made to allow more accurate timing of stimulus events (Reed, 1979). Presentation of stimuli was synchronized with the monitor's refresh cycle, which allowed items to appear for increments of 16.7 msec. The subjects were given 6 practice and 120 critical trials. The critical trials consisted of three sets of 40 trials each, presented in a random order. One set of critical trials used the target that was present in the sentence, one set used the relevant foils, and one set used the irrelevant foils. Assignment of groups of 40 critical sentences to each of these sets of trials was counterbalanced across subjects.

Each trial was conducted as in Experiment 1, except that the assignments of the response buttons were reversed: the left button was labeled NO and the right was labeled YES. In addition, no mention was made of anomalous words appearing in the contexts, because none of the sentences had been modified in that manner. Words in the context sentences presented on the first two practice trials appeared for 150 msec each. The duration of context words was reduced by 33.3 msec following these two trials and again after the second set of two practice trials. Thus, the duration for the final two practice trials and all critical trials was 83.3 msec.

Results and Discussion

A hit rate, based on correct detection of targets that were present in the context sentences, was computed for each subject. Two false-alarm rates were computed as well, one for relevant and one for irrelevant foils. The mean hit and false-alarm rates for the normal and scrambled context conditions are shown in Table 4. An analysis of variance of the hit rates indicated that there was a trend for an advantage in the normal condition [$F(1,72) = 3.07$, $MSe = 0.009$, $.05 < p < .10$]. An analysis of false-alarm rates with type of foil (relevant, irrelevant) and sentence context as factors indicated that the irrelevant foils were significantly more difficult to reject [$F(1,72) = 58.92$, $MSe = 0.008$]. The interaction approached significance [$F(1,72) = 3.59$, $MSe = 0.008$, $.05 < p < .10$], indicat-

Table 4
Hit Rate, False-Alarm Rate, Accuracy (A'), and Bias (B'') in Experiment 2

Context	Hit Rate*		False-Alarm Rate		A'		B''	
	M	SD	M	SD	M	SD	M	SD
Relevant Foil								
Normal	.839	.077	.122	.098	.918	.040	.186	.372
Scrambled	.800	.113	.131	.070	.901	.044	.133	.323
Irrelevant Foil								
Normal	.839	.077	.205	.165	.887	.065	.055	.419
Scrambled	.800	.113	.268	.122	.845	.071	-.130	.243

*The same hit rate was used for signal detection analyses based on relevant and irrelevant foils.

ing that there was a small advantage for the normal condition, but only when irrelevant foils were used.

Two nonparametric signal detection analyses were carried out, one for each type of foil. Each subject received two accuracy and bias scores, based on his/her hit rate combined, in turn, with the two false-alarm rates. The mean accuracy and bias scores are shown in Table 4. An analysis of variance of the accuracy scores was performed with type of foil and sentence context as factors. This analysis indicated that there was an overall advantage for normal contexts [$F(1,72) = 6.01$, $MSe = 0.005$] and that accuracy was significantly lower when based on irrelevant foils [$F(1,72) = 55.18$, $MSe = 0.001$]. There was also a significant interaction [$F(1,72) = 4.55$, $MSe = 0.001$]. A simple effects analysis of the interaction showed that there was a reliable normal sentence advantage when detection accuracy was computed on the basis of irrelevant foils [$F(1,72) = 6.79$, $MSe = 0.005$], but not when accuracy was computed on the basis of relevant foils.

A similar analysis of bias scores showed that the subjects adopted a significantly higher criterion when dealing with relevant foils than when dealing with irrelevant foils [$F(1,72) = 32.80$, $MSe = 0.044$]. There was also a tendency for subjects in the scrambled condition to use a lower criterion than subjects in the normal condition, but only when irrelevant foils were involved, as indicated by the fact that the interaction effect approached significance [$F(1,72) = 3.69$, $MSe = 0.044$, $.05 < p < .10$].

Experiment 2 successfully replicated the major findings of Experiment 1. When target presence and relevance were confounded, subjects in the normal sentence condition were able to obtain detection accuracy scores higher than those of subjects in the scrambled condition. The context effect was almost completely eliminated, however, when the confounding was removed by using thematically relevant foils. This pattern of results was obtained without modification of the original context sentences and when detection accuracy was higher in the situation that failed to produce a significant context effect. It is reasonable

to suppose, then, that the effects obtained in Experiment 1 did not arise from inclusion of an anomalous word in the contexts or from relatively low detection accuracy when the context effect failed to appear.

Subjects in the normal condition did not use a lower criterion than subjects in the scrambled condition when making decisions about trials involving relevant targets. Apparently, the subjects were not strongly enticed by foils that were supported by contextual evidence but not by substantial perceptual evidence. The false-alarm rate for relevant foils in the normal condition of Experiment 1, where there also was good perceptual support for the foils, was much greater than in Experiment 2. This may explain the small but nonsignificant context effect found with relevant foils in Experiment 2. The dependence of contextual evidence on perceptual support for establishing the viability of a candidate is consistent with the view that these two sources of evidence are integrated in producing a decision (see Potter & Noel, 1987; Rueckl & Oden, 1986). There is no support in these results for the claim that contextual evidence enhances the extraction of perceptual evidence. Instead, it appears that the persuasiveness of contextual evidence is dependent on the availability of perceptual support.

GENERAL DISCUSSION

The experiments reported here demonstrate that the influence of sentence context on detection accuracy is dependent on the validity of the contextual evidence. A positive sentence context effect was obtained only when the availability of contextual evidence for a target was directly related to its presence or absence. Without this relationship, sentence context had no effect on detection accuracy, and even reduced accuracy when target presence and relevance were negatively correlated.

It is apparent that in the target detection paradigm, accuracy is sensitive to confounds between target presence and nonperceptual characteristics of the target. Therefore, the only valid test of the influence of context on perceptual analysis is one in which this confounding is removed. Both of the present experiments showed that under these conditions sentence context does not alter the accuracy or rate of perceptual analysis of a visually presented word. The failure, under appropriate conditions, of sentence context to affect the accuracy of visual word identification is consistent with recent results in speech perception. Connine (1987) has shown that the influence of sentence context on auditory word recognition appears to operate post-perceptually, rather than at initial encoding of the auditory stimulus.

The evidence provided by the experiments reported here suggests the existence of a fundamental error in interactive models of word identification. Models that assume that processing of sentence context influences the rate or accuracy of perceptual processes clearly can be rejected in favor of modular and integration views of context effects. In particular, the integration model claims that con-

text reduces the amount of perceptual evidence needed to make a decision about stimulus identity (Rueckl & Oden, 1986). When contextual evidence for a word candidate is strong (e.g., when the target word is relevant to the sentence context), the relative amount of combined perceptual and contextual evidence supporting the candidate is enhanced. The relative amount of combined evidence is assumed to vary over time as both sources continue to contribute favorable evidence in direct proportion to the outcome of their respective analyses. In cases where contextual evidence for a candidate is strong, a decision about the word's identity may be made before perceptual analysis is complete. This results in faster word identification (see Sanocki et al., 1985) and also in the kind of criterion effect observed in Experiment 1.

Criterion effects appear because the availability of favorable contextual evidence may lead to acceptance of a word candidate that would have been rejected on the basis of further perceptual analysis. In fact, in natural reading situations such prematurely accepted candidates often are rejected after more perceptual information becomes available and the reader recognizes that an identification error has occurred. Experiment 2, however, demonstrated that these criterion effects are likely to occur only when at least some perceptual evidence is available to support contextually relevant candidates.

Dependence on contextual support in word identification is an adaptive skill, given that most messages adhere to the rules of contextual relevance. Under certain circumstances, subjects who rely on this skill appear to improve their word recognition ability by taking advantage of the context in which words appear (e.g., Stanovich, 1980). It is clear, however, that the skill does not involve improved accuracy or efficiency of perceptual analysis and that its effectiveness is entirely dependent on the degree to which words in a text submit to contextually defined constraints.

REFERENCES

- AUBLE, P., & FRANKS, J. J. (1983). Sentence comprehension processes. *Journal of Verbal Learning & Verbal Behavior*, **22**, 395-405.
- BIEDERMAN, I., MEZZANOTTE, R. J., & RABINOWITZ, J. C. (1982). Scene perception: Detecting and judging objects undergoing relational violations. *Cognitive Psychology*, **14**, 143-177.
- BRUNER, J. S., & POSTMAN, L. (1949). On the perception of incongruity: A paradigm. *Journal of Personality*, **18**, 206-223.
- CONNINE, C. M. (1987). Constraints on interactive processes in auditory word recognition: The role of sentence context. *Journal of Memory & Language*, **26**, 527-538.
- EHRLICH, S. F., & RAYNER, K. (1981). Contextual effects on word perception and eye movements during reading. *Journal of Verbal Learning & Verbal Behavior*, **20**, 641-655.
- FODOR, J. A. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.
- FORSTER, K. I. (1970). Visual perception of rapidly presented word sequences of varying complexity. *Perception & Psychophysics*, **8**, 215-221.
- FORSTER, K. I. (1979). Levels of processing and the structure of the language processor. In W. E. Cooper & E. C. T. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett* (pp. 27-85). Cambridge, MA: MIT Press.

- FRENCH, P. (1981). Semantic and syntactic factors in the perception of rapidly presented sentences. *Journal of Psycholinguistic Research*, **10**, 581-591.
- GIBSON, E. J., & LEVIN, H. (1975). *The psychology of reading*. Cambridge, MA: MIT Press.
- GLUCKSBERG, S., KREUZ, R. J., & RHO, S. H. (1986). Context can constrain lexical access: Implications for models of language comprehension. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **12**, 323-335.
- GOODMAN, K. S. (1976). Reading: A psycholinguistic guessing game. In H. Singer & R. B. Ruddell (Eds.), *Theoretical models and processes of reading* (2nd ed., pp. 497-508). Newark, DE: International Reading Association.
- GOUGH, P. B., ALFORD, J. A., JR., & HOLLEY-WILCOX, P. (1981). Words and contexts. In O. J. L. Tzeng & H. Singer (Eds.), *Perception of print: Reading research in experimental psychology* (pp. 85-102). Hillsdale, NJ: Erlbaum.
- GRIER, J. B. (1971). Nonparametric indexes for sensitivity and bias: Computing formulas. *Psychological Bulletin*, **75**, 424-429.
- HALE, B. L., & JOHNSTON, J. C. (1983, November). *How sentence context affects word identification: A signal detection theory analysis*. Paper presented at the meeting of the Psychonomic Society, San Diego, CA.
- JUOLA, J. F., WARD, N. J., & MCNAMARA, T. (1982). Visual search and reading of rapid serial presentations of letter strings, words, and text. *Journal of Experimental Psychology: General*, **111**, 208-227.
- MASSARO, D. W. (1979). Letter information and orthographic context in word perception. *Journal of Experimental Psychology: Human Perception & Performance*, **5**, 595-609.
- MASSON, M. E. J. (1986). Comprehension of rapidly presented sentences: The mind is quicker than the eye. *Journal of Memory & Language*, **25**, 588-604.
- MASSON, M. E. J., & MAY, R. B. (1985). Identification of words and letters during reading: A sentence inferiority effect for letter detection. *Canadian Journal of Psychology*, **39**, 449-459.
- MILLER, J. L., GREEN, K., & SCHERMER, T. M. (1984). A distinction between the effects of sentential speaking rate and semantic congruity on word identification. *Perception & Psychophysics*, **36**, 329-337.
- MORTON, J. (1969). Interaction of information in word recognition. *Psychological Review*, **76**, 165-178.
- ODEN, G. C. (1984). Dependence, independence, and emergence of word features. *Journal of Experimental Psychology: Human Perception & Performance*, **10**, 394-405.
- PASTORE, R. E., & SCHEIRER, C. J. (1974). Signal detection theory: Considerations for general application. *Psychological Bulletin*, **81**, 945-958.
- PILLSBURY, W. B. (1897). A study in apperception. *American Journal of Psychology*, **8**, 315-393.
- POTTER, M. C., & NOEL, A. (1987, November). *Conversion of non-words to words in RSVP*. Paper presented at the meeting of the Psychonomic Society, Seattle, WA.
- REED, A. V. (1979). Microcomputer display timing: Problems and solutions. *Behavior Research Methods & Instrumentation*, **11**, 572-576.
- REINITZ, M., & LOFTUS, G. R. (1986, November). *Primes speed up visual information acquisition rate*. Paper presented at the meeting of the Psychonomic Society, New Orleans, LA.
- ROSCH, E. (1975). Cognitive representations of semantic categories. *Journal of Experimental Psychology: General*, **104**, 192-233.
- RUECKL, J. G., & ODEN, G. C. (1986). The integration of contextual and featural information during word identification. *Journal of Memory & Language*, **25**, 445-460.
- RUMELHART, D. E. (1977). Toward an interactive model of reading. In S. Dornic (Ed.), *Attention and performance VI* (pp. 573-603). Hillsdale, NJ: Erlbaum.
- SAMUEL, A. G. (1981). Phonemic restoration: Insights from a new methodology. *Journal of Experimental Psychology: General*, **110**, 474-494.
- SANOCKI, T., GOLDMAN, K., WALTZ, J., COOK, C., EPSTEIN, W., & ODEN, G. C. (1985). Interaction of stimulus and contextual information during reading: Identifying words within sentences. *Memory & Cognition*, **13**, 145-157.
- SCHVANEVELDT, R. W., & McDONALD, J. E. (1981). Semantic context and the encoding of words: Evidence for two modes of stimulus analysis. *Journal of Experimental Psychology: Human Perception & Performance*, **7**, 673-687.
- SEIDENBERG, M. S., TANENHAUS, M. K., LEIMAN, J. M., & BIENKOWSKI, M. (1982). Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge-based processing. *Cognitive Psychology*, **14**, 489-537.
- SMITH, F. (1971). *Understanding reading*. New York: Holt, Rinehart & Winston.
- STANOVICH, K. E. (1980). Toward an interactive-compensatory model of individual differences in the development of reading fluency. *Reading Research Quarterly*, **16**, 32-71.
- STANOVICH, K. E., & WEST, R. F. (1983). On priming by a sentence context. *Journal of Experimental Psychology: General*, **112**, 1-36.
- SWINNEY, D. A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning & Verbal Behavior*, **18**, 645-659.
- TULVING, E., & GOLD, C. (1963). Stimulus information and contextual information as determinants of tachistoscopic recognition of words. *Journal of Experimental Psychology*, **66**, 319-327.
- TULVING, E., MANDLER, G., & BAUMAL, R. (1964). Interaction of two sources of information in tachistoscopic word recognition. *Canadian Journal of Psychology*, **18**, 62-71.
- TYLER, L. K., & WESSELS, J. (1983). Quantifying contextual contributions to word-recognition processes. *Perception & Psychophysics*, **34**, 409-420.

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