Journal of Experimental Psychology:
Human Perception and Performance
1987, Vol. 13, No. 3, 449–463

0096-1523/87/$00.75

Effects of Foveal Priming and Extrafoveal Preview on Object Identification

John M. Henderson, Alexander Pollatsek, and Keith Rayner
University of Massachusetts, Amherst

The results of three different experiments suggested that the relation between an object in the fovea on fixation n and an object subsequently brought into the fovea on fixation $n + 1$ affects the time to identify the second object. In Experiment 1 we extended previous work by demonstrating that a previously seen related priming object speeded the time to name a target object even when a saccade intervened between the two objects. In Experiment 2 we replicated this result and further showed that the benefit on naming time was due to facilitation from the related object rather than inhibition from the unrelated object. In addition, naming of the target object was much slower in both experiments when there was not a peripheral preview of the target object on fixation n. However, because the effect of the foveal priming object was greater when the target was not present than when it was present, priming did not appear to make extraction of the extrafoveal information more efficient. In Experiment 3, fixation times were recorded while subjects looked at four objects in order to identify them. Fixation time on an object was shorter when a related object was fixated immediately before it, even though the four objects did not form a scene. The size of the facilitation was roughly comparable to that in several analogous experiments where scenes were used. The results suggest that the effects of a predictive scene context on object identification may be explainable in terms of an object-to-object or "intralevel" priming mechanism.

In general, context has been shown to facilitate recognition of a wide variety of perceptual stimuli. For example, letters are more easily identified in words than in nonwords (Reicher, 1969; Wheeler, 1970); words are more easily identified when preceded by related contexts (Ehrlich & Rayner, 1981; Meyer, Schveneveldt, & Ruddy, 1975; Morton, 1969; Stanovich & West, 1983; Tulving & Gold, 1963); and parafoveal words are more easily identified with constraining semantic contextual information than without (Balota, Pollatsek, & Rayner, 1985; Balota & Rayner, 1983; McClelland & O'Regan, 1981).

Using pictures of objects as stimuli, researchers have shown that identification is facilitated when an object is presented in a coherent scene (Biederman, 1972) but is inhibited if the object violates its ordinary relation to the visual context (Biederman, 1981; Biederman, Mezzanotte, & Rabinowitz, 1982); object identification is facilitated by both single-object and single-word contexts (Kroll & Potter, 1984; Sperber, McCauley, Ragain, & Weil, 1979); object misidentification is more likely if the target object visually resembles another object that would be more likely in a given context (Palmer, 1975); and researchers recording eye movements have generally concluded that an object in a semantically appropriate context is more easily identified than an object that does not fit the context as well (Antes, 1974; Friedman, 1979; Loftus & Mackworth, 1978).

According to the dominant hypothesis regarding the nature of contextual effects on the identification of objects in scenes, higher level memory representations known as *frames* (Minsky, 1975) or *schemata* (Bartlett, 1932; Norman & Rumelhart, 1975; Rumelhart, 1980) interact with incoming perceptual information during object identification. On this view, context is facilitative because it acts to invoke the appropriate memory structure (henceforth, *schema*). Objects that are obligatory in the schema are encoded more or less automatically (with a minimal use of processing resources), whereas objects that do not fit as well require a more resource-expensive encoding process, and objects that do not fit the schema at all require resource-expensive active hypothesis testing (Friedman, 1979; Friedman & Liebelt, 1981).

A second hypothesis, which will be investigated in the current article, is that context effects in scene processing may be produced through object-to-object priming. On this view, the information available to the object-identification stage is perceptual information from lower levels of processing and information about other objects that have already been identified (intralevel information), but *not* higher level information. This approach will be referred to as the *intralevel priming* approach, and is consistent with the concept of modularity (Fodor, 1983; Marr, 1982).

Researchers have repeatedly demonstrated that identification

The research presented in this article was part of a master's thesis conducted by John M. Henderson, and was supported by National Institute of Mental Health Predoctoral Training Grant MH16745. The research was also supported by National Institutes of Health Grant HD12727 and National Science Foundation Grant BNS86-09336 to Keith Rayner and Alexander Pollatsek. A portion of these data were reported at the 1986 meeting of the Psychonomic Society in New Orleans.

We would like to thank the other members of the master's committee, Arnold Well and Rachel Keen Clifton, for their insights and suggestions. We would also like to thank Tom Carr, Peter DeGraef, William Epstein, Fernanda Ferreira, Judy Kroll, and Molly Potter for their helpful comments on an earlier draft of this article.

Correspondence concerning this article should be addressed to John M. Henderson, Department of Psychology, University of Massachusetts, Amherst, Massachusetts 01003.

of a pictured object presented foveally is facilitated when that object is preceded by a related object (also presented foveally), compared with when an unrelated object precedes the target object (e.g., Carr, McCauley, Sperber, & Parmelee, 1982; Kroll & Potter, 1984; McCauley, Parmelee, Sperber, & Carr, 1980). The results of these experiments mirror the effects found when both associated and semantically related words are used as stimuli (e.g., Fischler, 1977; Meyer et al., 1975) and are generally interpreted as reflecting an automatic process (Posner & Snyder, 1975) within a spreading-activation framework (Collins & Loftus, 1975).

In normal scene viewing, objects are often visible (though not necessarily fully identified) extrafoveally before they are fixated. The object-priming experiments conducted to date are unlike normal picture perception in that the two objects (the prime and the target) are presented in the same spatial position, so that no eye movement is made and no extrafoveal preview information is available. A paradigm that would mimic normal perception more closely would be to present one object foveally and another object extrafoveally in order to determine whether the relation of the two objects influenced the identification of the extrafoveal object once it was fixated. The version of this paradigm that we explored was to present the *prime* object foveally and the *target* object extrafoveally and then have the subject make an eye movement to the target object and name it. If priming effects can be observed in such a paradigm, it is then more plausible that intralevel priming can explain at least part of the context effects observed in normal scene perception.

This paradigm also allows for a diagnosis of how the prime object aids identification of the target object. Pollatsek, Rayner, and Collins (1984) showed that an extrafoveal preview of a target object aids identification of that object when it is subsequently fixated. By examining whether the priming effect (if observed) is greater when there is an extrafoveal preview of the object than when there is not, one can determine whether intralevel priming of objects allows extraction of extrafoveal information to operate more efficiently or whether it affects a different stage of processing.

In a second paradigm (employed in Experiment 3), first fixation duration on an object in an array of four objects is used as a measure of object identification. In studies in which this measure was used during scene viewing, results have been taken as evidence for the schema theory (Antes & Penland, 1981; Friedman, 1979; Loftus & Mackworth, 1978). To the extent that schema access is necessary in order to observe such effects, they should not be found in nonscene displays. However, the intralevel priming model predicts that effects similar to those found in scene processing will also be found in nonscene displays.

Experiment 1

In order to examine the combined effects of intralevel priming between objects and extrafoveal information integration across saccades, we presented two stimuli simultaneously, one foveally and the other extrafoveally. On one third of the trials, the critical object pairs were related; one third of the trials contained unrelated objects; and one third involved a nonmeaningful foveal *blob*. The blob was included as an attempt to provide a neutral prime, although it has recently become apparent that finding a truly neutral prime can be difficult (Carr et al., 1982; deGroot, 1983; Jonides & Mack, 1984; Rayner & Slowiaczek, 1981). The task was to execute an eye movement to the extrafoveal object and name it as quickly as possible. If priming from foveal to extrafoveal objects is possible, then naming times should be faster when the objects are related than when they are unrelated. (The schema theory makes no explicit predictions about what should happen in this situation, although as currently formulated, there is no mechanism to account for such priming if it should occur.)

A concurrent purpose was to determine whether more information can be gathered from an extrafoveal object when there is a related object in the fovea. Such an effect of foveal context on extrafoveal information extraction has been found with word targets in both single-word contexts (Balota & Rayner, 1983; Inhoff, 1982) and sentence contexts (Balota et al., 1985; McClelland & O'Regan, 1981). Accordingly, in half of the trials, there was an extrafoveal preview of the target, whereas in the other half of the trials, no preview was given.

In addition, several studies have shown differential effects of context on object identification depending on the distance of the to-be-identified object from the current fixation (Antes, 1974; Friedman, 1979; Parker, 1978). Also, the amount of extrafoveal information extracted has been shown to depend on visual distance (Nelson & Loftus, 1980; Pollatsek et al., 1984). Therefore, we varied the eccentricity of the extrafoveal stimulus (5° or 10°) to determine whether the ease of extrafoveal information extraction would influence the amount of priming observed. Finally, the parafoveal object appeared in either the right or left visual field so that we could determine whether there would be any visual field effects on object perception.

The intralevel priming explanation of context effects in scene perception predicts that naming times in the related foveal prime condition will be faster than those in the unrelated foveal prime condition. A finding of this type indicates that processing a foveal object on fixation n can affect the identification (at either a perceptual or a conceptual level) of another foveal object on fixation $n + 1$. This could be interpreted in two ways: (a) Schema explanations are not necessary to explain many of the context effects in scene viewing, insofar as the same type of effect can be obtained with single-object contexts (this would be an extremely strong conclusion to draw from these data; however, the burden of proof might then fall on schema theorists to show how a schema explanation adds to this explanation of context effects). (b) A schema can be activated on the basis of only two related objects without regard to the spatial relation between them (this would require major modification of the schema model).

Pollatsek et al. (1984) showed that an extrafoveal preview of an object facilitates subsequent encoding of that object when it is fixated. Such an effect is also expected in the present experiment. Of greater interest is how the effects of foveal prime and extrafoveal preview may combine. An overadditive interaction between these factors (i.e., more priming when there is a preview) would imply that more information can be obtained from an extrafoveal object when that object occurs in the context provided by a single related foveal object. On the other hand, if foveal prime and extrafoveal preview were to show additivity with respect to naming time, then additive factors logic (Sternberg, 1969) would suggest that these factors affect different stages of processing. For example, it could be postulated that the preview affects perceptual analysis of the object, whereas the prime affects higher level object categorization.

Method

Subjects. Eight members of the University of Massachusetts subject pool participated in the experiment. All of the subjects had previously been in eye-movement experiments, and none of them required corrective lenses for reading.

Materials. The stimuli were 60 line drawings of common objects that had been combined into 30 pairs of related objects, all easily identified and named (a complete list is given in Appendix A; the line drawings were mostly taken from Snodgrass & Vanderwart, 1980). The same drawings were also randomly combined into 30 pairs of unrelated objects to serve in the unrelated foveal prime condition.

In addition, two control stimuli were used: (a) A square, slightly larger than the objects, which was empty except for a small fixation cross in the center, was used as an extrafoveal stimulus in a no-extrafoveal-preview condition in order to give subjects a target to move their eyes to; and (b) a meaningless, roughly rectangular blob made up of irregularly drawn sides and filled with three irregularly drawn interior line segments, equated for the number of pixels contained by the average object drawing, was used as a nonmeaningful foveal prime.

Subjects were asked to name each of the objects before the experiment. If necessary, the experimenter corrected the subject, and the objects were presented until the experimenter was sure that the subject had the appropriate name for each object.

Apparatus. The stimuli were displayed on a Hewlett-Packard 1300A cathode-ray tube (CRT) with a P-31 phosphor. The CRT has the characteristic that removing a point results in a drop to 1% of maximum brightness in 0.25 ms. A black theater gel covered the CRT so that the display appeared clear and sharp to the subjects.

Eye movements were monitored via a Stanford Research Institute Dual Purkinje eyetracker. The eyetracker and CRT were interfaced with a Hewlett-Packard 2100 computer that controlled the experiment. The drawings were entered into the computer via a Summagraphics Bit-Pad. During the experiment, the computer kept a complete record of saccade latencies, accuracy, and naming latencies. The signal from the eyetracker was sampled every millisecond by the computer, and the position of the eye was determined every 4 ms. When the subject made an eye movement in the appropriate direction, the computer immediately replaced the extrafoveal preview item with the target object. The computer initiated the change when an eye movement of 0.5° in the appropriate direction was detected and the change was completed within 5 ms. Because a saccade of 5° (to the nearest target object) requires approximately 35 ms, the display change was always completed during the saccade when vision was suppressed, and subjects did not see the change taking place.

The subject's eyes were 46 cm from the CRT, and each object subtended approximately 2° of visual angle horizontally and from 1° to 3° vertically over the set of objects. Eye movements were monitored from the right eye, although viewing was binocular. The room was dark except for the displays on the screen and a dim indirect light source.

Procedure. Upon arriving for a session, each subject was seated comfortably with his or her head resting on a chin and forehead rest to minimize any head movements. The calibration of the eye movement system then took place. After calibration, 32 practice trials were given and were followed by two blocks of 360 test trials. A trial consisted of the following events: First, a fixation display appeared, and the calibration was checked by examining the fixation position of a cross that moved with the eye. If the calibration was satisfactory, the experimenter warned the subject that the trial was to begin, and approximately 250 ms later the fixation crosses were replaced by a foveal stimulus (object or blob) and an extrafoveal stimulus (object or box). The subject then moved his or her eyes to the extrafoveal stimulus. During the saccade, the extrafoveal stimulus was replaced by the target object (as described above), and the subject named this target object as quickly as possible. The computer recorded the latency of the vocal response (timed from when the eye crossed the 0.5° threshold point). The experimenter recorded the accuracy of the response and/or whether there had been a track loss on that trial. The experiment was completed in two sessions, one session for each block, generally run on consecutive days; each session lasted 45–60 min.

Design. Each subject received 720 trials, which were produced by the factorial combination of 30 target objects, 3 foveal prime conditions (related vs. unrelated vs. nonmeaningful prime), 2 extrafoveal preview conditions (preview vs. no preview), 2 visual eccentricities (5° vs. 10°), and 2 directions of eye movement (left vs. right). All factors were manipulated within subjects. Eye movement direction was blocked, the order of blocks was counterbalanced across subjects, and the 360 trials within each block were presented in a random order.

Table 1
Mean Time to Name the Target Object and Mean Percentage of Noise Trials by Eccentricity, Parafoveal Preview, and Foveal Prime: Experiment 1

	No preview			Preview		
Eccentricity	Rel	Unrel	Blob	Rel	Unrel	Blob
5°						
Naming time (ms)	720	731	723	631	629	605
% noise trials	7	6	7	5	7	7
10°						
Naming time (ms)	706	733	724	667	683	669
% noise trials	9	11	9	13	11	10

Note. Rel = related object; Unrel = unrelated object.

Results and Discussion

The corrected mean naming latencies, collapsed over items, subjects, and direction of eye movement (which neither produced a main effect, $F < 1$, nor interacted with any other factor), are presented in Table 1. Naming errors were very infrequent (less than 1% of the trials) and were randomly distributed across conditions. The analyses reported here were conducted on corrected mean response times. These corrected times excluded all "noise trials" on which (a) voice key failures, track losses, and naming errors occurred; (b) the saccade latency was either less than 150 ms or greater than 400 ms; and (c) the naming latency was greater than three standard deviations from that subject's mean latency for that particular block. The mean percentages of noise trials are shown in Table 1. The pattern of results for the corrected mean naming latencies did not differ from the pattern before correction. Only the results of the analysis treating subjects as the random effect are reported, though we also conducted an items analysis in which the patterns of significance were identical to those found with the subjects analysis.

First, there was a large benefit from an extrafoveal preview of an object, $F(1, 7) = 357.45$, $p < .001$, although the benefit derived from an extrafoveal preview was mediated by the distance of the extrafoveal stimulus, $F(1, 7) = 36.46$, $p < .001$. At 5° there was a benefit of 103 ms, whereas at 10° the benefit was 48 ms.

Second, identification of a fixated object was affected by the object fixated immediately before. Specifically, an object was identified faster if the object seen on the previous fixation was related rather than unrelated to it. Mean naming latencies for the related, unrelated, and blob conditions were 681, 694, and 680 ms, respectively, $F(2, 14) = 3.90, p < .05$. Thus even though subjects were never explicitly told to attend to the foveal primes and were told to move their eyes as quickly as possible to the extrafoveal stimulus, the foveal primes were encoded to a level at which they could exert an influence on subsequent processing. Because the target-naming latencies were facilitated when the foveal prime was related to that target compared with when the foveal prime was an unrelated object, $F(1, 7) = 6.32, p < .05$, it appears that a previously fixated object affects the speed of identification of the currently fixated object. Thus intralevel priming appears to be a reasonable mechanism for at least part of the facilitative effects of context in scene perception whereby a likely object in a scene is identified more rapidly than an unlikely object.

Another important aspect of these data is that the unrelated condition shows inhibition in relation to the blob condition, though this effect is only marginally significant, $F(1, 7) = 4.84$, $.05 < p < .10$, whereas the related and blob conditions are virtually identical. According to Posner and Snyder's (1975) two-process account of priming, a finding of inhibition for unrelated primes in relation to a neutral baseline indicates the use of an attentional process, rather than the use of an automatic process such as spreading activation. In other words, the fact that inhibition was apparently dominant may indicate that subjects were using attentional strategies, such as actively predicting the target objects, and were incurring a cost when their expectations were violated. Although this is a possibility that cannot be ruled out in this experiment, there are several aspects of the data that are inconsistent with this interpretation.

First, an attentional expectancy strategy would predict not only a cost for trials on which the prediction was incorrect, but also some facilitation for those trials on which the prediction turned out to be correct, such as on the related-prime trials in this experiment. However, the related and blob conditions were virtually identical, making it seem unlikely that a prediction strategy was being used. Second, the stimulus onset asynchrony (SOA) between the prime and the target was about 285–300 ms in this experiment (250-ms average saccade latency plus a 35- to 50-ms saccade duration), which is smaller than the SOAs of 500 ms usually needed to produce attentional expectancies (Neely, 1977; Posner & Snyder, 1975). Finally, evidence to be presented in Experiment 2 is inconsistent with this interpretation.

An alternative to the hypothesis that the use of an attentional strategy caused the inhibition shown for the unrelated condition is that the blob chosen in the current experiment as the neutral stimulus may, in hindsight, have been a poor choice (see Jonides & Mack, 1984, for a general discussion of the problems associated with identifying a neutral prime). The blob may have differed from the related and unrelated primes in several ways: (a) It had neither a name nor a concept associated with it; (b) though it was equated for the number of pixels that constituted it, it may have been visually simpler; and (c) because it was less meaningful, it may have been less efficient at capturing attention. The first difference may mean that there was a Stroop-like

Table 2
Amount of Priming (Unrelated Minus Related Conditions) by Parafoveal Preview and Eccentricity: Experiment 1

Eccentricity	No preview	Preview
5°	11 ms	−2 ms
10°	27 ms	16 ms

name competition when the foveal stimulus was meaningful, but it was absent when the foveal stimulus was a blob (see McCauley et al., 1980; Pollatsek et al., 1984). The latter two differences may have led to more efficient processing for the extrafoveal stimulus when the blob was in the fovea. One indication that this analysis may be correct is that there was a larger extrafoveal benefit when the foveal stimulus was a blob (86 ms) than when it was an object prime (70 ms), $F(1, 7) = 6.36, p < .05$. Similarly, having a preview at 5° rather than at 10° increased the preview effect by 45 ms with an object in the fovea but by 64 ms when the blob was in the fovea, $F(1, 7) = 9.27, p < .05$. Finally, Carr et al. (1982) attempted a cost–benefit analysis of object-priming effects and suggested that processing either a related or an unrelated prime may slow target processing in comparison with processing a target in isolation. To the extent that the blob prime is equivalent to no prime at all, the present results are consistent with theirs.

Recall that we originally hypothesized that the foveal primes and extrafoveal preview might show an overadditive relation, in that there would be more facilitation from an extrafoveal preview when there was a related, compared with an unrelated, object in the fovea. Such a result would indicate that extrafoveal information was more useful, given a related foveal object. There was a significant Foveal Prime × Extrafoveal Preview interaction, $F(2, 14) = 5.60, p < .05$; extrafoveal preview benefits for the related, unrelated, and blob conditions were 64, 76, and 86 ms, respectively. However, this interaction was only marginal when the blob condition was removed from the analysis, $F(1, 7) = 4.22$, $.05 < p < .10$. Furthermore, the marginal interaction was underadditive. It appears that, if anything, the extrafoveal preview was less useful, given a related foveal prime, or, conversely, the related foveal prime was less useful, given an extrafoveal preview (an unrelated minus related priming effect of 19 ms with no preview and 7 ms with a preview). If this interaction is reliable, it suggests that priming of the sort shown here is useful only when the object to be identified is difficult to see—for example, when it is far away or when it is masked by other objects.

The tendency toward underadditivity between foveal prime and extrafoveal preview was also found between foveal prime and eccentricity, $F(2, 14) = 8.04, p < .005$. This interaction was partly due to the fact, discussed above, that a closer preview in the blob condition was more useful than a closer preview in an object prime condition. However, removing the blob condition still resulted in a significant interaction of eccentricity with prime, $F(1, 7) = 7.92, p < .05$. At 10° there was a 22-ms priming effect, whereas at 5° the priming effect was 5 ms (see Table 2).

The effects of extrafoveal preview and eccentricity were additive with respect to the priming effect ($F < 1$, for the three-way interaction of Foveal Prime [related vs. unrelated] × Extrafoveal Preview × Eccentricity). As shown in Table 2, the related foveal prime was most useful when there was no preview and the target was 10° away. We found less facilitation when there was a preview or when the target was closer, and we found no facilitation at all for the related over the unrelated prime when the preview appeared at 5°. Thus the related foveal prime was most useful when the target was difficult or impossible to see in peripheral vision (i.e., the 10° eccentricity and no-preview conditions) and least useful when the target could be processed easily extrafoveally (when there was a preview at 5°). However, this generalization does not entirely capture the pattern of data, insofar as there was a difference in the amount of priming found at 5° and 10°, even when there was no preview. This difference is somewhat surprising because *eccentricity* here refers only to the distance the eye had to travel in order to fixate the eventual target. For the moment, the issue of why there is a difference in priming between these cells is deferred to Experiment 2.

In conclusion, several general statements about the data from this experiment can be made. First, identification of a fixated object is affected by the object fixated immediately before. In particular, an object is identified faster if the object seen on the previous fixation was related rather than unrelated to it. This aspect of the data thus supports the intralevel priming model of context effects in scene perception. Second, it is clear that visual information about an object gathered extrafoveally aids subsequent identification of the object when that object is fixated. This finding replicates the work of Pollatsek et al. (1984) and extends it to a situation in which there is a meaningful object in the fovea. It appears that although more information can be extracted extrafoveally when there is a nonmeaningful stimulus in the fovea, a great deal can also be extracted when there is a meaningful object in the fovea, even out to 10° of visual angle. Third, there was less of a priming effect both when there was an extrafoveal preview of the target and when the eye had a smaller distance to travel in order to fixate the target.

Experiment 2

In Experiment 1 the identification of an object was facilitated if a related object, rather than an unrelated object, was viewed on the previous fixation. However, because a meaningless blob was used as the control prime, it was impossible to determine whether the difference between the related and unrelated primes was due to actual facilitation from the related object, inhibition from the unrelated object, or some combination of both. The distinction between facilitation and inhibition is theoretically important because the automatic priming process posited here as an account of context effects found in scene processing specifically implies that facilitation without inhibition should be found. On the other hand, if the priming effect observed in Experiment 1 was due to an expectancy strategy, whereby subjects allocated attention to a particular response when given a particular prime, then inhibition would be predicted when the target was not the expected object.

In order to determine whether the priming effect demonstrated in Experiment 1 was facilitation rather than inhibition dominant, we chose more diagnostic neutral primes: four objects that were not predictive of any of the 30 targets. One of the objects appeared randomly whenever a neutral prime was called for. These neutral primes were equated with the related and unrelated primes in terms of physical complexity and meaningfulness, and they were nameable. Thus there should be no unwanted benefit for the neutral primes.

In order to test the conscious prediction versus automatic priming accounts of the facilitation of related over unrelated primes found in Experiment 1, 6 of the same 8 subjects who had participated in Experiment 1 were included in Experiment 2 (the other 2 subjects were unavailable). We assumed that these subjects would have a good idea of which objects tended to be paired together. In addition, 4 of these subjects were explicitly acquainted with the related pairs and with the fact that the new objects (neutral primes) had no related objects associated with them. These subjects therefore knew that the neutral primes differed from the unrelated prime condition in that the neutral primes had no predictive value. It seems unlikely that subjects with this knowledge would make any predictions when they saw the neutral primes. Thus if conscious predictive strategies were a major source of the difference between the related and unrelated prime conditions in Experiment 1, one would expect the unrelated prime condition to be slower than the neutral prime condition in Experiment 2 because the subjects would generate the wrong prediction with unrelated primes, whereas they would generate no prediction in the neutral prime condition. If, on the other hand, the priming effect found in Experiment 1 was due to expectancy-independent automatic priming, then the related prime condition should be faster than both the unrelated and neutral prime conditions, whereas the latter two should not differ from each other.

A second purpose of Experiment 2 was to determine whether a priming effect would occur at 5° if the extrafoveal preview were made more difficult to see. (Recall that in Experiment 1, there was a tendency for the priming effect to be smaller or even to disappear if the target could be seen clearly in the periphery—that is, if there was a close extrafoveal preview.) One of the differences between normal scenes and the stimuli used in Experiment 1 is that in scenes, extrafoveal objects are usually surrounded by other objects and background, and thus they are more difficult to see. In order to simulate this in the paradigm used here without adding the confound of having two nameable objects in the periphery, we placed the blob used in Experiment 1 between the foveal prime and the extrafoveal preview in half of the trials so that the preview would be more difficult to see. We expected this to decrease the extrafoveal preview effect but to increase the amount of priming shown at 5°.

Some of the results of Experiment 1 were unexpected. For example, more priming was found at 10° than at 5° even when there was no extrafoveal preview of the target. It is not clear why this should be so. Furthermore, there was a tendency for there to be less distance and preview benefit for related primes than for unrelated foveal primes. Experiment 2 served to determine whether these results were replicable.

Method

Subjects. Eight members of the University of Massachusetts subject pool participated in the experiment. Of the 8 subjects, 6 had participated in Experiment 1, and 4 of them were acquainted with the related prime–target pairs and with the fact that the four neutral primes had no related targets.

Materials. The stimuli were the same 60 line drawings used in Experiment 1. In addition, the blob used as a foveal prime in Experiment 1 was used as an extrafoveal lateral "mask." Also, four new line drawings (a bed, a cannon, a snowman, and a stoplight) taken from Snodgrass and Vanderwart (1980) replaced the blob as the neutral primes. Each of these neutral primes was in fact related to at least one of the targets in some way, insofar as it is virtually impossible to find four objects that are totally unrelated to any of 30 targets. The important point to keep in mind, however, is that, given one of the 30 nonneutral primes, there was a .50 probability that a *particular* related object would be the target and a .50 probability that a *particular* unrelated object would be the target, whereas given one of the neutral primes, the probability that the quasi-related object would be the target was only .033, and the probability that the target would be any other target object was also .033.

As in Experiment 1, subjects were asked to name each of the objects before the experiment and were corrected until they had the appropriate name for each object.

Apparatus and procedure. The apparatus and procedure were the same as in Experiment 1, with the following exceptions. First, as already described, the neutral foveal prime condition consisted of one of four objects randomly selected on a given trial, rather than the meaningless blob. Second, we introduced a new factor—extrafoveal mask—which was fully crossed within subjects with all other factors. The extrafoveal mask consisted of the blob used in Experiment 1. On half of the trials, this lateral mask appeared spatially between the foveal prime and the extrafoveal stimulus (target or box); its nearest outer edge was 0.5° from the nearest outer edge of the extrafoveal stimulus, and, like the foveal stimulus, it remained on the screen after the eye movement. On the other half of the trials, the mask did not appear. Like the eye-movement direction factor, extrafoveal mask was blocked. Therefore, all subjects participated in four blocks, which comprised all possible combinations of extrafoveal mask (mask or no mask) and eye-movement direction (left to right or right to left). The order of blocks was counterbalanced across subjects according to a Latin square. The experiment was completed in four sessions, one session for each block, generally run on consecutive days; each session lasted 45–60 min.

Design. Each subject received 1,440 trials, which were produced by the factorial combination of 30 targets, 3 foveal prime conditions (related vs. unrelated vs. neutral foveal prime), 2 extrafoveal mask conditions (mask vs. no mask), 2 extrafoveal preview conditions (preview vs. no preview), 2 visual eccentricities (5° vs. 10°), and 2 eye-movement directions (left vs. right).

Results and Discussion

The corrected mean naming latencies, collapsed over items, subjects, direction of eye movement, and extrafoveal mask, are presented in Table 3. Naming errors were again very infrequent (occurring on less than 1% of the trials) and were randomly distributed across conditions. As in Experiment 1, the analyses reported here were conducted on the corrected mean response times, excluding noise trials. The mean percentages of noise trials for each condition are shown in Table 3. The pattern of results for the corrected naming latencies did not differ from the pattern before correction. We also conducted an items analysis, and the patterns of significance were identical to those found in the subjects analysis.

Unexpectedly, the presence of the extrafoveal mask did not increase naming latencies ($F < 1$). In addition, the presence of the extrafoveal mask did not increase the amount of priming found at 5° when there was an extrafoveal preview (3-ms priming without the mask, −6-ms priming with the mask, neither of which differed from 0 by t test), as would be predicted if the lack of a priming effect at 5° with a preview were due to the ease of seeing the preview. It thus appears that subjects were able to ignore the mask, and therefore this condition does not allow a test of the hypothesis that priming would be found at 5° if the preview were made more difficult to see.

As in Experiment 1, direction of eye movement again produced no main effect ($F < 1$), though it did participate in two higher order interactions. However, because those interactions had no apparent meaning, this factor will not be discussed further.

Experiment 2 replicated the primary features of Experiment 1. There was a preview effect, $F(1, 7) = 207.08, p < .001$, which was larger at 5° (106 ms) than at 10° (52 ms), $F(1, 7) = 71.16$, $p < .001$. There was also a significant main effect of eccentricity, $F(1, 7) = 62.06, p < .005$, which primarily was caused by those trials on which there was a preview.

Of primary interest in Experiment 2 is the effect of the type of foveal prime seen on a trial. Consistent with the view that context effects in scene processing can be accounted for through the operation of passive spreading activation (intralevel priming), the main effect of foveal prime was significant, $F(2, 14) = 9.34, p < .005$. Mean naming latencies were 670, 678, and 681 ms for the related, unrelated, and neutral prime conditions, respectively. Planned comparisons showed that the difference between the related and unrelated conditions, $F(1, 7) = 8.24, p < .05$, and the difference between the related and neutral conditions, $F(1, 7) = 11.32, p < .05$, were both significant, whereas the difference between the unrelated and neutral conditions was not, $F(1, 7) = 3.56, p > .05$. When the neutral condition served as a baseline, there was an overall facilitation effect of 11 ms for a related prime and no cost for an unrelated prime. Therefore, within Posner and Snyder's (1975) framework, these results indicate automatic facilitative processing.

It is important to note that the pattern of data for the subjects who had participated in Experiment 1 did not differ from the pattern produced by those who had not. Also, the 4 subjects who were acquainted with the related prime–target pairs and with the fact that the neutral primes were nonpredictive produced the same pattern of facilitation without inhibition as those subjects who were not acquainted with these contingencies. As we argued earlier, it seems quite implausible that the 4 nonnaive subjects were making conscious predictions when they saw the neutral primes. Therefore, if these subjects were consciously predicting the related target when seeing the unrelated prime, the unrelated prime condition should have been slower than the neutral prime condition. Because such a difference was not found, it appears either that these subjects were not making conscious predictions or that these predictions were too slow to affect naming of the target. On the other hand, because the naive subjects may not have discriminated the neutral primes from the other primes, it is still possible that they were making conscious predictions from all targets and thus producing equal cost in both the neutral and unrelated prime conditions. However, it seems more parsimonious to explain the pattern of data for all subjects through the operation of automatic priming, insofar as the data for the naive and nonnaive subjects were virtually identical and the SOA in the experiment was below the magnitude usually required for conscious prediction to operate. Therefore, these data again suggest that the facilitation provided by the related targets was due to an automatic mode of processing.

Finally, the pattern of results observed in Experiment 1

Table 3
Mean Time to Name Target Object, Mean Percentage of Noise Trials, and Amount of Priming (Neutral Minus Related and Unrelated Conditions) by Eccentricity, Parafoveal Preview, and Foveal Prime: Experiment 2

	No preview			Preview		
Eccentricity	Related	Unrelated	Neutral	Related	Unrelated	Neutral
5°						
Naming time (ms)	708	712	716	607	606	606
% noise trials	5	7	6	4	5	4
Priming (ms)	8	4		−1	0	
10°						
Naming time (ms)	708	725	726	658	670	675
% noise trials	7	9	8	8	8	9
Priming (ms)	18	1		17	5	

(when the nonmeaningful blob prime was removed from the analysis) among foveal prime, eccentricity, and extrafoveal preview was again found in Experiment 2. In Table 3 we present the amount of priming found (the difference between the neutral condition and the related and unrelated conditions) as a function of eccentricity and preview. First, there was more of a priming effect at 10° (18 ms) than at 5° (3 ms), $F(2, 14) = 6.38, p < .05$. Second, there was again a moderate though nonsignificant tendency for there to be a larger priming effect when there was no preview (13 ms) than when there was a preview (7 ms), $F(2, 14) = 2.59, p = .11$. This result is inconsistent with the hypothesis that more extrafoveal information can be extracted with a related object in the fovea. Third, the three-way interaction between these factors was not significant ($F < 1$), indicating that the eccentricity benefit on priming was as large when there was no preview as when there was a preview. As was indicated in Experiment 1, this last result is somewhat counterintuitive because when there was no preview, the only difference between the 5° and 10° eccentricity conditions was the distance the eye had to travel.

One explanation for the greater priming at 10° than at 5° even when there was no preview is that the effective SOA was greater at 10 degrees.[1] In order to test this assertion, the data from both experiments were divided in a mean split according to saccade latency. There was, in fact, no tendency for there to be more priming with longer saccade latencies: Experiment 1, $F < 1$; Experiment 2, $F(2, 14) = 1.01$.

A second explanation for this effect is that at 5° the box used as the extrafoveal target in the no-preview condition was encoded to a degree sufficient to cause disruption to the process that integrates information across saccades. Unfortunately, there is no obvious way to directly test this possibility, given the data at hand.

A third explanation for more priming at 10° than at 5° given no extrafoveal preview is that subjects land less accurately on the target object after a longer saccade. Because previous work has shown that priming effects increase when the target is visually degraded (Meyer et al., 1975; Sperber et al., 1979), the greater priming at 10° may result from poorer visual information because of a less advantageous fixation point following a 10° saccade. In fact, subjects were more accurate in landing at 5° than at 10°. First, the standard deviations of landing position at 5° (19 pixels in Experiment 1, 16 pixels in Experiment 2) were less than at 10° (52 and 35 pixels in Experiments 1 and 2), $t(7) = 6.03, p < .001$ for Experiment 1 and $t(7) = 4.28, p < .005$ for Experiment 2. Second, the first fixation on the target was appreciably closer to the fixation position when the target was actually named (which is presumably the preferred landing position) at 5° (12 and 9 pixels in Experiments 1 and 2) than at 10° (31 and 19 pixels in the two Experiments), $t(7) = 4.13, p < .005$ for Experiment 1 and $t(7) = 5.60, p < .001$ for Experiment 2. This indicates that the conditions in which subjects landed less accurately were those in which greater priming was observed. However, such a correlation is admittedly weak evidence.

A more direct test of the "bad landing gives more priming" hypothesis would be a comparison of trials at 5° and 10° in which landing accuracy was approximately equal. However, because there were few accurate landings at 10° and few inaccurate landings at 5°, such a comparison was not feasible. Thus, although the data support the poorer accuracy of a 10° saccade, it must be left to future research to determine whether this does in fact increase the effect of context on object identification.

Additional Analyses

Name Frequency

The naming paradigm used in these experiments may involve at least three separate stages of processing: an object-encoding stage, conceptual activation, and a name-retrieval/production stage (Potter, 1979; Seymour, 1973, 1976). The locus of the demonstrated priming effect could have been at any of these stages. Because name retrieval is not a logically necessary stage in normal object identification, the generality of the priming effect to scene processing would be reduced if the priming effect

[1] The saccade latency (the amount of time it took to begin an eye movement toward the extrafoveal target) was greater with a 10° target in both experiments: 20 ms longer in Experiment 1, $F(1, 7) = 113.54, p < .001$, and 14 ms longer in Experiment 2, $F(1, 7) = 43.75, p < .001$. Several other factors were also found to affect saccade latency. In Experiment 1, latencies were shorter with the blob in the fovea (247 ms) than without (253 ms and 250 ms for the related and unrelated primes), $F(2, 14) = 9.58, p < .005$. In Experiment 2, latencies were shorter with the blob lateral mask (231 ms) than without (243 ms), $F(1, 7) = 5.86, p < .05$, and the effect of eccentricity on saccade latency was larger without the blob mask (19-ms difference) than with the blob mask (9-ms difference), $F(1, 7) = 18.28, p < .005$.

occurred predominantly at the name-retrieval/production stage. In order to test whether the priming effect was occurring at the latter stage, we used additive factors logic (Sternberg, 1969). If the priming effect was occurring at the name-retrieval/production stage, then priming should interact with another factor known to affect this stage. Such a factor is the frequency in the language of the word or name produced. If, on the other hand, the priming effect is occurring at either the object-encoding stage or at the conceptual retrieval stage, then the effects of name frequency and prime should combine additively.

To test this, we found the name frequencies of the 30 target objects in Kučera and Francis's (1967) corpus. We then rank ordered and split the targets into three groups of 10 according to name frequency. The mean name frequencies were 8 (range 0–17), 34 (range 18–59), and 130 (range 60–352) for the low-, medium-, and high-frequency groups, respectively. We then conducted an analysis of variance (ANOVA) for each experiment on the mean naming latencies, averaged over subjects, treating name frequency as a between-items factor. The results of these analyses were clear: Although there was a main effect of name frequency in both Experiment 1, $F(2, 27) = 5.17$, $p < .05$, and Experiment 2, $F(2, 27) = 5.10$, $p < .05$, so that naming latency was inversely related to target name frequency, there was no hint in either experiment of a Foveal Prime × Name Frequency interaction (both Fs < 1). Therefore, these results are consistent with the conclusion reached by previous researchers (e.g., Huttenlocher & Kubicek, 1983; Kroll & Potter, 1984; McCauley et al., 1980) that the object priming effect is not a result of object naming. It appears, instead, that the priming effect is located at either the perceptual encoding level or the conceptual retrieval level of processing.

Visual Similarity

Aside from a passive spreading-activation account of the priming effect demonstrated here, it is possible that the facilitation found for related primes was due to the greater visual similarity of the related primes to the target objects. A visually similar prime could facilitate the low-level feature processing of the target through simple feature overlap (Sperber et al., 1979). A priming effect due to simple feature overlap between related objects would suggest an additional explanation of the context effects found in scenes (because related objects typically look more like each other, even in scenes). However, such an effect would seem less robust than a priming effect at the conceptual level because it might be affected by such visual stimulus factors as object orientation.

To determine whether visual similarity was playing a role in the priming effect, we asked 4 subjects to rate the related pairs on a 5-point scale of visual similarity. The ratings were extremely reliable for the 10 least and 10 most visually similar pairs, and these were selected as the most extreme test of the visual similarity hypothesis. The mean similarity rating for the low-similarity group was 1.1 (range 1.0–1.25), and for the high-similarity group was 3.65 (range 3.0–4.5). We then examined the overall priming effect for these two groups of 10 items. As seen in Table 4, there was no indication of a reduced priming effect for the 10 targets that were less visually similar to their primes ($p > .25$ in both experiments). In addition, there was no indication that visual similarity played more of a role at 5° than at 10° ($F < 1$ for the Visual Similarity × Eccentricity interaction in both experiments). This result is consistent with that of Huttenlocher and Kubicek (1983), who explicitly controlled the visual similarity of related and unrelated primes to targets and still found a sizable priming effect. There is, therefore, no evidence that the priming effect that we found can be explained at the level of visual similarity.

Table 4
The Priming Effect (in Milliseconds) in Experiments 1 and 2 for All Targets (n = 30) and for Targets That Had High (n = 10) and low (n = 10) Visually Similar Primes

	Priming		
Experiment	All items	High similarity	Low similarity
1	13	12	15
2	11	10	17

Naming Latency Frequency Distribution Analyses

The effect of having an extrafoveal preview of the target was shown to be quite large and robust. The cause of this effect is thought to be an integration of the information picked up in the periphery with the information picked up once the eye fixates the target (Pollatsek et al., 1984). In other words, because some information has been picked up in the periphery, less processing needs to be done in order to identify the object once it has been fixated.

An alternative account of the preview effect is that subjects are sometimes identifying and beginning to name the extrafoveal target before they move their eyes. According to this explanation, the preview effect is due to a full identification of the object in the periphery on some proportion of the trials rather than to the integration of partial information across saccades. Although Pollatsek et al. (1984) provided some evidence against this explanation, it seems beneficial to show such evidence for our experiments. To this end, frequency distributions of the naming latencies were constructed. If the extrafoveal preview benefit is due to subjects' identifying and beginning to name the target before they move their eyes on a significant proportion of the preview trials, then the naming latency distributions should tend to be bimodal when there is a preview. The two peaks of the bimodal distribution would reflect the trials on which subjects did and did not identify the peripheral stimulus. On the other hand, if the extrafoveal benefit is primarily due to the integration of information picked up before and after the eye movement, the distributions for the preview and no-preview trials should be similar; the mean of the former would be merely shifted to the left (faster responses).

The mean naming latency for a subject in each condition was found and the frequencies tabulated in each 25-ms interval around the mean. These frequencies were cumulated across subjects and across eye movement direction. Then the trials that did not include the extrafoveal mask in Experiment 2 were cumulated with those of Experiment 1 to produce more reliable distributions. Because the neutral prime conditions were different in the two experiments, only the related and unrelated

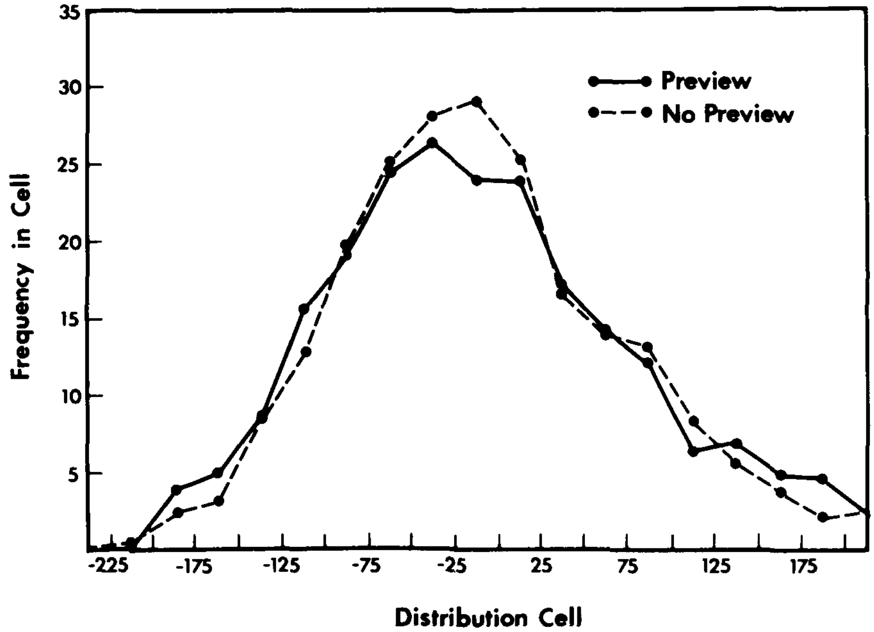

Figure 1. Frequency distributions for 5° related trials, preview and no preview, centered at their means.

conditions are presented. The resulting distributions are shown in Figures 1 through 4. Each point along the *X* axis represents one distribution interval of 25 ms.

As can be seen in Figure 1 and Figure 2, the shapes of the distributions for the preview and no-preview conditions are extremely similar. Figure 1 presents the preview and no-preview distributions, centered at their means, for the related prime condition at a 5° eccentricity. Figure 2 presents the same distributions for the unrelated prime condition. Although the preview distributions are flatter and a bit wider than the no-preview distributions, they are strikingly similar, and there is no evidence of bimodality given a preview. Figures 3 and 4 present distributions analogous to those of Figures 1 and 2, except with a 10° eccentricity. These distributions are more variable than their 5° counterparts, but the same conclusion emerges. There does not appear to be any evidence in these distributions favoring the hypothesis that the preview effect is due to the identification of the target in the periphery. Instead, it appears that the

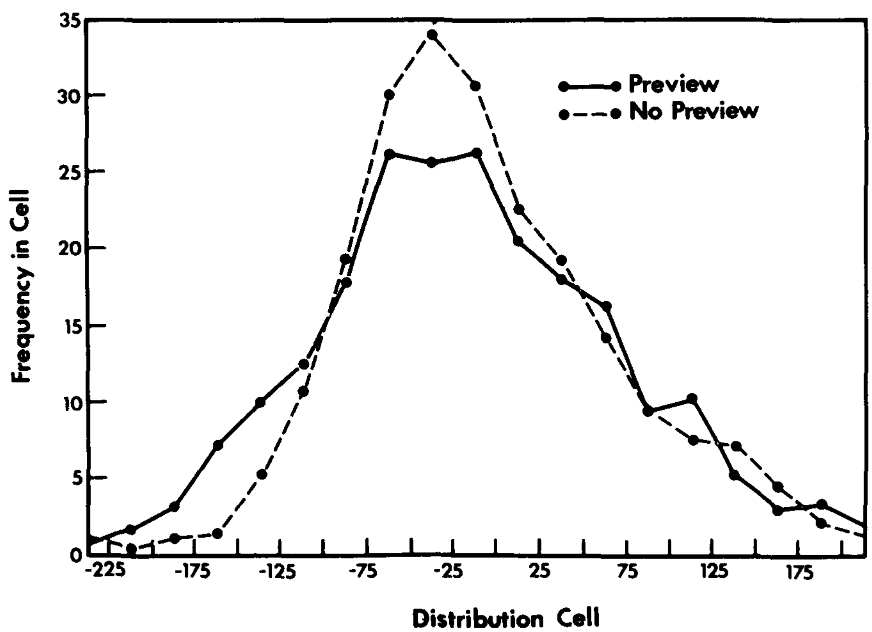

Figure 2. Frequency distributions for 5° unrelated trials, preview and no preview, centered at their means.

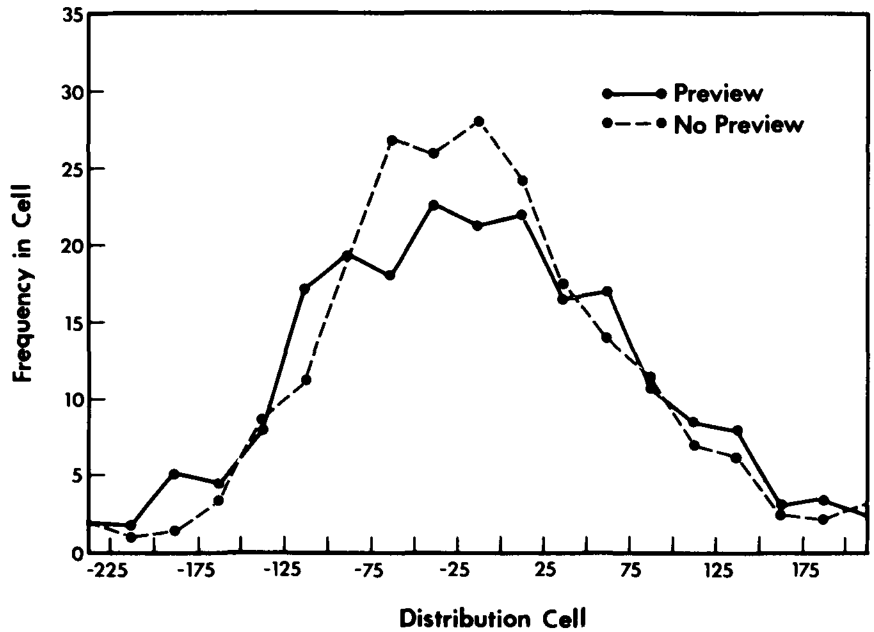

Figure 3. Frequency distributions for 10° related trials, preview and no preview, centered at their means.

extrafoveal preview gives those targets a head start, so that they are identified faster once they are fixated.

We should note that the slight flattening and bulging of the preview distributions (especially the bulges at about −200 ms from the mean) may indicate that on a small proportion of the trials, subjects are in fact recognizing the target in the periphery. However, the fact that the shapes of the distributions are nearly identical makes it unlikely that such trials are the predominant cause of the preview effect.

Experiment 3

The first two experiments provided evidence for the possibility of an intralevel priming explanation for some of the effects of a scene context on object identification. They demonstrated that naming latency for an object is facilitated if that object is fixated after fixation on a related object. Previous experiments in which eye fixations were recorded during scene viewing have shown that fixation time on a critical object is shorter when the

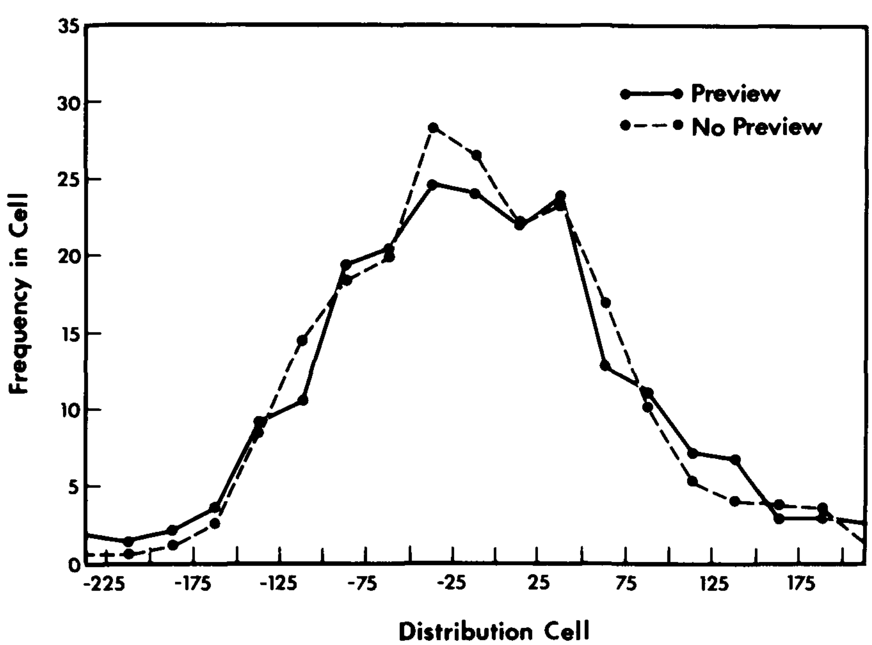

Figure 4. Frequency distributions for 10° unrelated trials, preview and no preview, centered at their means.

object is predicted by the scene than when it is inconsistent with the scene (Antes & Penland, 1981; Friedman, 1979; Loftus & Mackworth, 1978). In Experiment 3 we attempted to determine whether similar effects on fixation time can also be found with nonscene displays of objects, as predicted by the intralevel priming hypothesis.

Subjects were shown displays of four objects arranged in a square, and their eye movements were recorded while they looked at the displays. Two types of displays were used. In one type, three of the objects were related to each other, and the fourth object was unrelated. Two targets appeared in each of these displays: One target was a related object (related condition), and the other was neither related to any of the other objects nor consistent with the categorical grouping that they formed (unrelated category condition). For example, in one display used, the four objects were a boat, truck, car, and shoe. The truck was predefined as the related target and the shoe as the unrelated category target. In the second type of display, all four objects were unrelated, so that no category was formed, and one of these objects was a target object (unrelated noncategory condition). The subjects were to look at each display until they knew what the four objects were, and then to hit a key to terminate the display. After display termination, the subject was verbally given the name of an object and asked to indicate whether that object had appeared in the previous display. The primary dependent measure was mean first fixation duration (FFD) on the targets across conditions, which was taken as an on-line indication of identification time (Friedman, 1979; Loftus & Mackworth, 1978).

According to most schema theorists, a true scene, which includes appropriate spatial relations among objects, is required for a schema to become activated and for consistent objects to show benefit in identification time. In nonscene displays, no schema can be activated, and therefore no context effects should be found. However, according to Biederman (1981), in a nonscene display containing a group of related objects and one unrelated object, the unrelated object will "pop out" or be identified more rapidly than the related objects. The idea is that in scene contexts in which a schema is available, consistent objects are facilitated because of the influence of top-down predictability information, whereas in nonscene arrays of objects in which a schema is not available, processes such as those postulated for visual search tasks operate (Egeth, Jonides, & Wall, 1972). Therefore, either there should be no difference in identification times for the related and unrelated objects, or a target in the unrelated category condition should be identified more rapidly than the same target in the related and unrelated noncategory conditions.

In contrast, the intralevel priming hypothesis suggests that the benefit on identification time for consistent objects found in scenes derives from passive spreading activation between object or conceptual nodes and therefore is not dependent on the accessibility of a scene-level description. The prediction is that the target object in the related condition will be identified more rapidly than the same object appearing in both the unrelated category and the unrelated noncategory conditions. Further, the intralevel priming hypothesis does not predict any inhibition for unrelated objects that results from display-level category effects. By examining identification time for targets in the two unrelated conditions, one should be able to determine whether there is an inhibitory effect on unrelated category targets arising from the fact that they are inconsistent with the category suggested by the other three objects.

Method

Subjects. Ten members of the University of Massachusetts subject pool participated in the experiment. All of the subjects had previously participated in eye-movement experiments, and none of them required corrective lenses for reading. All subjects were naive with respect to the hypotheses being tested.

Materials. The stimuli were 36 line drawings of common objects, mostly drawn from the first two experiments, all of which could be easily identified and named. Of these 36 objects, 12 were predefined to be the target objects.

The 36 objects were combined into 24 displays of 4 objects each. (Appendix B lists the 24 displays along with the target objects.) The objects in each display occupied the corners of an imaginary square, with 5° of visual angle between the centers of any two objects along a side of the square as displayed to the subjects. Twelve of the displays contained 3 related objects and 1 unrelated object. In these displays, one of the related objects was a target object (related condition), and the single unrelated object was also a target object (unrelated category condition). The other 12 displays contained 4 unrelated objects, one of which was a target object (unrelated noncategory condition). Each target object appeared exactly three times, once in each condition, always with three different objects, and always in the same location in the square across conditions. Across displays, targets appeared equally often at each of the four positions in the square. From the subject's perspective, there was nothing to distinguish the target objects from the nontarget objects.

Subjects were asked to name each of the objects before the experiment. If necessary, the experimenter corrected the subject so that there would be no confusion later in the experiment.

Apparatus. The equipment was the same as that used in the first two experiments. In this experiment, the computer kept a complete record of the subject's eye movement behavior, including fixation position and fixation duration. The eyetracker has a resolution of 10′ of arc.

Procedure. The experimental setting and calibration of the equipment were as described in the first two experiments, except that a bite bar rather than a chin rest was used to eliminate head movements, and the calibration included the vertical as well as horizontal dimension. After calibration, two blocks of 24 test trials were given. A trial consisted of the following events: First, a central fixation cross (initiated by the experimenter) appeared, and the experimenter checked to see whether the calibration was accurate. If the calibration was satisfactory, the experimenter warned the subject that the trial was to begin, and approximately 250 ms later the fixation cross was replaced by a display. The subject then made a saccade from the center of the display (where there was no object) and looked around the display to see which objects were there. Subjects were told that they could look at the objects in the display in any order that they chose.

When the subject had identified the objects in the display, he or she pushed a display termination key. This caused the objects to disappear and be replaced by four pattern masks for 250 ms, one in each position formerly occupied by an object. The experimenter then asked the subject whether a particular object had appeared in that display. Half of the questions required a *yes* response, and half required a *no* response. Approximately 25% of the questions involved a target object. Subjects signaled yes or no without coming off of the bite bar. These questions were included in order to ensure that the subject was encoding the objects; the subjects had no difficulty in answering the questions correctly (no subject made more than one error, and most subjects made no errors).

Each subject participated in two blocks of trials. In the first block, the subject saw all 24 displays in a random order. After a short rest, the subject received the second block, which consisted of the same displays in a new random order. Thus each subject received 48 trials in total. The entire experimental session lasted from 30 to 45 min.

Results and Discussion

Despite the fact that subjects were told that they could look at the objects in each display in any order that they chose, each subject adopted a particular pattern and generally adhered to it. (Subjects chose a particular location to fixate first throughout the experiment, and then always moved either clockwise or counterclockwise from that location around the display.) Therefore, there was no tendency for subjects to move their eyes to the targets in the unrelated category condition first.

Several analyses of the first fixation duration (FFD) data were conducted. All of these analyses excluded trials on which track losses occurred for the target objects and trials on which target objects were not fixated. Less than 1% of the data were lost to such trials, and they were randomly distributed across conditions. In addition, block neither produced a practice main effect nor interacted with condition ($Fs < 1$), and the data to be reported were collapsed over this factor.

In the first analysis we compared mean FFD on the target objects contingent on whether a related object had been seen on the previous fixation. Accordingly, we excluded from this analysis those trials in which the target object was the first object fixated in the display and those trials in which the related target was fixated immediately after the unrelated category target in that display. (Such trials are analyzed separately below.)

The mean FFDs in the first analysis were 269, 315, and 300 ms for the related, unrelated category, and unrelated noncategory conditions, respectively, $F(2, 18) = 4.8512$, $p < .05$. Planned comparisons revealed that the 46-ms advantage for the target objects when they were in the related condition versus unrelated category condition was reliable, $F(1, 9) = 8.2142$, $p < .05$, as was the 31-ms advantage of the related condition over the unrelated noncategory condition, $F(1, 9) = 5.0352$, $p < .05$. Further, the slight difference between the two unrelated conditions did not approach statistical significance ($F < 1$). These data are thus consistent with the view that a schema need not be activated to produce context effects when subjects are looking around at objects in order to identify them. These data do not support the prediction derived from schema theory that objects in nonscene displays will show effects different from those found when objects are processed in scenes, and in particular, do not provide evidence for a "pop-out" effect for the unrelated category condition.

It is possible that the difference in identification time between the related and unrelated conditions was due to consistency effects attributable to the entire display rather than to priming from the last object fixated. If this is true, then a target object in the related condition should still show a benefit even when it was fixated immediately after fixation on the single unrelated object in that display and also when it was the very first object fixated in the display. On the other hand, if it is necessary that a target be fixated after fixation on a related object in order to show facilitation, then no facilitation should be found under these circumstances. To test this, we conducted a second analysis in which we compared mean FFD in the three conditions for those targets that were the first object fixated in a display and for those targets that in the related condition were fixated after fixation on the unrelated category target. In accordance with the view that the facilitation in the related condition was due to priming from an immediately preceding fixation on a related object, there was no difference found between conditions ($F < 1$). The mean FFDs were 274, 282, and 278 ms for the related, unrelated category, and unrelated noncategory conditions, respectively.[2] Furthermore, there was no interaction between condition and whether the related target was fixated first or fixated after the unrelated target ($F < 1$).

It is interesting to note that the size of the priming effect found in this experiment is quite a bit larger than was found in the first two experiments. This at first seems a bit puzzling because the objects were only 5° away from each other here. The 5° eccentricity condition produced the least evidence of priming in the other two experiments. However, it seems likely that part of this difference is due to the fact that in the earlier experiments, the subjects did not have a reason to attend to the foveal object, whereas in this experiment, they were presumably attempting to identify each object as they fixated on it. Attending to the foveal object may have both increased its strength as a prime and reduced the amount of information extracted from objects in the parafovea. If the analysis in the first two experiments is correct and more priming is likely when less information has been extracted from a parafoveal object, then this probably served to increase priming in this experiment.

It is also worth noting that the size of the priming effect found here was comparable in size to the size of the effects attributed to schema activation in previous studies (Antes & Penland, 1981; Loftus & Mackworth, 1978). Only Friedman (1979) found larger effects, and, given that the size of those effects was about 300 ms, it is likely that other processes beyond object identification were being tapped.

In summary, this experiment provides evidence consistent with the intralevel priming hypothesis and counter to the schema theory. We found a priming effect in which related objects were identified faster when they were fixated immediately following fixation on a related object, despite the fact that these objects did not appear in scene contexts. Furthermore, using nonscene displays, we found facilitation effects quantitatively similar to those found by researchers examining fixation duration in scene contexts (Antes & Penland, 1981; Loftus & Mackworth, 1978), which contradicted the predictions of most schema theorists. Finally, there was no evidence of a "pop-out" effect of the type predicted by Biederman (1981).

---

[2] Because each target object appeared in only one position around the imaginary square, the target objects in the first analysis and in the second analysis were in fact different objects, which made a direct comparison of mean first fixation durations (FFDs) across analyses impossible. The fact that mean FFDs were faster in the second analysis seems to be partly due to this difference in target objects. These shorter mean FFDs may also have been due to the fact that more parafoveal benefit could be derived from the first object fixated in the display because the immediately preceding fixation was in the center of the imaginary square, where there was no foveal object requiring processing resources for identification and where the first object fixated was closer (3.5°) than fixations between objects (5°).

General Discussion

The results of the three experiments reported in this article suggest that an object is more easily identified when it is fixated immediately after fixation on a related rather than an unrelated object. This result seems to be due to the operation of a passive intralevel priming mechanism that does not derive from conscious prediction. To the extent that this effect is due to automatic processing, it would also be expected to operate during scene perception. This suggests that at least part of the effects of a scene context on object identification may be attributable to these same effects.

Previous researchers focused on two main paradigms in order to explore the effects of context in scene processing. In one paradigm (Biederman et al., 1982), scenes are presented tachistoscopically and subjects are asked to produce a *yes/no* response to whether a cued object appeared in the scene. Subjects tend to be more accurate at this object-detection task when the object is consistent (either semantically or syntactically; see Biederman et al., 1982) with the scene than when it is not. Using a second paradigm, various researchers have similarly found that the first fixation duration on an object tends to be shorter when the object is consistent with the scene (Antes & Penland, 1981; Friedman, 1979; Loftus & Mackworth, 1978). Without exception, researchers working in this area have discussed such context effects in terms of a schema model. Although these schema models have not been clearly spelled out, the assumption in all of them is that a scene-level representation is computed very rapidly (on the order of 100 ms) and that this representation then feeds information top-down to the object level, facilitating the recognition of objects that are predicted by the scene.

An alternative explanation for the effects of context on object identification is suggested by our data. According to the intralevel priming hypothesis, some, if not all, of the effects of a predictive scene context on object identification can be explained by passive spreading activation between nodes either at the level of object representations or perhaps at an amodal conceptual level of representation (Potter, 1979; Seymour, 1973, 1976). Consistent with this hypothesis, we demonstrated in Experiment 1 that objects were identified faster after a saccade if a related object rather than an unrelated object had been fixated previously. In Experiment 2 we replicated this result and further showed that the benefit on identification time was due to facilitation from the related object rather than to inhibition from the unrelated object. Thus these data supported the hypothesis that passive spreading activation was producing the difference in identification time. Using the same measure of identification time as has been used in the literature on scene processing (first fixation duration on an object) as evidence that object identification is influenced by schema activation, we found in Experiment 3 similar facilitation effects in a situation in which it should not be possible to activate a schema.

In order for the intralevel priming hypothesis to explain the effects of a scene context on object identification, one must make several assumptions. First, one must assume that an object that fits in a scene is more likely to be semantically related to other objects in the scene than is an object that does not fit in the scene. A moment's reflection will show that this assumption is reasonable. Second, one must assume that the automatic priming found here between two objects across a saccade would also operate in a scene. Given that the priming effect is automatic and not a result of conscious experiment-specific strategies and given that it appears to operate when subjects are simply looking at objects to determine what they are, such priming would be expected to operate in scenes as well.

It is, of course, possible that both intralevel priming and a more top-down process contribute to the effects of a scene context on object identification. Biederman et al. (1982) provided evidence that the position of an object in a scene influences its detection. The intralevel priming hypothesis would not predict such an effect and has no way to account for it. On the other hand, although Biederman et al.'s result is suggestive, it may be that other levels of representation besides object identification are being tapped in the object detection task when scenes are displayed tachistoscopically and the response follows a pattern mask. Object identification is one stage in a series of processing stages required for the construction and retention of the representation of a scene in memory. In order to isolate the object identification stage from later stages in the processing sequence, it is necessary to choose a measure of object identification carefully. Most preferably, one would use an on-line measure of performance, defined as a measure that taps a representation as it is being constructed. With regard to object identification, such a measure should be unaffected by processes and representations that occur after the object identification stage. The object detection task used by Biederman et al. may not be an on-line task, and it is not clear to what extent postidentification processes are contributing to the demonstrated effects.

An account of the Biederman et al. (1982) results that relies on a postidentification explanation is that coherent scenes allow formation of an integrated memory representation (or schema) and that objects which can be easily included in this representation are facilitated at the time of response. On this view, objects are identified equally well in tachistoscopic presentations regardless of whether they are undergoing semantic or syntactic violations. It would be postulated that the schema, instead of feeding information top-down to affect the identification stage, would affect the availability of information at the time of response, either because objects that did not fit easily into the schema were never included in the memory representation or because they were included but are more difficult to retrieve during response generation. Such an explanation is consistent with the work of Potter (1975, 1976) and Intraub (1980, 1981), who showed that objects may be very quickly identified but not remembered if masked by a following visual stimulus.

Clearly, it would be premature to argue on the basis of our results that schema theory can be entirely dispensed with. However, according to the schema theory, an enabling condition for context effects to occur is the presence of a scene. The present study has shown that even without a scene, similar effects of context can occur. Furthermore, a simple mechanism (semantic priming) has been elaborated to account for these context effects both in and out of scenes. To the extent that context effects are similar regardless of whether a scene is used, the intralevel priming hypothesis offers a unitary account of both and therefore is to be preferred.

References

Antes, J. R. (1974). The time course of picture viewing. *Journal of Experimental Psychology, 103*, 62–70.

Antes, J. R., & Penland, J. G. (1981). Picture context effects on eye movement patterns. In D. F. Fisher, R. A. Monty, & J. W. Senders (Eds.), *Eye movements: Cognition and visual perception* (pp. 157–170). Hillsdale, NJ: Erlbaum.

Balota, D. A., Pollatsek, A., & Rayner, K. (1985). The interaction of contextual constraint and parafoveal visual information in reading. *Cognitive Psychology, 17,* 364–390.

Balota, D. A., & Rayner, K. (1983). Parafoveal visual information and semantic contextual constraints. *Journal of Experimental Psychology: Human Perception and Performance, 9,* 726–738.

Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology.* Cambridge, England: Cambridge University Press.

Biederman, I. (1972). Perceiving real-world scenes. *Science, 177,* 77–80.

Biederman, I. (1981). On the semantics of a glance at a scene. In M. Kubovy & J. R. Pomerantz (Eds.), *Perceptual organization* (pp. 213–253). Hillsdale, NJ: Erlbaum.

Biederman, I., Mezzanotte, R. J., & Rabinowitz, J. C. (1982). Scene perception: Detecting and judging objects undergoing relational violations. *Cognitive Psychology, 14,* 143–177.

Carr, T. H., McCauley, C., Sperber, R. D., & Parmelee, C. M. (1982). Words, pictures, and priming: On semantic activation, conscious identification, and the automaticity of information processing. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 757–777.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82,* 407–428.

deGroot, A. M. B. (1983). The range of automatic spreading activation in word priming. *Journal of Verbal Learning and Verbal Behavior, 22,* 417–436.

Egeth, H., Jonides, J., & Wall, S. (1972). Parallel processing of multielement displays. *Cognitive Psychology, 3,* 674–698.

Ehrlich, S. F., & Rayner, K. (1981). Contextual effects on word perception and eye movements during reading. *Journal of Verbal Learning and Verbal Behavior, 20,* 641–655.

Fischler, I. (1977). Associative facilitation without expectancy in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance, 3,* 18–26.

Fodor, J. A. (1983). *Modularity of mind.* Cambridge, MA: MIT Press.

Friedman, A. (1979). Framing pictures: The role of knowledge in automatized encoding and memory for gist. *Journal of Experimental Psychology: General, 108,* 316–355.

Friedman, A., & Liebelt, L. S. (1981). On the time course of viewing pictures with a view toward remembering. In D. F. Fisher, R. A. Monty, & J. W. Senders (Eds.), *Eye movements: Cognition and visual perception* (pp. 137–155). Hillsdale, NJ: Erlbaum.

Huttenlocher, J., & Kubicek, L. F. (1983). The source of relatedness effects on naming latency. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9,* 486–496.

Inhoff, A. W. (1982). Parafoveal word perception: A further case against semantic preprocessing. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 137–145.

Intraub, H. (1980). Presentation rate and the representation of briefly glimpsed pictures in memory. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 1–12.

Intraub, H. (1981). Rapid conceptual identification of sequentially presented pictures. *Journal of Experimental Psychology: Human Perception and Performance, 7,* 604–610.

Jonides, J., & Mack, R. (1984). On the cost and benefit of cost and benefit. *Psychological Bulletin, 96,* 29–44.

Kroll, J. F., & Potter, M. C. (1984). Recognizing words, pictures, and concepts: A comparison of lexical, object, and reality decisions. *Journal of Verbal Learning and Verbal Behavior, 23,* 39–66.

Kučera, H., & Francis, W. N. (1967). *Computational analysis of present day English.* Providence, RI: Brown University Press.

Loftus, G. R., & Mackworth, N. H. (1978). Cognitive determinants of fixation location during picture viewing. *Journal of Experimental Psychology: Human Perception and Performance, 4,* 565–572.

Marr, D. (1982). *Vision: A computational investigation into the human representation and processing of visual information.* San Francisco: W. H. Freeman.

McCauley, C., Parmelee, C. M., Sperber, R. D., & Carr, T. H. (1980). Early extraction of meaning from pictures and its relation to conscious identification. *Journal of Experimental Psychology: Human Perception and Performance, 6,* 265–276.

McClelland, J. L., & O'Regan, J. K. (1981). Expectations increase the benefit derived from parafoveal visual information in reading words aloud. *Journal of Experimental Psychology: Human Perception and Performance, 7,* 634–644.

Meyer, D. E., Schveneveldt, R. W., & Ruddy, M. G. (1975). Loci of contextual effects on visual word recognition. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V* (pp. 98–118). New York: Academic Press.

Minsky, M. (1975). A framework for representing knowledge. In P. H. Winston (Ed.), *The psychology of computer vision* (pp. 211–277). New York: McGraw-Hill.

Morton, J. (1969). The interaction of information in word recognition. *Psychological Review, 76,* 165–178.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General, 106,* 226–254.

Nelson, W. W., & Loftus, G. R. (1980). The functional visual field during picture viewing. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 391–399.

Norman, D. A., & Rumelhart, D. E. (1975). *Explorations in cognition.* San Francisco: W. H. Freeman.

Palmer, S. E. (1975). The effects of contextual scenes on the identification of objects. *Memory & Cognition, 3,* 519–526.

Parker, R. E. (1978). Picture processing during recognition. *Journal of Experimental Psychology: Human Perception and Performance, 4,* 284–293.

Pollatsek, A., Rayner, K., & Collins, W. E. (1984). Integrating pictorial information across eye movements. *Journal of Experimental Psychology: General, 113,* 426–442.

Posner, M. I., & Snyder, C. R. R. (1975). Facilitation and inhibition in the processing of signals. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V* (pp. 669–682). New York: Academic Press.

Potter, M. C. (1975). Meaning in visual search. *Science, 187,* 965–966.

Potter, M. C. (1976). Short-term conceptual memory for pictures. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 509–522.

Potter, M. C. (1979). Mundane symbolism: The relations among objects, names, and ideas. In N. R. Smith & M. B. Franklin (Eds.), *Symbolic functioning in childhood* (pp. 41–66). Hillsdale, NJ: Erlbaum.

Rayner, K., & Slowiaczek, M. (1981). Expectations and parafoveal information in reading: Comments on McClelland and O'Regan. *Journal of Experimental Psychology: Human Perception and Performance, 7,* 645–651.

Reicher, G. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology, 81,* 275–280.

Rumelhart, D. E. (1980). Schemata: The building blocks of cognition. In R. J. Spiro, B. C. Bruce, & W. F. Brewer (Eds.), *Theoretical issues in reading comprehension* (pp. 33–58). Hillsdale, NJ: Erlbaum.

Seymour, P. H. K. (1973). A model for reading, naming, and comparison. *British Journal of Psychology, 64,* 35–49.

Seymour, P. H. K. (1976). Contemporary models of the cognitive processes: II. Retrieval and comparison operations in permanent memory. In V. Hamilton & P. V. Vernon (Eds.), *The development of cognitive processes.* London: Academic Press.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174–215.

Sperber, R. D., McCauley, C., Ragain, R. D., & Weil, C. M. (1979). Semantic priming effects on picture and word processing. *Memory & Cognition, 5,* 339–345.

Stanovich, K. E., & West, R. F. (1983). On priming by a sentence context. *Journal of Experimental Psychology: General, 112,* 1–36.

Sternberg, S. (1969). Memory scanning: Mental processes revealed by reaction time experiments. *American Scientist, 57,* 421–457.

Tulving, E., & Gold, C. (1963). Stimulus information and contextual information as determinants of tachistoscopic recognition of words. *Journal of Experimental Psychology, 4,* 319–327.

Wheeler, D. D. (1970). Processes in word recognition. *Cognitive Psychology, 1,* 59–85.

Appendix A

Target Objects and Their Related Foveal Primes: Experiments 1 and 2

Foveal prime	Target
hand	foot
dog	cat
coat	hat
bee	flower
horse	cow
knife	gun
doctor	nurse
hammer	saw
truck	car
fridge	stove
lock	key
leaf	tree
shirt	tie
sock	shoe
table	chair
fork	spoon
leg	arm
rabbit	squirrel
bat	ball
cheese	mouse
lightbulb	lamp
apple	pear
glass	cup
horn	drum
ashtray	pipe
comb	brush
wagon	sled
star	moon
bell	whistle
anchor	boat

Appendix B

Stimulus Displays: Experiment 3

	Position on screen			
Display	Upper left	Lower left	Lower right	Upper right
1.	hand[a]	arm	leg	chair[b]
2.	tie	shirt	hat[a]	squirrel[b]
3.	boat	truck[a]	car	shoe[b]
4.	apple[b]	spoon	cup[a]	glass
5.	hand[b]	dog[a]	cat	horse
6.	bell[b]	table	lamp	chair[a]
7.	cow	hammer[b]	rabbit	squirrel[a]
8.	tree	truck[b]	leaf[a]	flower
9.	bell[a]	dog[b]	drum	whistle
10.	apple[a]	cheese	hat[b]	pear
11.	foot	sock	cup[b]	shoe[a]
12.	saw	hammer[a]	leaf[b]	knife
13.	knife	flower	car	chair[c]
14.	lamp	drum	foot	squirrel[c]
15.	lamp	knife	cow	shoe[c]
16.	apple[c]	arm	cat	whistle
17.	hand[c]	shirt	rabbit	pear
18.	bell[c]	sock	horse	flower
19.	tree	hammer[c]	horse	leg
20.	tie	truck[c]	spoon	cow
21.	spoon	dog[c]	boat	cheese
22.	saw	table	hat[c]	boat
23.	leg	drum	cup[c]	cheese
24.	shirt	foot	leaf[c]	glass

[a] Related condition. [b] Unrelated category condition. [c] Unrelated noncategory condition.

Received November 1, 1986
Revision received February 13, 1987
Accepted February 16, 1987 ■