Journal of Experimental Psychology:
Human Perception and Performance
1983, Vol. 9, No. 5, 726-738

Parafoveal Visual Information and Semantic Contextual Constraints

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Two experiments are reported that examine the influence of semantic contextual constraints on an individual's ability to use parafoveal visual information. Subjects were presented either a word (*reptile*) or a row of Xs in foveal vision along with a parafoveal nonword (*snckks*) centered 2.3° or 5° to the left or right of fixation. The subjects were asked to pronounce the parafoveal stimulus aloud. During their eye movement to that stimulus, the nonword was replaced by a word that was either (a) semantically related to the foveal item and visually related to the parafoveal preview nonword (*snakes*), (b) semantically unrelated to the foveal item and visually related to the preview (*sneaks*), (c) semantically related to the foveal item and visually unrelated to the preview (*lizard*), or (d) semantically unrelated to the foveal item and visually unrelated to the preview (*limits*). In Experiment 1, subjects were only given 250 msec to use the semantic context, whereas in Experiment 2, subjects were given 1,250 msec. The results of both experiments yielded highly significant effects of contextual constraints and parafoveal visual information. However, the first experiment yielded additive effects of the two variables, whereas the second experiment yielded interactive effects. The results are discussed in light of recent arguments regarding the importance of contextual constraints for the use of parafoveal visual information.

Recently, there has been considerable interest in the topic of whether individuals can use parafoveal visual information in word recognition. Rayner and his colleagues (Rayner, 1978; Rayner, McConkie, & Ehrlich, 1978; Rayner, McConkie, & Zola, 1980) have published a series of studies which indicate that subjects can indeed use such parafoveal visual information in a word-naming task. The basic paradigm in these experiments was that a letter string was presented to the subject's parafovea as the subject was fixated on a cross. During the subject's eye movement to that parafoveal item, the initial stimulus was replaced by a target word that the subject was asked to pronounce aloud. The results indicated that increasing the similarity of the parafoveal stimulus to the target item decreased the time taken to pronounce that target item. In particular, it was found that if the first two or three letters in the initial parafoveal string and the target were identical, facilitation occurred. Furthermore, this facilitation depended on how far into the parafovea the stimulus occurred. That is, there was more facilitation at 1° than at 3° and more facilitation at 3° than at 5°. Thus, these results indicate that subjects can use partial parafoveal information to aid their recognition of that parafoveal word after a saccade has been made that brings that word into the fovea.

There have been, however, two recent articles reported by McClelland and O'Regan (1981) and Paap and Newsome (1981) which appear to question the generalizability of this conclusion. These authors have suggested that because there was a relatively small set of target words in the earlier Rayner studies (in most cases 30), which were repeated throughout a given experiment, there may have been suf-

Portions of this research were presented at the 1982 meeting of the Psychonomic Society.

This research was supported by a grant from the A. P. Sloan Foundation, National Institutes of Health Grant HD 12727, and National Science Foundation Grant BNS79-17600.

Thanks are extended to Chuck Clifton, Janet Duchek, and Sandy Pollatsek for their helpful comments on an earlier draft of this article. We would also like to acknowledge Janet Duchek and Sandy Pollatsek for their assistance in conducting this research.

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ficient contextual constraint to allow subjects to generate expectancies about potential parafoveal targets. Their argument is that these expectancies allowed the subjects in the Rayner studies to use the partial parafoveal information. In fact, both McClelland and O'Regan and Paap and Newsome have argued that without these expectancies subjects will benefit very little, if at all, from parafoveal visual information. Furthermore, both studies have provided data, which apparently indicate that expectancies are the crucial component to extracting useful parafoveal visual information. Although we have some reservations (cf. Rayner & Slowiaczek, 1981) regarding both the methodology and conclusions reached from the data reported by McClelland and O'Regan and Paap and Newsome, we will postpone discussion of their studies until the present data can be reported. In the same light, however, it would be useful to describe briefly the McClelland and O'Regan interactive model in order to specify its predictions regarding the present research.

McClelland and O'Regan appealed to a modified interactive logogen model (cf. Grossberg, 1978; Morton, 1969), which assumes that logogens accumulate activation from a number of sources of information, including contextual and parafoveal visual sensory inputs. To influence performance, a logogen must accumulate sufficient activation to reach its threshold. Apparently they believe that a single source of parafoveal information does not produce a sufficient amount of activation to influence performance. Moreover, they suggested that although there will be activation produced by parafoveal visual information, this activation will occur for a number of visually consistent logogens. These activated logogens will mutually inhibit each other such that very little net facilitation for any single logogen is produced. In the same manner, a single weak source of contextual constraint will produce activation for a number of related logogens, which ultimately will have the impact of mutually inhibiting each other to produce very little net effect of contextual activation. On the other hand, if that weak source of contextual constraint is coupled with parafoveal visual information, a single logogen may receive sufficient activation from both sources to surpass what McClelland and O'Regan refer to as an "interactive threshold," which actually facilitates performance. Thus, their model predicts interactive effects of context and parafoveal information, since two weak sources of information may have little effect by themselves but when combined may produce facilitation. In fact, in McClelland and O'Regan's second experiment this is precisely the pattern found. Furthermore, this model suggests that the parafoveal effects found by Rayner and his colleagues were due to the extra activation fed into the logogens representing the constrained target set.

The present study was an attempt to further explore the relationship between contextual information and the use of parafoveal visual information. The manner in which parafoveal visual information and contextual information are combined is obviously an important issue to be addressed, because both types of information are almost always available during normal reading.

The purpose of the present study was twofold. First, we were interested in directly investigating the conjoint effects of semantic contextual information and parafoveal visual information. On a given word prime trial, the subject was simultaneously presented a foveal word prime (e.g., *reptile*) along with a parafoveal preview nonword (e.g., *snckks*), which was centered 2.3° or 5° from fixation in the subject's left or right visual field. The subject's task was to make a saccade to that parafoveal position and pronounce the item aloud. During the saccade, the nonword was replaced with either a word that was (a) semantically related to the foveal word and visually related to the parafoveal preview (*snakes*), (b) semantically unrelated to the foveal word and visually related to the parafoveal preview (*sneaks*), (c) semantically related to the foveal word and visually unrelated to the parafoveal preview (*lizard*), or (d) semantically unrelated to the foveal word and visually unrelated to the preview item (*limits*). According to the McClelland and O'Regan model already presented, one should clearly find an interaction between semantic context and parafoveal visual information, indicating larger visual effects for semantically related targets than for semantically unrelated targets. Only the semantically and visually related targets should have sufficient conjoint activation to exceed

Table 1
Parafoveal Target Conditions as a Function of Foveal Prime and Parafoveal Preview

Condition	Type of item		
	Foveal prime	Parafoveal preview	Parafoveal target
SEMR, VISR	reptile	snckks	snakes
SEMR, VISU	reptile	snckks	lizard
SEMU, VISR	reptile	snckks	sneaks
SEMU, VISU	reptile	snckks	limits
Neutral, VISR	xxxxxxx	snckks	snakes
Neutral, VISU	xxxxxxx	snckks	lizard
Neutral, VISR	xxxxxxx	snckks	sneaks
Neutral, VISU	xxxxxxx	snckks	limits

Note. SEMR and SEMU refer to semantically related and semantically unrelated, respectively, whereas VISR and VISU refer to visually related and unrelated, respectively.

their thresholds. On the other hand, the semantically related, visually unrelated targets should receive some semantic activation, but this activation should be insufficient to surpass the interactive threshold because of the inhibition from other primed semantically related targets and visually related targets. Moreover, according to the McClelland and O'Regan model, one should find very little impact of visual parafoveal information for the unrelated targets. It is unclear how the unrelated items could surpass their interactive threshold, since they should actually receive some inhibition by the logogens activated that are indeed semantically related to the foveal prime. Thus, the same interactive model that predicts little or no parafoveal visual facilitation when there are no contextual constraints available must predict no parafoveal visual facilitation when the available constraints are unrelated to the targets.

The second major purpose of Experiment 1 was an attempt to replicate the Rayner results when (a) there was virtually no context presented foveally (i.e., a row of Xs) and (b) the set size of potential word targets was sufficiently large (512 words) to eliminate any possibility that subjects could generate expectancies about the targets based on repetition.

Experiment 1

Method

Subjects. Eight subjects were paid to participate in an experiment which involved four different sessions, each lasting 2 hours. All subjects were members of the University of Massachusetts community and had normal, uncorrected vision.

Materials. A total of 128 sets of items were constructed, as shown in Table 1. There were eight major conditions produced by crossing two levels of foveal-prime and parafoveal-target relations (semantically related vs. unrelated) by two levels of parafoveal prime and target relations (visually related vs. unrelated) by two levels of context (neutral context vs. word context). Obviously, the distinction between semantically related and unrelated targets for the neutral context condition was a pseudodistinction for purposes of analyses (see the Results section). It is important to note here that the visual-parafoveal-relatedness manipulation always involved the first two letters of the targets. Thus, as shown in Table 1, there were two pairs of words each having the first two letters in common. The first two letters were used in the parafoveal-visual manipulation because Rayner et al. (1980) found that the first two letters were the primary determinants of parafoveal visual priming.

There was a total of 128 unique foveal primes, 256 unique parafoveal nonword previews (*lizirs* would be the other parafoveal nonword preview for the set shown in Table 1), and 512 unique targets. Across the four test sessions each subject saw a given target four times and each target occurred at each of the four visual angles. Furthermore, across the eight subjects each of the 512 targets occurred once in each of the following 32 cells: 2 (left vs. right visual field) × 2 (5° vs. 2.3° from the fovea) × 2 (word prime vs. neutral prime) × 2 (visually related vs. unrelated condition) × 2 (first two sessions vs. second two sessions).

The only counterbalancing that was not accomplished was that each target did not occur in both the semantically related and unrelated conditions. Including this counterbalancing would have severely restricted the size of our target set, and we therefore opted to create a very large target set, since this is one of the major issues being addressed in the present study. Moreover, by comparing the neutral prime condition to the word prime condition we found that our semantic-relatedness manipulation had an effect above and beyond that due to items.

Apparatus. The stimuli were displayed on a Hewlett-Packard 1300A CRT, which has a P-31 phosphor in which the removal of a character results in a drop to 1% of maximum brightness in .25 msec. The letters making up the stimuli were all in lowercase. A black theater gel covered the CRT so that the letters 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 to a Hewlett Packard 2100 computer that controlled the experiment. The computer kept a complete record of saccade latencies, accuracy, and pronunciation latencies. The signal from the eyetracker was sampled every 1 msec by the computer and the position of the eye was determined every 4 msec. When a subject made an eye movement in the appropriate direction, the computer immediately replaced the parafoveal preview item with the parafoveal target word. The computer initiated the change when an eye movement of .5° in the appropriate direction was detected and the change was completed within 5 msec. Because a saccade of 2° requires approximately 25 msec, the display change was always completed during the saccade when vision is suppressed. None of the subjects ever reported seeing the display change actually take place. Occasionally, the subject reported seeing a word at 2.3° right of fixation prior to making an eye movement only to find a different word in that location following the saccade. Of course, the parafoveal preview item was never really a word, and therefore the extent to which subjects thought they had seen a word was due to constructing a word on the basis of partial parafoveal information, possibly in conjunction with foveal information. Moverover, this occurred very infrequently and only in the visually unrelated condition. These observations, as well as pilot testing with ourselves as subjects, led us to conclude that subjects were not aware at a conscious level of what the parafoveal preview item was, due to a combination of visual and cognitive masking from the target item (also, see Rayner et al., 1980).

The subject's eye was 46 cm from the CRT and three characters equalled 1° of visual angle. Eye movements were monitored from the right eye, although viewing was binocular. Luminance on the CRT was adjusted to a comfortable level throughout the experiment. The room was dark, except for a dim indirect light source.

Procedure. Upon arriving for an experimental session, each subject was seated comfortably with his or her head resting on a chin rest to minimize any head movements. The calibration of the eye-movement system then took place. After calibration, subjects were given 32 practice trials followed by a total of 16 blocks of 32 test trials. At the beginning of each trial, the subject was asked to fixate on the middle cross of 3 crosses displayed on the CRT. Also, a fourth cross was visible on the screen, which moved in accordance with the position of the subject's eye. If this fourth cross was aligned with the center cross (indicating correct alignment), the experimenter would say the word "ready," after which a button was pressed to initiate the stimulus display. During each display, a parafoveal and foveal item were presented with the foveal item always presented for 200 msec and the parafoveal item presented until a saccade was detected by the eyetracker. During the subject's saccade, the parafoveal preview item was replaced by the target word. This target word remained displayed until a microphone detected the subject's voice onset, which was then followed by the presentation of the calibration crosses (as mentioned earlier) to begin the next trial.

Results

Because errors in pronunciation were rare (less than 1% of the trials in both Experiments 1 and 2), response latency was the major dependent variable of interest.

The mean latency was calculated for each subject/cell for both (a) saccade latency and (b) pronunciation latency after a saccade was detected. Although the primary variable of interest in the present results was the pronunciation latencies, a preliminary 2 (first half vs. second half) × 2 (right vs. left visual field) × 2 (5° vs. 2.3° from fixation) × 2 (word vs. neutral prime) analysis of variance (ANOVA) was performed on the mean saccade latencies. (The semantically related and visually related variables were not included in this analysis because, since their manipulation only occurred after the saccade was initiated.) There were three significant effects worth noting from this analysis. (Unless otherwise specified, all significant effects have $ps < .05$.) First, subjects' saccade latencies were faster during the second half (261 msec) than during the first half (280 msec), $F(1, 7) = 7.57$, $MS_e = 6{,}051$. Second, subjects' saccade latency was faster when the preview items were presented centered 2.3° from fixation (265 msec) than 5° (277 msec), $F(1, 7) = 9.26$, $MS_e = 1{,}877$. Third, latencies were faster in the neutral condition (255 msec) than in the word condition (287 msec), $F(1, 7) = 13.92$, $MS_e = 9{,}311$. This latter effect of word versus neutral prime suggests that although subjects were not required to read the foveal prime, its lexicality influenced their latencies to make a saccade. Because this difference suggests that subjects had parafoveal information available for differing amounts of time between the neutral and word prime conditions, it was decided to present the word prime and neutral prime data separately.

Word prime conditions. The mean pronunciation latencies for the word prime conditions as a function of visual angle, visual field, semantic relatedness, and visual relatedness are displayed in Figure 1. There are five major points to note from Figure 1. First, subjects were faster the closer to the fovea the target appeared. Second, subjects were faster when the target was semantically related to the foveal word than when it was unrelated. Third, subjects were faster when the target was visually related to the preview item than when it was unrelated. Fourth, this visual parafoveal priming effect was more pronounced at 2.3° than at 5°. Fifth, and most important, semantic relatedness and visual relatedness had additive effects on performance. More specifically, the visual relatedness effect was approximately the same size for the semantically related targets as the unrelated targets.

These observations were supported by a 2 (first half vs. second) × 2 (visual field) × 2 (parafoveal distance) × 2 (semantic relatedness) × 2 (visual relatedness) ANOVA. This analysis yielded main effects of semantic relatedness, $F(1, 7) = 34.7$, $MS_e = 829$; visual relatedness, $F(1, 7) = 20.52$, $MS_e = 604$; and

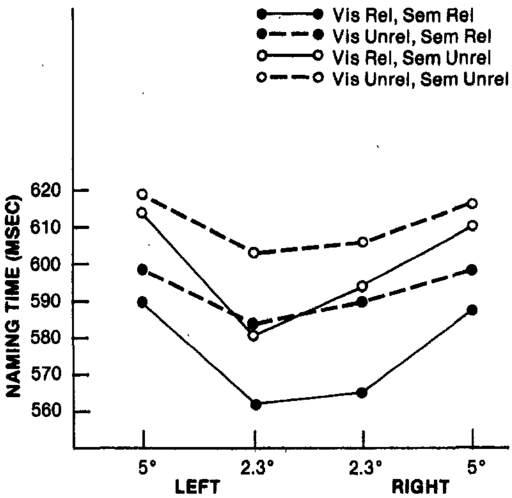

Figure 1. Mean pronunciation latencies as a function of visual angle, visual field, visual relatedness (Vis Rel), and semantic relatedness (Sem Rel) for the word prime conditions in Experiment 1. (Vis Unrel = visual unrelatedness; Sem Unrel = semantic unrelatedness.)

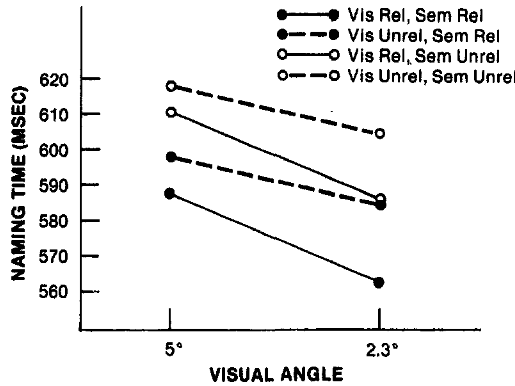

Figure 2. Mean pronunciation latencies as a function of visual angle, visual relatedness (Vis Rel), and semantic relatedness (Sem Rel) for the word prime conditions in Experiment 1. (Vis Unrel = visual unrelatedness; Sem Unrel = semantic unrelatedness.)

visual angle, $F(1, 7) = 17.16$, $MS_e = 1{,}288$, along with an interaction between visual relatedness and visual angle, $F(1, 7) = 9.35$, $MS_e = 240$. This analysis also indicated that the interaction between semantic relatedness and visual relatedness did not approach significance, $F(1, 7) = 2.08$, $MS_e = 162$, nor did any higher order interaction in which these two variables participated (all Fs < 1.79). The additivity of the semantic-relatedness and visual-relatedness variables is most clearly shown in Figure 2, where we have collapsed the data across the left and right visual fields. Here one can see that the beneficial effect of visual relatedness is the same for semantically related and unrelated targets at both 2.3° and 5° visual angle. It is interesting to note in Figure 2 that the facilitative effect of visual relatedness at 2.3° appears to be equivalent to the facilitative effect of semantic relatedness, whereas at 5°, where the visual parafoveal information is less available, there was considerably more benefit from the semantic relationship. Thus, as expected, the semantic priming effect was found for all eccentricities, whereas the parafoveal visual priming effect decreased with increasing eccentricities.

The only remaining effect that reached significance in this analysis was a three-way interaction between first versus second half, visual field, and visual angle, $F(1, 7) = 11.25$, $MS_e = 73.14$. This interaction simply indicated that the practice effect was larger at 5° right and 2.3° left than at 2.3° right and 5° left.

Neutral prime conditions. As noted in the introduction, our major interest in the neutral conditions was whether one can find visual facilitation without contextual constraints. Figure 3 displays the mean pronunciation latency as a function of visual relatedness, visual angle, and visual field for the neutral prime conditions. There are three points that should be noted from Figure 3. First, subjects were again faster when the target was closer to the

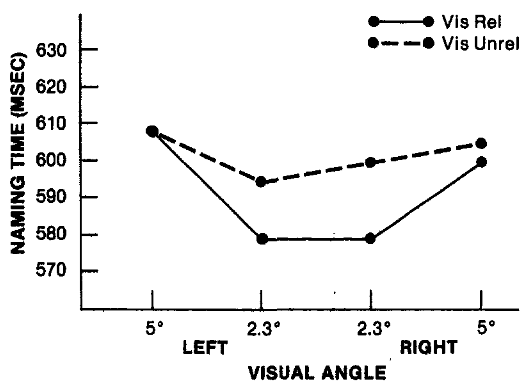

Figure 3. Mean pronunciation latencies as a function of visual angle, visual field, and visual relatedness (Vis Rel) for the neutral prime conditions in Experiment 1. (Vis Unrel = visual unrelatedness.)

fovea. Second, subjects were faster when there was a visually related parafoveal preview item presented. Third, this visual-relatedness effect was larger at 2.3° than at 5°. It is interesting that these data almost precisely mimic Rayner et al.'s (1980) results for their comparable conditions.

These observations were supported by a similar analysis that was described for the word prime data. This analysis yielded a main effect of visual angle, $F(1, 7) = 21.77$, $MS_e = 974$, and visual relatedness, $F(1, 7) = 11.3$, $MS_e = 628$, along with a significant Visual Angle × Visual Relatedness interaction, $F(1, 7) = 7.01$, $MS_e = 429$. It is also noteworthy that the interaction between visual relatedness and first versus second half did not approach significance, $F(1, 7) = .4$, $MS_e = 280$, indicating that repeating each word 4 times per subject did not influence the visual parafoveal priming effect.

This neutral prime analysis also yielded a small (7 msec) but reliable main effect of semantic relatedness, $F(1, 7) = 26.1$, $MS_e = 114$, and an interaction between semantic relatedness and visual angle, $F(1, 7) = 5.77$, $MS_e = 45$, indicating that the semantic effect was slightly larger at 2.3° than at 5°. These differences probably reflect item-selection effects, since as noted earlier (see Method section) we opted to construct large unique lists instead of repeating items within subjects. One could, of course, argue that this small semantic effect may reflect some type of parafoveal semantic priming. That is, if subjects extract *snckks* from their parafovea, this may not only prime the word *snakes* but also a semantically related word to *snakes* such as *lizard.* Although this is not a primary concern in the present study, it seems highly unlikely that such semantic priming could actually occur from a nonword parafoveal stimulus. Moreover, it is noteworthy that there have been repeated failures to produce such parafoveal semantic effects (Inhoff, 1982; Inhoff & Rayner, 1980; Rayner et al., 1980; Stanovich & West, 1983; see, however, Underwood[1], 1976, 1980, 1981). The important point to note with respect to the present research is that in an overall analysis of the present word prime and neutral prime conditions, the interaction between foveal prime type and semantic relatedness was highly significant, $F(1, 7) = 19.53$, $MS_e = 338$, indicating that the semantic effect was indeed primarily localized for the related word prime conditions.

Discussion

The results of Experiment 1 were clear. First, the results yielded reliable effects of parafoveal visual information when only a neutral row of Xs was presented as the constraining context. Thus, these results clearly conflict with the recent arguments made by McClelland and O'Regan (1981) and Paap and Newsome (1981) that parafoveal visual information is useful primarily when contextual constraints are placed on that information. Second, when subjects were provided contextual constraints in the word prime conditions, there were highly significant effects of semantic relatedness and parafoveal visual information. However, as shown in Figure 2, these two variables had additive rather than interactive effects on performance.

The obvious question that needs to be addressed at this point is what produced the difference in the present results and those obtained by McClelland and O'Regan and by Paap and Newsome. First, with respect to the latter study, we feel that the task that Paap and Newsome used (a lexical decision task, LDT, with nonwords formed by replacing single letters) may have forced subjects to be cautious about using nonword parafoveal visual information because that information was just as likely to lead to a word target as a nonword target. Thus, we feel that a LDT with highly confusable nonwords may force subjects to pay special attention to the visual details of a target word and discourage their use of "partial" parafoveal visual information. Our concerns about the LDT become clearer when one considers the results of Paap and Newsome's first experiment in which they attempted to get baselines of semantic and visual priming for their set of items when they were all presented foveally. The results of this study indicated

[1] It is difficult to evaluate the contradictory data reported by Underwood because he typically has not provided controls for eye-fixation locations. Moreover, in some experiments, Underwood has reported facilitatory effects, whereas in other experiments, inhibitory effects are reported.

that their visually related nonword primes facilitated lexical-decision times only to nonword targets and actually inhibited decision times to words. This crossover probably reflects response priming rather than visual priming. Clearly, if one cannot find unequivocal evidence for visual priming in their foveal condition with the LDT then it is unclear why one would expect the same items to be potent parafoveal visual primes. Thus, we believe that the more likely account of the Paap and Newsome results is that the task demands of a LDT, which probably include postaccess decision processes (cf. West & Stanovich, 1982; Balota & Chumbley, Note 1) may simply preclude obtaining parafoveal priming. Future research is needed to address this possibility.

Now, consider the McClelland and O'Regan results. Although the results of their first experiment have been addressed elsewhere (cf. Rayner & Slowiaczek, 1981), the results of their second experiment appear to be in direct conflict with the results of the present Experiment 1. In their second experiment, subjects were asked to read (at their own pace) either a neutral, weak, or strong constraining sentence context after which they pressed a button to display a parafoveal item for 170 msec. The parafoveal preview was either a row of Xs, a nonword with the same shape as the target, or the target word itself. The results of this experiment did yield a significant interaction between constraining context and visual similarity of the parafoveal preview item, indicating that the visual facilitation produced by the parafoveal item increased with increasingly strong constraining contexts. Obviously, this appears to be in direct conflict with the present results.

One possible account for the discrepancy in results is that in the McClelland and O'Regan study, subjects were given sufficient time to instantiate expectations about the parafoveal word based on the sentence contexts.[2] In fact, because subjects actually initiated the display themselves, it is unclear how much time the sentences were available. One might guess that to read the sentence for comprehension and press the display button would involve at least 1 sec. On the other hand, the contextual semantic information in the present Experiment 1 was only available for approximately 250 msec before the target word was presented. This difference in the time available for the contextual information is especially important when one considers the research of Neely (1977) and Balota (1983), which suggests that context has automatic nonattentional effects at short context target-onset intervals and attentional effects at long onset intervals. Thus, one possible account for the difference between Experiment 1 and McClelland and O'Regan's results may be the time available to use the contextual information.

In an attempt to address this possibility, a second experiment was conducted in which the foveal item was presented for 750 msec followed by a 500-msec dark interval. After this dark interval, subjects were then presented the foveal and parafoveal primes as they occurred during Experiment 1. In this way subjects would have sufficient time to instantiate expectations about the parafoveal targets. Thus, if attentional expectancies were the important factor that led to the difference between the present Experiment 1 and McClelland and O'Regan's results, one should expect interactive effects of context and parafoveal visual information in Experiment 2.

Experiment 2

Method

Subjects. Eight subjects were paid to participate in an experiment that involved four different sessions, each lasting approximately 2 hours. All subjects were members of the University of Massachusetts community and had normal, uncorrected vision. One of the eight subjects also participated in the first experiment 8 months earlier. It is important to note, however, that the pattern of data for this subject did not differ from that obtained for the remaining seven subjects.

Materials. The same materials used in Experiment 1 were used in Experiment 2.

Procedure. The only difference in procedure from Experment 1 is that on each trial the foveal item was presented for 750 msec followed by a 500-msec dark interval followed by the simultaneous presentation of the foveal prime and parafoveal preview, as occurred during Experiment 1.

[2] It should be noted that McClelland and O'Regan reported that they instructed their subjects to read the passages as naturally as possible and not to make explicit predictions about the possible identity of the target word. Unfortunately, because (a) subjects were given as long as they wished to read the sentences and (b) there were no data reported regarding how long the sentences were, on the average, available to the subjects, it is unclear how the subjects were processing the sentence contexts.

Results

All major analyses that were described in the earlier Results section were also conducted on the results from Experiment 2.

Saccade latencies. The results of the analysis on the saccade latencies indicated that subjects were faster (a) during the second half (214 msec) than during the first half (236 msec), $F(1, 7) = 7.99$, $MS_e = 7531$; (b) when the target was presented 2.3° (219 msec) compared to 5° (231 msec) from fixation, $F(1, 7) = 9.11$, $MS_e = 1{,}840$; (c) when a word prime was foveally presented (224 msec), compared to the neutal foveal prime (227 msec), $F(1, 7) = 7.11$, $MS_e = 131$; and (d) when the target was presented to the left visual field (213 msec), compared to the right visual field (237 msec), $F(1, 7) = 12.87$, $MS_e = 5{,}901$. With respect to these latter two effects, it is noteworthy that both are in the opposite direction to what was found in Experiment 1. This analysis also yielded a significant Visual Angle × Visual Field interaction, $F(1, 7) = 6.31$, $MS_e = 1{,}886$, indicating that subjects were considerably slower to initiate a saccade to 5° right (248 msec) than either 2.3° right (227 msec), 2.3° left (212 msec), or 5° left (214 msec). We shall return to these saccade latency effects after the pronunciation latency data are presented, since it appears there may be some trade-off in pronunciation latency and saccade latency.

Word prime conditions. The mean pronunciation latencies for the word prime conditions as a function of visual angle, visual field, semantic relatedness, and visual relatedness are displayed in Figure 4. One should first note that subjects were faster to pronounce targets (a) presented to the right visual field, $F(1, 7) = 34.01$, $MS_e = 357$; (b) semantically related to the context, $F(1, 7) = 95.62$, $MS_e = 392$; and (c) visually related to the parafoveal preview item, $F(1, 7) = 43.8$, $MS_e = 537$. Furthermore, as in Experiment 1, this parafoveal visual priming effect was larger at 2.3° than at 5°, $F(1, 7) = 24.3$, $MS_e = 276$. However, in contrast to Experiment 1, there was an interaction between parafoveal visual information and semantic contextual information, $F(1, 7) = 11.68$, $MS_e = 92.39$, indicating that there was a larger beneficial effect of parafoveal visual information for the semantically related targets than for the unrelated targets. This latter interaction can be more clearly seen in Figure 5, where we collapsed the data across the left and right visual fields. Here one can see that the parafoveal visual priming effect was larger for the semantically related targets than for the unrelated targets at both 2.3° and 5° visual angle.

There are a number of other points that should be noted about the word prime data.

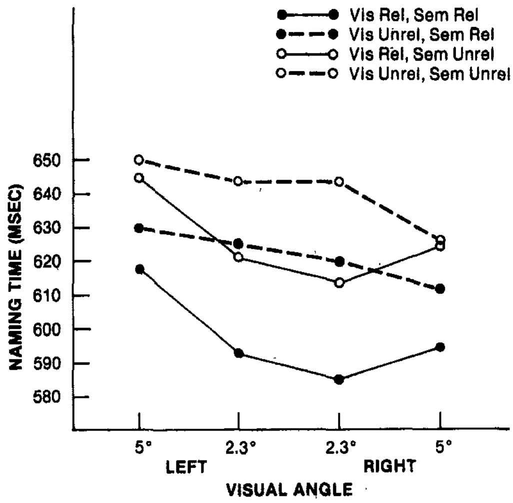

Figure 4. Mean pronunciation latencies as a function of visual angle, visual field, visual relatedness (Vis Rel), and semantic relatedness (Sem Rel) for the word prime conditions in Experiment 2. (Vis Unrel = visual unrelatedness; Sem Unrel = semantic unrelatedness.)

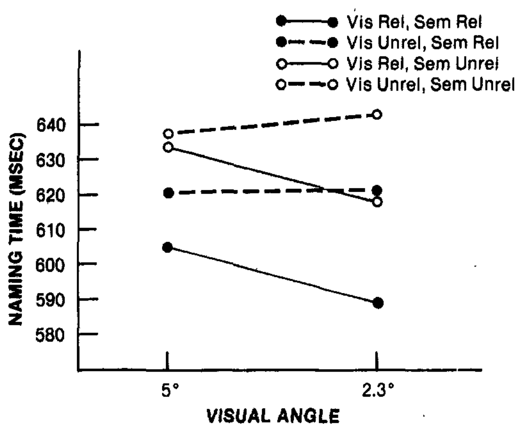

Figure 5. Mean pronunciation latencies as a function of visual angle, visual relatedness (Vis Rel), and semantic relatedness (Sem Rel) for the word prime conditions in Experiment 2. (Vis Unrel = visual unrelatedness; Sem Unrel = semantic unrelatedness.)

First, a significant interaction between visual relatedness and the first versus the second half of the experiment was obtained, $F(1, 7) = 26.92$, $MS_e = 31.78$, which indicated that the visual effect was larger during the second half (23 msec) than during the first half of the experiment (16 msec). This pattern suggests that through experience with the foveal-prime parafoveal-target pairings, subjects became able to use (during the 1,250-msec stimulus-onset asynchrony, SOA) the foveal word-prime information to generate expectancies regarding both related and unrelated parafoveal targets. In this same light, it is worth noting that the visual effect found in Experiment 2 was not entirely due to experience with the foveal-prime parafoveal-target pairings, since an analysis of the first fourth of the data, in which subjects only saw each target word once, yielded a significant visual parafoveal priming effect, $F(1, 7) = 12.46$, $MS_e = 740$, and interaction between visual angle and visual relatedness, $F(1, 7) = 11.86$, $MS_e = 357$. Thus, although the results of the second experiment do suggest that attentional expectancies influence the utility of parafoveal visual information, it is also clear that one can use visual parafoveal information devoid of any contextual constraints.

There were two other effects that reached significance in the word prime data. First, subjects were faster during the second half (603) than during the first half (639), $F(1, 7) = 27.62$, $MS_e = 8{,}224$. Second, there was an interaction between visual angle and visual field, $F(1, 7) = 27.62$, $MS_e = 171.2$, which indicated that, in the left visual field, latencies were slower to targets at 5° than 2.3°, whereas this pattern was reversed in the right visual field. As can be seen in Figure 4, this reversal appears to be due to the visually unrelated conditions in the right visual field.

Neutral prime conditions. The mean pronunciation latencies for the neutral prime data as a function of visual angle, visual field, and visual relatedness of the parafoveal preview item are displayed in Figure 6. There are two major points to note from Figure 6. First, the visually related condition was faster than the unrelated condition, $F(1, 7) = 72.01$, $MS_e = 161.4$, and second, this visual facilitation occurred more at 2.3° than at 5° visual angle, $F(1, 7) = 22.00$, $MS_e = 121.6$. Both of these

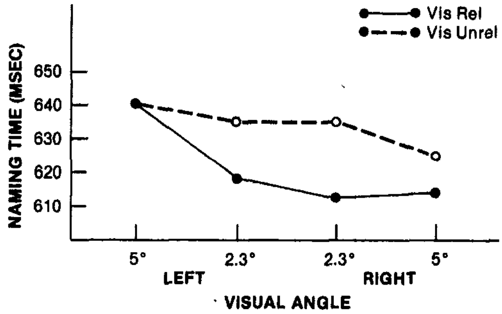

Figure 6. Mean pronunciation latencies as a function of visual angle, visual field, and visual relatedness (Vis Rel) for the neutral prime conditions in Experiment 2. (Vis Unrel = visual unrelatedness.)

effects were also significant in an analysis of the first fourth of the data in which targets were not repeated.

The analysis of the neutral prime data also yielded: (a) a speed-up of 44 msec during the second half of the trials, $F(1, 7) = 17.77$, $MS_e = 7{,}282$; (b) a right-field advantage of 12 msec, $F(1, 7) = 10.88$, $MS_e = 914$; and (c) an interaction between visual angle and visual field, $F(1, 7) = 14.01$, $MS_e = 419$. As can be seen in Figure 6, this is the same interaction that occurred for the word prime data previously mentioned. Finally, this analysis, as in Experiment 1, yielded a main effect of semantic relatedness (8 msec), $F(1, 7) = 17.16$, $MS_e = 212$, which probably reflects item-selection effects. Again, an overall analysis of the word and neutral prime data yielded a highly significant interaction between prime type and semantic relatedness, $F(1, 7) = 42.00$, $MS_e = 211$, which indicated that the semantic effect was indeed primarily localized for the word prime conditions.

A reconsideration of the Experiment 2 data. One concern that occurred in both the word prime and the neutral prime data from the second experiment is that pronunciation latencies at 2.3° right visual field were actually slower than at 5° right visual field for the visually unrelated targets. This pattern suggests some inhibition from subjects seeing one stimulus on fixation n and a different stimulus on fixation $n + 1$. It is noteworthy that this is the only point in both experiments that suggests some inhibition of the visually unrelated conditions, since in both the first and second experiments, all other points are faster at 2.3°

than at 5°. We shall return to this one discrepant point later in the discussion because it appears to reflect an interesting difference between the impact of the foveal contextual constraints across the two experiments.

In an attempt to address whether this discrepant point is the primary point producing the obtained effects in the second experiment, two ANOVAs were performed on the word and neutral prime data without the data from 2.3° right visual field. The results indicated that all of the effects previously reported remained significant without the data from this potentially discrepant point. The only exception to this was the interaction between visual relatedness and first versus second half, which was highly significant in the earlier analysis but only approached significance, $F(1, 7) = 4.88$, MS_e 79.3, $p < .10$, when the data from 2.3° right visual angle were excluded. Interestingly, this decrease primarily occurred because of the semantically unrelated condition in which the visual effect was 19 msec larger, at 2.3° right visual angle, during the second half of the trials compared to the first. Possibly, this may reflect a true inhibition effect during the second half of the trials in which the subject was misdirected by both the intra- and extraexperimental associations along with inappropriate parafoveal visual information.

Discussion

The results of Experiment 2 differed from Experiment 1 in terms of the interaction between semantic context and parafoveal visual information; however, they were consistent with the McClelland and O'Regan results. That is, when subjects were given sufficient time to instantiate expectations about parafoveal targets, we found interactive effects between parafoveal visual information and semantic contextual information. Furthermore, the results of Experiment 2 indicated that after subjects were given exposure to the foveal-prime parafoveal-target pairings, they were better able to use parafoveal visual information. Clearly, both of these effects appear to be localized in the time available to generate expectancies based on the information provided by the foveal prime word, since neither of these effects occurred during Experiment 1 nor for the neutral prime condition in Experiment 2. Be-

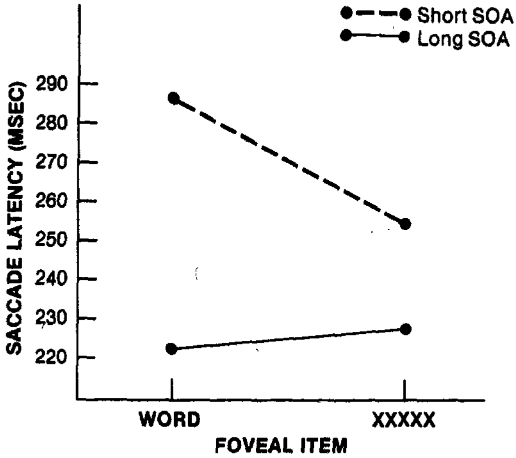

Figure 7. Mean saccade latencies as a function of type of foveal prime (word vs. neutral) for Experiments 1 and 2. (SOA = stimulus-onset asynchrony.)

fore describing a potential framework to interpret these results, there were two other discrepancies between the results of the first and second experiments that need to be addressed.

First, as shown in Figure 7, subjects were considerably slower to make a saccade during Experiment 1 than Experiment 2. Furthermore, during the first experiment, subjects' saccade latencies were considerably slower with foveal word primes than neutral primes, whereas a slight tendency in the opposite direction was found in the second experiment. This pattern of data can be accommodated if one considers that the 1,250-msec preview of the foveal item during the second experiment allowed subjects to extract most of the useful information from the foveal stimulus. Thus, subjects were faster to leave the foveal item when the parafoveal stimulus was presented. On the other hand, during the first experiment, because there was no preview of the foveal item, subjects could not leave the fovea until sufficient information was extracted, even though their task was to pronounce only the parafoveal item as quickly as possible. This argument is also consistent with the finding that during the first experiment, subjects were considerably slower to make a saccade when a foveal word was presented, compared to a neutral row of Xs. Obviously, the information contained in a word is greater than a repeated row of Xs, and therefore subjects may have remained fixated for a longer period of time before a saccade could be made. It appears as if a lexical stimulus demands the subject's attention a minimal amount of time. This latter effect is especially noteworthy because it suggests that in studies in which short prime-target SOAs are used (e.g., Antos, 1979; Balota, 1983; Neely, 1977), it is possible that subjects may have not completed processing the prime during target presentation. Furthermore, this extended processing may be different for neutral and word primes.

A second difference in results between the first and second experiment is that there was a considerable right-field pronunciation-latency advantage during the second experiment, whereas there was no difference between right and left visual field in the first. During the second experiment, this right-field advantage in pronunciation latencies appeared to be traded for a left-field advantage in saccade latency. It appears that in the second experiment subjects were extracting parafoveal information in the right visual field during their extended fixations when a target was presented to that field. Clearly, the right-visual-field target condition was most akin to eye movement conditions in reading, and possibly there are some trading relations between time on fixation n and word-recognition processes on fixation $n + 1$. This is, of course, only speculation, and we must await further empirical investigation.

Parafoveal visual and contextual information. The results of the first experiment can be accounted for quite easily within a simple logogen-type model of word recognition in which lexical representations receive activation from both foveal semantic context and parafoveal visual information. Furthermore, the results of this experiment suggest that both sources of information have additive effects in the sense that the difference between a semantically and visually related target and a semantically and visually unrelated target equals the sum of the semantic effect and the visual effect. In this light, the data are inconsistent with the interactive model proposed by McClelland and O'Regan and the arguments made by Paap and Newsome. We prefer a more passive logogen account of the first experiment's results because (a) the parafoveal visual preview effects found in Experiment 1 are clearly facilitatory rather than inhibitory (cf. Posner & Snyder's, 1975, distinction between automatic facilitatory dominance effects and attentional facilitatory and inhibitory effects); (b) there was no interaction between practice with foveal-prime parafoveal-target pairings and parafoveal visual relatedness, which would suggest attentional involvement of the subjects; and (c) there was only 250 msec available to process the semantic context, which should primarily yield automatic unattended context effects (cf. Neely, 1977).

On the other hand, when subjects are given sufficient time to instantiate expectations regarding the parafoveal targets, the results appear to be consistent with McClelland and O'Regan's results. That is, the results of Experiment 2 yielded larger parafoveal visual effects when the targets were related to the foveal prime than when they were unrelated. Possibly, with the 1,250-msec preview the instantiated targets have sufficient time to become considerably more salient than without the preview, most likely because of attentional allocation to the semantic/episodic attributes of the foveal prime. In this way, the parafoveal visual information could be used in a more discriminative manner to influence performance. Obviously, as one increases the salience of a potential set of targets, any discriminating features take on more importance in specifying a particular lexical item. Specifically, the letters *sn* are more discriminating in the semantic set of items instantiated for *reptile* as one increases the activation for their corresponding lexical representations. In fact, it is possible that the extraction of an *sn* in the parafovea (which should be most likely to occur at 2.3° right visual angle) along with the specified target set may be sufficiently salient to produce pronunciation inhibition if the parafoveal display changes to a word beginning with *li,* as the results of Experiment 2 indicated.

On the other hand, with respect to the impact of the foveal prime item, we have been primarily emphasizing facilitatory effects. One could, of course, argue that the effects produced by the foveal prime context in the present research are at least in part inhibitory in nature. In fact, according to Neely's (1977) work, one would clearly expect such inhibitory effects in the present second experiment, since a long SOA was used. Furthermore, within Becker's (1980) model, if the instantiated target set is sufficiently large, one would again expect inhibitory effects. In light of the differences in saccade latencies from the foveal item between the neutral and word prime conditions, we opted not to conduct a cost benefit analysis to measure inhibitory effects. In fact, if one does such an analysis, the results of Experiment 2 yielded a net −1-msec inhibitory effect for the semantically unrelated condition. It may be that because a pronunciation task was used in the present study we found little evidence for inhibition. Moreover, West and Stanovich (1982) have recently presented data and arguments that such inhibition effects are restricted to the LDT and will not be found with a pronunciation task. Because of the potential difficulties regarding the use of the LDT to investigate parafoveal visual effects, we decided to use the pronunciation task in the present study.

Conclusion

The present study was conducted to determine (a) whether parafoveal visual information can be used in word recognition when there are no contextual constraints and (b) whether contextual information influences parafoveal visual extraction. The results of Experiment 1 clearly yielded parafoveal facilitatory effects when there were virtually no contextual constraints available to the subjects. Thus, context is not the crucial factor in obtaining visual parafoveal priming, as has been recently argued (McClelland & O'Regan, 1981; Paap & Newsome, 1981). Furthermore, the results of Experiment 1 indicated that at a short SOA (250 msec), the influence of context and parafoveal visual information have additive effects on pronunciation latency. During Experiment 2, subjects were given 1,250 msec to process the context. This experiment yielded interactive effects between context and parafoveal visual information, which indicated larger parafoveal visual effects for related targets than for unrelated targets.

The obvious question that needs to be addressed in future research is which of the experimental results found in the present study more clearly reflects the use of context and parafoveal visual information in reading. Clearly, Experiment 1 is closer to reading if one considers the time parameters across two successive fixations, whereas Experiment 2 more closely mimics the buildup of contextual information across multiple fixations. Whatever the ultimate answer to this question may be, we feel the present results firmly establish the fact that subjects can use parafoveal visual information without any contextual constraints.

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1. Balota, D. A., & Chumbley, J. I. *Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage.* Manuscript submitted for publication, 1983.

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Received December 27, 1982
Revision received April 4, 1983 ■

Articles Published in the Most Recent Issue of JEP: Learning, Memory, and Cognition

October 1983 **Vol. 9, No. 4**