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The Interaction of Contextual Constraints and Parafoveal Visual Information in Reading

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An experiment is reported which demonstrates that contextual constraints and parafoveal visual information interact during reading. As subjects read sentences, the parafoveal visual information available from a target area in the sentence was varied: the parafoveal information was either visually similar or dissimilar to a target word the subject would later fixate. The visual similarity of the parafoveal preview was factorially combined with the predictability of the target word based on the preceding sentence context. That is, as the subjects made a saccade to the target area, the parafoveal preview was replaced by either a target word that was highly predictable or one that was relatively less predictable from the sentence context. Eye movements and fixation durations were affected both by the visual similarity of the parafoveal information and the target predictability. Moreover, although the visual similarity of the parafoveal preview produced an effect even when the target was not predictable from the context, the effect of parafoveal information was greater when it was predictable. There was also evidence indicating that when the parafoveal information was highly predictable, subjects appeared to use more detailed parafoveal visual information. The results are interpreted within an interactive framework in which lexical representations accumulate activation via both contextual constraint and parafoveal information.

The question of whether prior context affects the intake of visual information, and if so, how, is of central importance in cognitive psychology. One common situation in which visual and contextual information may interact is in reading. Here prior context may facilitate processing one or two words to the right of the fixated word. Understanding whether this contextual information influences the processing of to-be-fixated visual information in reading has interested psychologists for a long time, and there have been numerous speculations about how these

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two sources of information interact (e.g., Haber, 1978; Hochberg, 1978; Rumelhart, 1976; Stanovich, 1980). However, there have been no experiments that have directly examined the interaction of context and the intake of parafoveal information in a reading situation.

The word *context* can apply to a multitude of phenomena. In reading, one might wish to distinguish between the contributions of (1) syntax, (2) the semantic relatedness of individual words, and (3) higher order variables such as "schemata" or "mental models." Such distinctions are not central to our concerns. Instead, we deal with context (and contextual constraint) largely in terms of a word's predictability given the prior text. Although the present manipulations are in terms of predictability, we do not presuppose that the impact of context is either in terms of conscious or unconscious prediction of a word from the prior text.

Some of the more popular models of reading, however, have placed an especially strong emphasis on such predictions for the encoding of parafoveal information. These are the "hypothesis testing" or "guessing game" models of reading (Goodman, 1967; Haber, 1978; Hochberg, 1978; Levin & Kaplan, 1970; Smith, 1971). According to this view, during a given fixation the reader obtains information from parafoveal vision and, on the basis of the contextual information up to that point, generates a hypothesis about the nature of the to-be-fixated word. The reader then moves her or his eyes to the next location, quickly confirms the hypothesis, and begins the cycle again by generating a hypothesis about the next word or words in parafoveal vision. Such a model was proposed partly because it was assumed that the visual encoding stage was very slow and represented a bottleneck in the processing system (Smith, 1971). The process of generating a hypothesis was assumed to be faster than visual encoding, and it was further assumed that readers would be correct about their hypothesis far more often than they were incorrect.

A number of problems quickly emerged with this "top-down" or "conceptually driven" model. First, for this model to work, readers should be relatively efficient at guessing the next word based on the available context. However, with normal text, readers are in fact not very good at predicting the next word, even with unlimited amounts of time. (Gough, Alford, & Holley-Wilcox, 1981; McConkie & Rayner, 1976). Second, the assumption of slow visual encoding has been challenged by results demonstrating that visual encoding is quite fast (Pollatsek & Rayner, 1982; Rayner, Inhoff, Morrison, Slowiaczek, & Bertera, 1981). In fact, successful reading may still proceed even though the fixated stimulus is masked after 50 ms. Third, the hypothesis-testing model suggests that the majority of time during a given fixation is spent processing (or hypothesizing about) words yet to be fixated in parafoveal vision. However, a great deal of recent evidence (Ehrlich & Rayner, 1981; Frazier &

Rayner, 1982; Just & Carpenter, 1980; Rayner, 1977) suggests that there is a strong link between the duration of a fixation and certain characteristics of the fixated word such as its grammatical class, frequency, and relationship to previous words in the text. Thus, it appears that the time spent fixating a given word is modulated by factors reflecting what the individual has read and where the individual is currently fixated rather than guesses regarding the next word in the text.

Because of these difficulties with "guessing" or "hypothesis-testing" models, a number of interactive models have been recently proposed in which a more continuous processing of bottom-up (sensory) information is modulated by top-down conceptual information (e.g., Ehrlich & Rayner, 1981; McClelland & O'Regan, 1981; Mitchell, 1982; Rumelhart, 1976; Stanovich, 1980). For example, McClelland and O'Regan (1981) proposed a modified interactive logogen model (Morton, 1969), which assumes that logogens accumulate activation from various information sources, including contextual and parafoveal visual sensory inputs. To influence performance, a logogen must accumulate sufficient activation to reach its threshold. However, a single source of parafoveal information may not produce sufficient activation to influence performance: although parafoveal visual information will produce activation, this activation will occur for a number of visually consistent logogens, and these activated logogens will mutually inhibit each other such that very little net facilitation for any single logogen will be produced. Likewise, a single weak source of contextual constraint will produce activation for a number of constrained logogens, which ultimately will have the impact of mutually inhibiting each other. Thus, there will also be very little net effect of a single source of weak contextual constraint. However, if a weak source of contextual constraint is coupled with parafoveal visual information, a single logogen may receive sufficient activation from both sources to surpass the interactive threshold. Thus, the McClelland and O'Regan model predicts interactive effects of context and parafoveal information, since two weak sources of information that have little effect by themselves can produce facilitation when combined.

McClelland and O'Regan's empirical support for this model is based on experiments conducted to investigate the impact of contextual constraint and the use of parafoveal visual information. In their first experiment, they used a paradigm developed by Rayner and his colleagues (Rayner, 1978; Rayner, McConkie, & Ehrlich, 1978; Rayner, McConkie, & Zola, 1980) to investigate the type of information integrated across saccades in word recognition. In the Rayner et al. experiments a letter string was presented in parafoveal vision as the subject fixated on a centrally located cross. During the subject's eye movement to the parafoveal stimulus, the parafoveal letter string was replaced by a target that the subject pronounced aloud. The result was that pronunciation latency decreased with increasing visual similarity between the preview item and the target. In particular, if the first two or three letters in the initial parafoveal stimulus and the target word were identical, facilitation occurred (Rayner et al., 1980). Furthermore, this facilitation depended upon how far into the parafovea the stimulus occurred; there was more facilitation at 1° than at 3° and more facilitation at 3° than at 5°. Thus, the Rayner et al. results indicate that subjects can use partial parafoveal information to aid recognition of a parafoveal word after a saccade has been made to that word.

McClelland and O'Regan (see also Paap & Newsome, 1981) reported data which appear to question the generalizability of the Rayner et al. studies. McClelland and O'Regan argued that because Rayner et al. used a relatively small set of target words (in most cases 30), which were repeated throughout a given experiment, there may have been sufficient contextual constraint to allow subjects to generate expectancies about potential parafoveal targets. These expectancies may have allowed subjects to use this partial parafoveal information in an interactive fashion to produce the parafoveal visual facilitation effects, and the subjects would have benefited very little, if at all, from parafoveal information without such expectancies. McClelland and O'Regan's data provided some empirical support for the hypothesis that expectancies are the crucial component for extracting useful parafoveal visual information (see Rayner & Slowiaczek, 1981, for a critical discussion of these results). Such an interaction was viewed by McClelland and O'Regan to be quite consistent with the interactive logogen model described above.

More recently, Balota and Rayner (1983) reported experiments in which they used a sufficiently large set of target words (512) to minimize the likelihood that subjects could generate expectancies and found clear evidence that subjects could use parafoveal visual information without any contextual constraints. Furthermore, Balota and Rayner attempted to test directly the interactive model by presenting a foveal word (e.g., *reptile*) along with an initial parafoveal preview item (e.g., *snckks*). During the eye movement to the parafoveal item, the parafoveal preview was replaced by a word that was either (a) semantically related to the foveal word and visually related to the parafoveal preview item (*snakes*), (b) semantically unrelated to the foveal word and visually related to the parafoveal preview item (*sneaks*), (c) semantically related to the foveal word and visually unrelated to the parafoveal preview item (*lizard*), or (d) semantically unrelated to the foveal word and visually unrelated to the parafoveal preview item (*limits*). The results indicated that when subjects only had 250 ms to use the semantic context (Experiment 1) there were additive effects of context and parafoveal information. However, when subjects were given 1250 ms to use the semantic context (Experiment 2) there were interactive effects of context and parafoveal information. (It should be noted that, in Experiment 2, there was facilitation due to parafoveal preview information even when the foveal word was semantically unrelated to the target.) Thus, when subjects were given sufficient time to instantiate expectations regarding the parafoveal targets, the results indicated that context was modulating the impact of parafoveal visual information. On the other hand, when contextual information was only available for a brief period of time, the additive pattern suggests that context was influencing a different stage of processing than was the parafoveal information.

Balota and Rayner raised the question of whether the additive or the interactive pattern of results they obtained more clearly reflects the use of context and parafoveal information in reading. They pointed out that the time parameters of their first experiment appeared to mimic those context effects that would be expected if context was established on fixation n and the facilitation was occurring on fixation $n + 1$ (approximately 250 ms later). On the other hand, the results from the second experiment might mimic a reading situation in which much of the relevant context was established at least several words before encountering the target word.

The major focus of the present research was to assess the effects of context on the processing of parafoveal information in reading. In particular, we were interested in knowing how contextual information influences the use of parafoveal information and whether the extraction of parafoveal information only occurs in reading when there is a strong prior constraining context.

OVERVIEW OF THE PRESENT STUDY

In the present study, subjects were presented sentences of the form:

> Since the wedding was today, the baker rushed
> the wedding *cake* to the reception.

The critical target area in this sentence is the location of the word *cake*. In this critical area, subjects either received the highly predictable word *cake* or the word *pies*, which is acceptable but less predictable from the sentence context. One question of interest is whether subjects will spend less time fixated on the word *cake* than on the word *pies*. Although there has been an enormous amount of research on the effect of contextual constraint on word recognition (using tachistoscopic recognition, lexical decision, and pronunciation tasks), there are only a few studies which have investigated the influence of context on subjects' eye-movement records as they were actually reading (Ehrlich & Rayner, 1981; Zola, 1982). Obviously, if the models of word recognition developed to account for data in simple word recognition tasks are relevant to word recognition processes that occur during reading, then one needs to extend similar manipulations to a more natural reading situation. Such an extension becomes even more important given that the two major tasks utilized to investigate lexical access processes (pronunciation and lexical decision) involve potentially misleading task specific postaccess processes (see Balota & Chumbley, 1984, 1985; Chumbley & Balota, 1984).

The only two studies addressing contextual effects in an "on-line" reading task have investigated extremes of contextual manipulations. Zola (1982) investigated the impact of a single constraining adjective, whereas Ehrlich and Rayner (1981) investigated the impact of a complete preceding paragraph. Zola (1982; see also McConkie & Zola, 1981) constructed short passages that were identical except for an adjective immediately to the left of a target word. The adjective either highly constrained the following noun (*buttered popcorn*) or was neutral with respect to it (*delicious popcorn*). Zola found that the average fixation time on the target word was 16 ms less when the adjective constrained the target word than when it was neutral. However, subjects were no more likely to skip the target word when it was highly predictable than when it was not. Ehrlich and Rayner (1981) had subjects read passages in which the contextual constraint of a target word was established by a series of preceding sentences. They found a considerably larger impact of constraint on the average fixation duration on the target: 33 and 55 ms in their first and second experiments, respectively. Also, Ehrlich and Rayner found that subjects were more likely to skip over the target word in the high-constraint than low-constraint conditions.

The context manipulation in the present study was between the two extremes used by Zola and by Ehrlich and Rayner. While the context was usually established before the word prior to the target word, the present experiment employed single sentences so that context was not as well established as in the Ehrlich and Rayner study. The constraint conditions of our study appear to be more typical of ordinary text and are similar to the sentential constraint investigated in word recognition tasks (cf. Stanovich & West, 1983a; West & Stanovich, 1982).

In addition to context, we also varied the parafoveal visual information the subject had available before fixating on the target word (e.g., *cake* or *pies*). By using an eye-tracking system we were able to manipulate the parafoveal information available to the subject as he or she was reading. Thus, while the subject was fixated on the word *wedding* (preceding the target area) one of the following parafoveal preview items was presented: (a) the word *cake*, (b) the word *pies*, (c) the nonword *cahc*, (d) the nonword *picz*, or (e) the anomolous preview *bomb*. Each of these preview items was factorially combined with the type of target (*cake* or *pies*) the subject actually received. Based on research by Rayner and colleagues (Rayner, 1975; Rayner et al., 1980; Rayner, Well, Pollatsek, & Bertera, 1982) we expected subjects to spend less time fixating on the critical target word when the preceding parafoveal preview is visually related than when it is visually unrelated to the target. This parafoveal manipulation is of considerable interest because McConkie, Zola, Blanchard, and Wolverton (1982) have recently reported data that question whether such parafoveal information is actually used during reading. We shall return to the McConkie et al. data below.

The third, and most important, issue addressed by the present research is how context influences the use of parafoveal visual information. An interactive model such as McClelland and O'Regan's predicts that there will be a much larger parafoveal preview effect for the highly predictable targets than for the less predictable targets. That is, although the contextual constraint may be insufficient, by itself, to push a lexical representation above its threshold it may be sufficient when combined with parafoveal visual information. This would be reflected by an interaction between visual relatedness and target predictability. That is, in the present example sentence, subjects should be better able to use the parafoveal information (*cake* or *cahc*) that is consistent with the highly predictable target than the parafoveal information (*pies* or *pirc*) that is consistent with the less predictable target.

METHOD

Subjects

Thirty members of the University of Massachusetts community were paid to participate in the experiment. All subjects had normal uncorrected vision and were naive with respect to the stimuli in this experiment. Approximately half of the subjects previously had been in an eye movement experiment.

Procedure

When a subject arrived for the experiment, a bite bar that eliminated head movements during the experiment was prepared. The initial calibration of the eye movement recording system was usually accomplished in less than 5 min. Calibration was followed by 10 practice sentences (one in each of the 10 conditions) followed by 100 experimental sentences. Before a sentence was presented, the experimenter ensured that the subject (a) was still correctly calibrated and (b) was fixating on the area in which the beginning of the sentence would be presented.

The experimenter started each trial by saying "Ready." Approximately 0.5 s later the sentence was displayed. After reading the sentence subjects pressed a button which terminated the display. Subjects were instructed to read for comprehension and were told that they would periodically be asked to release the bite bar and report (verbatim or paraphrase) the sentence they had just read. Subjects were also instructed to immediately report any abnormalities in the display.

Materials and Apparatus

Two-line sentences extending with up to 42 characters per line were used as stimuli. The target word never appeared at the end of either line. Sentence frames were written such that two alternative words could appear in a target location with one word being highly predicted by the prior context and the second word of the pair being less predicted (but not anomolous). For example, in the sentence frame

> Since the wedding was today, the baker rushed
> the wedding ____ to the reception

the word *cake* is highly predictable from the prior context. On the other hand, the word *pies* is not at all predictable from the prior context but is an acceptable word in that context.

One hundred such sentence frames were prepared, each with two alternative target words. To establish the difference in the levels of predictability for the two target words, two procedures were used. First, 20 undergraduate students who did not participate in the main experiment were presented booklets containing the sentences up to the point of the target word. Two forms were prepared so that if in Form A the high-predictable word was presented for Sentence 1, on Form B the low-predictable word was presented for Sentence 1. Thus, an equal number of high-predictable and low-predictable words were presented on each form and the same frame did not appear twice. The subjects were asked to rate on a 5-point scale how well the target word (which was the last word in the frame) fit the rest of the sentence. A rating of 5 meant that the word fit in very well and a rating of 1 meant that the word did not fit in very well. The mean rating was 4.47 for the target words in the high-predictable condition and 2.32 for the target words in the low-predictable condition. For every pair of target words the mean rating was higher for the high-predictable word than for the low-predictable word. In the second procedure, another group of 20 undergraduates were presented the sentence frames up to the target word and were asked to produce the next word in the sentence. The target words that were used in the high-predictable condition in the present study were produced 64% of the time, whereas the target words that were used in the low-predictable condition were produced less than 1% of the time.

The target words ranged from 4 to 8 letters in length (mean length = 5.2 letters) with length being matched across the high-predictable and low-predictable target words for a given sentence. The word frequency, based on the Kučera and Francis (1967) norms, was 58.8 per million for the high-predictable target words and 57.8 per million for the low-predictable target words. Table 1 displays example sentence frames.

In addition to varying the predictability of the target words, we also varied the parafoveal visual information. For each target word, a visually similar nonword was prepared consisting of the same first two or three letters with all other letters in the original target word replaced with visually similar letters. Thus, for the target words *cake* and *pies, cahc* and *picz,* respectively, represented the visually similar parafoveal nonword previews. This condition is referred to as the visually similar (VS) condition. In the visually dissimilar (VD) condition, target words were crossed with visually dissimilar parafoveal nonword previews (*cake-picz* and *pies-cahc*). In the identical (Ident) condition, the target word was paired with itself (*cake–cake; pies–pies*). In the semantically related (SR) condition, the target words for a given sentence were paired with each other (*cake–pies; pies–cake*) and in the anomolous (AN) condition an unrelated word that was anomolous in the sentence context was paired with each target word (*cake–bomb; pies–bomb*).

As shown in Table 1, the two levels of predictability for the target word combined with the 5 parafoveal preview conditions yield 10 conditions. Each subject received 10 sentences per condition. Each frame occurred once in each of the 10 conditions across each of the

TABLE 1
Examples of Test Stimuli

Sentence frame 1

Since the wedding was today, the baker rushed the wedding ___ to the reception.

Indent	VS	SR	VD	AN
	Parafoveal previews for the high-predictable word *cake*			
cake	cahc	pies	picz	bomb
	Parafoveal previews for the low-predictable word *pies*			
pies	picz	cake	cahc	bomb

Sentence frame 2

The banker loaned the businessman some more ___ for his new project.

Indent	VS	SR	VD	AN
	Parafoveal previews for the high-predictable word *money*			
money	moncg	tools	toohz	house
	Parafoveal previews for the low-predictable word *tools*			
tools	toohz	money	moncg	house

three 10-subject groups. Sentence frames were not repeated for any subject, and all sentences were randomized anew for each subject.

A boundary location was determined for each sentence. The boundary location was always the next to the last letter in the word immediately to the left of the target word. Thus, in our example sentence, the boundary was the letter *n* in wedding. This boundary location was chosen to take advantage of the preferred viewing location (Rayner, 1979; O'Regan, 1981) which is halfway between the beginning of the word and the middle of the word. Thus, only a small percentage of saccades actually land on the end of words, unless there is a second fixation on the word (Rayner, 1979). As soon as the reader's saccade crossed the boundary location, the initially presented parafoveal preview was replaced by the target word.

Eye movement recording was accomplished by using a Stanford Research Institute Dual Purkinje eyetracker, which has a resolution of 10′ arc and a linear output over the horizontal visual angle (14°) subtended by the sentences. The sentences were displayed on a Hewlett–Packard 1300A CRT, with a P-31 phosphor, which drops to 1% of maximum brightness in 0.25 ms. The letters making up the sentences were printed in lowercase (except for the first letter of the sentence and proper names). A black theater gel covered the CRT so that the letters appeared clear and sharp to the subjects. The eyetracker and the CRT were interfaced with a Hewlett–Packard 2100 computer that controlled the experiment. The signal from the eyetracker was sampled every millisecond, and the position of the eye was determined every 4 ms. The display change was accomplished in 5 ms. For the vast majority of the cases, the display change occurred entirely during the saccade when vision was suppressed.

The subject's eye was 46 cm from the CRT and three characters subtended 1° of horizontal visual angle. Eye movements were monitored from the right eye, although viewing was binocular. Luminance on the CRT was adjusted to a comfortable level for the subjects, and the subjective brightness was held constant throughout the experiment. The room was dark, except for a dim indirect light source. More details about the apparatus are described by Rayner et al. (1981, 1982).

RESULTS AND DISCUSSION

The data are based on one mean per condition calculated for each of the 30 subjects. The following kinds of sentences were not included in the analyses: (a) sentences in which the eyetracker lost track of the eye (6%); (b) sentences in which the subjects reported that they saw the display change (1%); and (c) sentences in which the first fixation past the boundary landed on the last two characters of the word prior to the target word (4%). In the latter case the display change occurred before the target word was fixated. On these trials, since the eye would have crossed the boundary as the saccade ended, there would have been a greater chance that subjects actually saw the display change occur. Indeed, in all cases where subjects reported seeing a display change, the saccade crossed the boundary location at the end of the eye movement.

Skipping the Target Word

While the primary focus of this paper is on the influence of parafoveal information on later target processing, the data on what influences the likelihood of skipping the target word are straightforward and help to frame the discussion. In this analysis the predictability of the target word is irrelevant since the saccade of interest was initiated before the display change (subjects cannot change the trajectory of a saccade once initiated) and hence before the target word appeared. What is relevant, therefore, is what was available to the subject prior to the display change (i.e., the parafoveal preview). Accordingly, we first consider the data collapsed across the high-predictable and low-predictable conditions and adopt the following nomenclature for the five parafoveal preview conditions. The "high-predictable word" refers to the preview word that is highly predicted from the sentence context, and the "high-predictable nonword" refers to its visually similar counterpart. Likewise, the "low-predictable word" is the word which is less predicted from the sentence context, and the "low-predictable nonword" is its visually similar counterpart. Finally, the word that does not fit within the context is the "anomolous word." The data for these five parafoveal conditions are displayed in the third row of Table 2. (Differences between the first and second row of Table 2 are due to chance, since the target has not yet been presented.)

As shown in Table 2, there was a clear difference among the five preview conditions, $F(4,116) = 32.6$, $MSe = 0.0014$, $p < .001$. Subjects

TABLE 2
Probability of Skipping the Target Word for the Ten Experimental Conditions

	Preview string				
Target	High-pred. word	High-pred. nonword	Low-pred. word	Low-pred. nonword	Anomolous word
High predictable	.11 (.10)	.11 (.10)	.02 (.01)	.00 (.00)	.01 (.00)
Low predictable	.12 (.06)	.13 (.06)	.05 (.04)	.04 (.03)	.00 (.00)
$\overline{X}$	.11 (.08)	.12 (.08)	.03 (.02)	.02 (.01)	.005 (.00)

Note. The preview conditions are classified differently in this table than in the following tables. Values in parentheses are the probability of skipping the target area when regressions back to the target are included.

were more likely to skip the target area when the high-predictable word or its visually similar nonword counterpart appeared in the parafovea (11.5%) than when the low-predictable word or its visually similar nonword appeared in the parafovea (2.5%). When the target position was occupied by the anomolous word, the target area was virtually never skipped.

Several clear conclusions emerge from the skipping data. First, the parafoveal word was identified some fraction of the time, and the sentential context influenced whether the parafoveal word was identified (cf. also Ehrlich & Rayner, 1981). Second, the decision to skip the target word was not based on a full analysis of the parafoveal word, since the reader was just as likely to skip over the high-predictable nonword as to skip over the high-predictable word. The data imply that when the word is skipped, only the beginning two or three letters of the parafoveal word were actually identified. Thus, on these occasions, a strong context helps readers to fill in information that is not totally available in their parafovea. As we shall see below, this filling in did not appear to occur when they did not skip the word.

When regressions to the target word are included in the analyses, the display change has occurred, and therefore the predictability of the target word becomes relevant. The numbers in parentheses in Table 2 reflect the probability of skipping a target area when regressions are included in the analyses. (Hence, the difference between the parenthesized and the nonparenthesized numbers in a given cell reflect the percentage of regressions back to the target area after that area was skipped.) Clear differences remained between the parafoveal preview items, $F(4, 116) = 11.12$, $MSe = 0.0035$, $p < .001$, along with an effect of predictability, $F(1,29) = 10.78$, $MSe = 0.0037$, $p < .01$, and an interaction, $F(4,116) = 12.85$, $MSe = 0.0027$, $p < .001$. The interaction reflected that regressions to the target word occurred on approximately 6% of the sentences if the target word changed from the high-predictable word or nonword (both of which were apparently identified as the predictable word) to the low-predictable word, while there was less than 1% chance of a regression to the target word in all other conditions.

The latter result is interesting because these are trials in which the subjects were skipping over the target word. In order for the subjects to have noticed the change, they must either have processed it during the saccade (which is unlikely) or noticed it after skipping the target word. The latter implies that subjects were processing significant information to the left of the fixated word. If this were true, it would contradict the conclusions by Rayner, Well, and Pollatsek (1980). In Rayner et al.'s Experiment 3, readers who were presented with mutilated text to the left of the fixated word read only slightly slower than readers of normal text. Rayner et al. thus suggested that readers utilize very little parafoveal information to the left of the fixated word. However, they did report a small decrement (8 words per minute), and therefore, it may be that information to the left of fixation is used in special cases, such as confirming the last few letters of a skipped word.

Fixated Targets

Subjects fixated the target word on the majority of trials. Our primary measure for analyzing the data from these trials was gaze duration, the total time spent fixating the target word *before another word was fixated* (i.e., not including regressions back to the word).

Inspection of Table 3 indicates two obvious features of the gaze duration data. First, there was a significant effect of the type of parafoveal preview appearing in the target position, $F(4,116) = 23.78$, $MSe = 853.39$, $p < .001$, indicating that subjects spent less time on the target word when it was preceded by a visually related parafoveal preview. Second, there was a clear interaction between predictability of the target and the parafoveal preview conditions, $F(4,116) = 3.20$, $MSe = 936.71$, $p < .05$. This interaction suggests that a parafoveal preview visually similar or identical to the fixated target produced more facilitation when the word was highly predictable from the sentence context.

There are several ways to evaluate this interaction. Perhaps the simplest is to average across the conditions in which the parafoveal preview was visually similar or identical to the target word (the left two columns of Table 3) and across the conditions in which it was visually dissimilar to the target word (the right three columns of Table 3). When the target was the high-predictable word, there was a 43-ms advantage of a visually similar parafoveal preview (Ident and VS), whereas when the target was the low-predictable word, there was only a 21-ms advantage of a visually similar parafoveal preview. This contrast was highly significant, $t(29) =$

TABLE 3
Mean Gaze Duration (milliseconds) on the Target Word in the Ten Experimental Conditions

Target	Preview condition					
	Ident	VS	SR	VD	AN	$\bar{X}$
High predictable	232	248	280	280	292	266
Low predictable	264	263	287	277	290	276
$\bar{X}$	248	256	284	279	291	

2.87, $p < .01$. Thus, visual information from the parafovea facilitated later foveal processing, but facilitated it more when the target word was highly predictable from the sentential context than when it was less predictable.

While this contrast captures much of the interaction between target predictability and parafoveal preview, a closer inspection of Table 3 reveals that when the parafoveal preview was highly predictable from the sentence context, readers sometimes used more than just the first two or three letters of the parafoveal preview. For example, consider the left two columns of Table 3. When the target was the high-predictable word, there was a 16-ms advantage when the preview item was identical compared to when it was only visually similar. But when the target word was the low-predictable word, the identical preview was actually 1 ms slower than the visually similar preview condition. This contrast, which is independent of the previous contrast, was also significant, $t(29) = 2.26$, $p < .05$. Next, let us turn to columns 3 and 4, which provide data for the semantically related and visually dissimilar preview conditions. Here, when the target was the low-predictable word, subjects were 10 ms slower when the preview was the semantically related preview, compared to the visually similar condition; however, when the target was the high-predictable word, there was no difference between the two conditions. This latter pattern suggests that lexical processing of the preview occurred more often when it was the high-predictable word than when it was its visually similar counterpart and that this lexical processing caused the subject to do a "double take" when the display was changed to the low-predictable word. While this contrast was small and did not reach significance, it fits quite nicely with the previous interaction. Moreover, there is a further aspect of the data which points to the same conclusion.

Spillover Effects

Spillover refers to the first fixation to the right of the target area. These data were analyzed to see if there were any spillover effects of the experimental conditions (see Table 4). The spillover data show a clear effect of predictability of the target word, $F(1,29) = 8.65$, $MSe = 844.01$, $p < .01$, and also of the type of parafoveal preview, $F(4,116) = 3.58$, $MSe = 1360.54$, $p < .01$. The most striking aspect of the spillover data concerns when the target was the low-predictable word. For this target condition, when the parafoveal preview was the high-predictable word, the spillover duration was 16 ms longer than when the preview was the high-predictable nonword. Again, it appears that subjects do a double take when they are given the high-predictable parafoveal preview word, but actually receive the low-predictable word foveally. In contrast, when the target was the high-predictable word, the spillover durations were actually 4 ms shorter when the parafoveal preview was the low-predictable word than when it was the low-predictable nonword. Although this contrast did not reach significance, $t(29) = 1.47$, $p < .20$, it is noteworthy that separate comparisons yielded a highly significant effect of predictability for the SR word preview condition, $t(29) = 2.93$, $p < .01$, whereas the effect of predictability did not approach significance for the VD nonword preview condition, $t(29) = 0.77$.

To summarize, readers appear to use more parafoveal information when it is highly predicted by the sentence context than when it is not. Parafoveal previews of highly predictable words produce greater facilitation than did parafoveal previews of less predictable words. Moreover, if the parafoveal stimulus was the high-predictable word, more than the first three letters were processed.

A Finer Grained Analysis of the Time Course of Processing

The gaze duration analyses indicated that both the predictability of the target and the type of parafoveal preview influenced the time spent on the target word. Moreover, these two variables appear to have interactive effects on gaze duration.

Gaze duration, however, is a global measure. When gaze duration varies, one can only infer that a manipulation had some impact on pro-

TABLE 4
Mean Fixation Duration (milliseconds) on the First Fixation Following the Fixation(s) on the Target Word (Spillover Data)

	Preview condition					
Target	Ident	VS	SR	VD	AN	$\bar{X}$
High predictable	223	218	232	236	240	230
Low predictable	227	232	258	242	240	240
$\bar{X}$	225	225	245	239	240	

cessing the target word. Possibly, a more diagnostic measure of the early foveal processing of the target word is the duration of the first fixation on the target (Inhoff, 1984). As can be seen in Table 5, this pattern of data is somewhat different from that of the gaze duration data. There was again a clear effect of the parafoveal preview, $F(4,116) = 5.94$, $MSe = 691.16$, $p < .01$, with the visually similar parafoveal previews (Ident and VS conditions) being 14.7 ms shorter than the visually dissimilar previews (SR, VD, and the AN conditions), $t(29) = 4.88$, $p < .01$. However, no other effects remotely approached significance. The overall difference between the high-predictable target words and the low-predictable target words was only 1 ms. The only hint of a predictability effect was in the Ident condition; however, even this 9-ms difference did not approach significance, $t(29) = 1.37$, $p > .10$.

Thus, the similarity of the parafoveal preview had an effect on the length of the first fixation, but the predictability of the fixated word and its relationship to the parafoveal preview had little influence on the first fixation data. This pattern of data suggests that the predictability of the target word and its relationship to the type of parafoveal preview affects gaze duration largely through the probability that the fixated target word will be fixated again before a saccade to another word. Table 6 displays the mean probability of a second fixation on the target word. As shown in Table 6, it is clear that the probability of a second fixation on the target word was greater when the target word was visually dissimilar to its preceding parafoveal preview item than when it was visually similar, $F(4,116) = 8.83$, $MSe = 0.018$, $p < .001$. Moreover, there was clearly an interaction between the type of parafoveal preview and the predictability of the target word, $F(4,116) = 3.67$, $MSe = 0.02$, $p < .01$. When the parafoveal word was identical to the target word, the high-predictable word was 13% less likely to be fixated a second time than the low-predictable word. There were relatively small differences between the high-predictable and low-predictable target words in the other preview conditions, although the difference was slightly larger (4%) when the preview was visually similar.

TABLE 5
Mean First Fixation Duration (milliseconds) on the Target Word

	Preview condition					
Target	Ident	VS	SR	VD	AN	$\overline{X}$
High predictable	216	224	236	235	238	230
Low predictable	225	222	232	237	241	231
$\overline{X}$	221	223	234	236	240	

TABLE 6
Mean Probability of a Second Fixation on the Target Word

	Preview condition					
Target	Ident	VS	SR	VD	AN	$\overline{X}$
High predictable	.09	.14	.26	.24	.27	.20
Low predictable	.22	.18	.28	.22	.22	.22
$\overline{X}$	.16	.16	.27	.23	.25	

To summarize, the first fixation duration appears to be sensitive chiefly to the visual relationship of the parafoveal preview to the target word. The interaction between predictability of the target word and parafoveal preview was primarily reflected in the probability of fixating the target word a second time. It is noteworthy, however, that both effects occurred within the first 250 ms of fixating the target word, since both the decision of how long to remain in the first fixation and where to move the eyes next must be made during the first fixation.

GENERAL DISCUSSION

The major results of the present study are as follows. First, there was a strong influence of the visual similarity between the parafoveal preview and the target. This effect appeared in the first fixation data, the gaze duration data, and the spillover data. Second, there was an influence of target predictability that occurred in the gaze duration and in the spillover data, but not in the first fixation data. Third, there was evidence that subjects were better able to utilize the parafoveal information when that information was highly predictable from the sentence context than when it was less predictable. This latter interactive effect occurred in the gaze duration data and to some extent was also reflected in the spillover data. These three major findings provide relevant information to three major concerns in reading research.

Parafoveal Processing during Reading

The present study yielded consistent differences between visually similar and visually dissimilar parafoveal previews. This finding is consistent with the results from numerous studies conducted by Rayner and his associates (e.g., McConkie & Rayner, 1975; Rayner, 1975; Rayner et al., 1981, 1982), which show that subjects use parafoveal visual information during reading. While these results also converge with a great deal of research on the perceptual span during reading (see Rayner, 1984, for a review), a recent study by McConkie, Zola, Blanchard, and Wolverton (1982) raises the question of whether subjects actually do use partial parafoveal information during reading. Since the McConkie et al. study runs counter to both the present results and a considerable amount of past literature, it is necessary to address this study in some detail.

In the McConkie et al. study, short texts were constructed such that each of four words differing in their initial or fourth letter position (e.g., *weedy, weepy, seedy, seepy*) could fit within a single sentence context. In the experimental condition, two words would alternate across successive fixations, e.g., *weepy* would change to *seepy* and then back to *weepy* etc., on successive fixations. Although McConkie et al. found that the experimental condition produced 10 to 12.5 ms slower first fixation durations than a control condition in which there was no change made, this difference was not significant. Also, McConkie et al. found that subjects' later recognition memory for the words in the text was uninfluenced by the parafoveal information that subjects received and was primarily dependent upon the words that the subjects actually fixated on. Based on these failures to reject the null hypothesis, the authors argued that the target words were read only when directly fixated and there was no influence from prior parafoveally obtained partial information.

We have several objections to the conclusions of McConkie et al. First, we do not find the memory data compelling since many other perceptual span studies have shown clear effects of restricting window size even though subjects are usually unaware of any display changes (cf. Rayner et al., 1982). In addition, stimuli presented below awareness thresholds have been shown to influence perceptual processes (lexical decisions) without influencing episodic memory storage (Balota, 1983). In reading, various word and letter representations may become momentarily activated by the parafoveal information, but then decay quickly when the subject actually fixates the target word. This disambiguated target word should be what is embedded within the subject's memory representation—not all momentarily activated candidates.

Our second objection to the conclusions of McConkie et al. is that the trends in their first fixation duration data (10- to 12.5-ms difference) suggests that the parafoveal visual information was having some influence. In fact, if we compare the present first fixation data for the visually similar conditions (Ident and VS) and the visually dissimilar conditions (SR, VD, and AN), we find a difference of only 14.7 ms. We feel that the trends in the McConkie et al. data were not statistically significant because their experimental design lacked power. In the McConkie et al. study there were on average 154 observations/condition, whereas there were approximately 530 observations in each of the five parafoveal preview conditions in the present study. Furthermore, the present data yielded larger effects of visual similarity on gaze duration than on first fixation duration. If McConkie et al. had used gaze duration instead of first fixation data as their dependent measure, significant effects might have emerged. Unfortunately, their methodology (changing the target word on each subsequent fixation) did not allow the use of gaze duration.

It is also noteworthy that McConkie et al. used target words which were both very low in word frequency (47 of the 88 target words used in their study had counts of 5 or less/million, based on the Kučera & Francis, 1967 norms) and relatively unconstrained by the sentence context. These two factors probably contributed to the relatively long fixation durations in their study (278 ms) and also could have added to the variability in their data.[1] Furthermore, the present research clearly indicates that the use of parafoveal information is greater when items are highly constrained by the sentence context; similarly, one might expect greater use of parafoveal information from high-frequency words than from low-frequency words. Thus, the nonsignificant trends in the McConkie et al. data could also be viewed as suggesting that the impact of parafoveal visual information is attenuated when that information is not constrained by the sentence context and, possibly, is relatively low in frequency.

One final issue needs to be addressed concerning the influence of parafoveal information in reading: does the difference between related and unrelated conditions reflect facilitation of the related condition or inhibition of the unrelated condition? Past researchers have attempted to distinguish between facilitation and inhibition effects in pronunciation and lexical decision studies through the use of a neutral baseline condition (e.g., the word *blank* or a row of *x*'s). However, there has been recent concern over which neutral baseline is most appropriate in these word recognition studies (see de Groot, Thomassen, & Hudson, 1983; Rayner & Slowiazcek, 1981), and the selection of an appropriate neutral baseline condition becomes even more difficult when one considers a natural reading situation. For example, a row of *x*'s or a blank area in the parafovea would probably draw attention because of its unnatural appearance in text.

Although there is no obvious neutral baseline in the present study, our data still allow important conclusions to be made about reading. First, consider the main effect of visual similarity in the first fixation data. This effect could be interpreted as reflecting either facilitation from visually similar previews or inhibition from dissimilar previews. In either case the conclusion is the same: Visual information in the parafovea is processed in reading. The only uninteresting interpretation would be that superficial inhibition was being produced by gross changes in the display. This interpretation is unlikely for two reasons: First subjects were almost always

[1] Although it is difficult to make comparisons across studies, this dramatic difference across first-fixation data is of interest because it is consistent with the notion that there was an increased difficulty in recognizing the target words in the McConkie et al. study.

unaware of the display changes, and second the gross disruption hypothesis would not account for the interactive effects found using gaze duration.

With respect to the latter interactive effects, we again come to the same conclusion whether we use a facilitation or inhibition interpretation. In either case, the results indicate that (1) the content of the parafovea is more important for predictable targets than for less predictable targets, and (2) more parafoveal visual information is used if the parafoveal stimulus closely matches a highly predicted word. Thus, although the present research cannot distinguish between facilitation or inhibition, we feel that it does provide further converging evidence that readers process parafoveal visual letter information.

The Influence of Contextual Constraint in Reading

In the present experiment, context influenced (1) the probability the target word would be skipped, (2) the gaze duration on the target word, and (3) the first fixation following the target word (spillover). These influences of context are consistent with the effects found by Zola (1982) and Ehrlich and Rayner (1981). Although it is difficult to make comparisons across studies and materials, it is of some interest that the size of the predictability effect in the present sentence context study (23 ms in gaze duration) was the same as that obtained in the Zola (1982) study (23 ms in total time fixating the target word) in which contextual constraint was induced by only a single preceding adjective.[2] Moreover, the size of the present context effect is also similar to that of a recent word pronunciation study by Stanovich and West (1983b) in which they found, on average, a 19-ms effect of sentence context for nonterminal target words. It is, of course, reassuring to find convergence with similar materials across different paradigms. As noted earlier, Ehrlich and Rayner (1981) found a considerably larger influence of predictability when it was induced by a preceding paragraph. This latter influence of target predictability may in part reflect the time taken to incorporate the target word into a more complete text representation which has built up across the paragraph (see discussion below, and Foss, 1982).

The present conjoint manipulation of context and parafoveal information allows a more diagnostic statement about "how" predictability of a word influences reading. First, and most importantly, the finding that context influenced both the impact of the parafoveal preview and the amount of

[2] Actually the 23-ms effect on total reading time reported by Zola includes regressive fixations. Thus, the exact size of the effect is not directly comparable to the present gaze duration measure in which regressive fixations were not included. However, because of the low frequency of regressive fixations, this is a relatively useful estimate of the effect size obtained in the Zola study.

useful information extracted from that preview indicates that at least part of the effect of context was on accessing the target word. This finding extends the results of Balota and Rayner (1983) in which a 1200-ms preview of a foveally presented semantic associate influenced the visual extraction of parafoveal information in a word-naming task. Second, the influence on first fixation duration by parafoveal preview but not by target predictability suggests that context may not influence early stages of visual processing.[3] However, as noted earlier, this conclusion must be hedged somewhat: since predictability affects the probability of refixating a word, it influences a decision made during the first fixation and thus well within the first 250 ms of fixating on the target word. While there is evidence that decisions about *where* vs. *when* to move the eye are made independently (Rayner & McConkie, 1976; Rayner & Pollatsek, 1981), it is by no means clear which decision is made first. Third, the effect of predictability on the spillover data suggests that the predictability of the target word also influences postlexical processes such as integrating the meaning of the target word with the previous sentence context. An alternative possibility, which seems less likely, is that readers are still extracting the meaning of the target word when fixating the following word.

Thus, the present results indicate that context has an influence both at the lexical access level and at a postaccess level such as integrating the meaning of the word within the text representation. Such an identification of dual influences of context is important in light of recent research by Foss (1982), Gough et al. (1981), and the linguistic modularity approach advocated by Forster (1979), who have suggested that the influence of context in reading is only on postlexical text integration. Although the present results indicate that context also influences lexical access, it is indeed possible that context is more likely to have postlexical than lexical access effects in reading. Possibly only the strongest forms of context, such as high predictability, that are established sufficiently before processing the target word have consistent effects on lexical access time (cf. Balota & Rayner, 1983).

In this vein it is of interest to compare the present effects of predictability of the target word with other types of contextual manipulations in reading. The analysis above suggests that spillover effects primarily reflect ongoing discourse processing, most plausibly reflecting difficulty of

[3] It is, of course, possible that with a stronger within sentence manipulation of contextual constraint, one might find some effect of context on the first fixation duration. However, with extreme manipulations of constraint, one may be decreasing the relevance of the research to more natural reading situations (Stanovich & West, 1983b, have recently made a similar point). In fact, the manipulations in the present study clearly are stronger than one finds in reading, and yet, we found little evidence of constraint on the first fixation duration data.

integrating words into the sentence context. Research by Ehrlich and Rayner (1983) supports such a contention. They manipulated the distance between a pronoun and its antecedent noun, and found that the postlexical search for the antecedent noun was primarily reflected in the obtained spillover data, after the target pronoun was first fixated. However, Frazier and Rayner (1982) investigated syntactically ambiguous sentences in which normal processing strategies lead subjects to parse the sentence incorrectly (they were led down the "garden path"). Although Frazier and Rayner also reported spillover effects, they found an immediate effect on the first fixation on the disambiguating word (i.e., the first place where the incorrect parsing could be realized). This latter effect is interesting with respect to the present research because we found very little impact of context on the first fixation on the target area. It appears that with such "garden path" sentences there is an immediate slowdown on the first fixation in addition to a slowdown on subsequent fixations. Whether syntactic analyses are the unique postlexical processes that can influence the first fixation duration on the target remains to be seen (also see Rayner, Carlson, & Frazier, 1983).[4] An intriguing extension of the present research would be to determine whether such syntactic contextual effects interact with the availability of parafoveal information.

Context and the Use of Parafoveal Visual Information

Earlier we presented McClelland and O'Regan's (1981) interactive logogen model as a potential framework to describe how context and parafoveal information interact to influence reading performance. This model predicts that for some sentences neither the contextual constraint nor the available parafoveal visual information may be sufficient to surpass a target word's interactive threshold to influence performance. However, a combination of the two activation sources may be sufficient to reach threshold. This model predicts that subjects should be better able to use the parafoveal information when it is highly predictable from the preceding sentence context than when it is less predictable. The present results provide several pieces of evidence for such interactive effects.

First, subjects were more likely to skip over the target area if it was

[4] It is possible that, within the first fixation, decisions based on contextual analyses lag behind decisions based on syntactic analyses or that these analyses have impacts on different decisions. In fact, Rayner, Carlson, and Frazier (1983) have recently argued for independence of a syntactic and semantic processor. Possibly, together with the Frazier and Rayner first-fixation data, the present first-fixation data may also reflect such a distinction. It also should be noted, however, that the Frazier and Rayner manipulations could be viewed as extreme manipulations of syntactic constraint, and, as noted in footnote 3, one might find effects of extreme manipulations of contextual constraint also on first-fixation data.

identical or visually similar to a highly predictable word than to skip over a less predictable word. Within the interactive model, this finding would suggest that on these occasions, the lexical representation for the predictable target received sufficient parafoveal visual activation to surpass its interactive threshold which in turn sent the eyes past the recognized parafoveal target word. Furthermore, since the high-predictable nonword (e.g., *cahc*) was as likely to be skipped as the high-predictable word (e.g., *cake*), it appears that the visual activation needed to surpass threshold was not very great on these trials.

A second source of evidence for interactive effects was in the gaze duration data. Here we found that subjects spent less time looking at the target word when the preceding parafoveal preview was visually consistent with the highly predictable target. Within the interactive model this finding suggests that the contextual constraint and parafoveal preview information together produced sufficient activation for the predicted target to influence the speed of lexical access. Based on the present study, however, it is not clear why this conjoint impact of the two variables had more of an effect on where to look next (the probability of a second fixation data) rather than on when to terminate the current fixation (the first fixation data).

The present data also suggest that subjects used more visual information from the parafoveal preview when that item was highly predictable from the sentence context. We view this finding as the strongest evidence that predictability affects lexical access rather than only having its effect on postlexical integration processes. This suggests that the activation produced by the high-predictable identical parafoveal preview (e.g., *cake*) was sufficiently greater than the activation produced by its visually similar counterpart (e.g., *cahc*) such that it influenced performance. Previous research (e.g., Rayner et al., 1980) has indicated that in word recognition tasks, letter information about the first two letters in the preview item was the crucial aspect of the parafoveal information. However, in the previous studies there was relatively little contextual constraint. The present results suggest that with high contextual constraint, readers can use a considerable amount of detailed parafoveal visual information.

This analysis suggests that in reading, the interactive threshold may be set rather high so that highly consistent levels of activation are needed from both context and parafoveal information. Such a conservative threshold may be advantageous because, as noted earlier, readers are poor at guessing the next word in a passage based on available context. For instance, although the ambiguous string *cahc* is similar to the constrained target *cake*, the first two letters are also consistent with the words *calf*, *card*, and *cart*, which are less constrained but potential candidates in the context. If the reader was employing a low threshold to activate the lexical representation for *cake* and then actually received *card,* then he or she may be forced to make additional disruptive and capacity-demanding analyses.

In the present experiment, such disruptive effects appeared to occur in both the gaze duration and spillover data when the subject received *cake* in the parafovea and then received the low-predictable target word *pies*. In this situation, even the high threshold, for *cake*, was surpassed by the strong contextual constraint and the identical preview. The data suggest that when the subject attempts to integrate the word *pies* into the text representation there apparently is some competition with the activated lexical representation for *cake*. This competition led to what we have termed a double take effect in which the subject is forced to make another fixation on the word *pies* (possibly to corroborate the original analysis), and is likely to spend more time on the subsequent fixation after the target area (possibly to reach a resolution between the two activated representations), as indicated by the spillover data. Since in normal reading there are no such display changes the reader can usually avoid these disruptive double take effects by setting a relatively high threshold.[5]

There is one final point regarding the interactive effects. The present pattern of data suggests that bottom-up parafoveal information has more impact when the contextual constraint is strong than when it is weak. This interaction between top-down and bottom-up information contrasts with the more common view in which strong contextual constraint reduces the need for detailed bottom-up analyses. This latter view has been supported by a considerable amount of research in visual word recognition (e.g., Becker & Killion, 1977; Meyer, Schvaneveldt, & Ruddy, 1975; Morton, 1969; Tulving & Gold, 1964) and in speech perception (e.g., Cole, 1973; Marslen-Wilson & Welsh, 1978). In the past research, subjects typically have been required to make a response to a degraded stimulus. In

[5] It is important to note here that although there were converging aspects of the gaze and spillover data which indicated a difference in parafoveal processing between the identical and visually similar high-predictable previews both when the subjects received the high-predictable target and when they received the low-predictable target, the present data reflecting the probability of skipping the target area did not yield any difference in processing between these two preview conditions. Since the skipping data only involved 10% of the trials, one must be cautious in making any strong statements regarding this difference in pattern. However, it is possible that there may be different criteria involved in the decision to skip a word. That is, the mere decision to skip a word suggests that the subjects are somehow lowering their criterion and that they feel that there is sufficient information from the context and parafoveal vision to alleviate the need to bring the target into a clear and sharp fixation. With such a lowering of criteria, it is possible that the visually similar preview along with the context produced sufficient activation to surpass this relaxed criterion. Admittedly this is highly speculative, and it is hoped that future research will provide evidence regarding any differences between skipping vs gaze and spillover data.

such situations, context may be especially useful to resolve any perceptual ambiguities. Thus, context (top-down information) plays a greater role with such degradation (decreased bottom-up information). However, the conditions in the present experiment that might be considered degraded, those in which the parafoveal visual information was inconsistent with the target, yielded very little evidence of an impact of constraining context.

The present reading situation contrasts with much of the previous research in that, in the present situation, subjects need not make a response to a degraded stimulus, since in 200 to 250 ms the subject will fixate on a very clear and sharp target word. It appears that unless the context and parafoveal visual information uniquely constrain the item, the subject will not make any strong commitments regarding the identity of the parafoveal stimulus. There is little doubt (as indicated by the present production task norms) that subjects could have guessed that the next word in our example sentence to be *cake* based on relatively ambiguous parafoveal information (*cahc*). However, because of the dynamics of the eye-movement system in reading, the subjects usually waited until their eyes directly fixated the target to identify it. This is not to say that context and parafoveal visual information do not have their separate influences, but rather that their synergistic effects appear to occur when both pieces of information strongly converge on a particular lexical representation, as opposed to one being strong while the second is weak.

CONCLUSIONS

The present results suggest that both context and parafoveal information are used during reading. Furthermore, it appears that contextual constraint can modulate the use of parafoveal information. We have suggested that parafoveal information primarily influences visual analyses, which most likely influence the speed of lexical access. We have also suggested that context affects both the speed of lexical access and the speed of integrating a word into a discourse representation of the prior context. When there are both strong contextual constraints and identical parafoveal visual information, the two types of information combine to produce synergistic or superadditive effects on performance.

We are left with the view that a reader is sensitive to a number of types of information. However, it appears that subjects were not likely to make a strong commitment about ambiguous parafoveal information even when the target words were highly predictable from the sentence context. We feel that this is the case because of the high likelihood (90% in the present study) of fixating a very sharp and clear target word. Thus, the data contradict a view of reading wherein expectations and predictions about forthcoming information are primary and visual information is there merely for confirmation.

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