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AUTHOR	Blanchard, Harry E.
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ABSTRACT

A series of studies investigated the manner in which information is utilized during fixations in continuous reading. Utilization refers to visual information being processed to further the comprehension of the text being read, in contrast to registration, which refers to visual information simply being available to the brain. The studies considered three patterns of utilization during fixation: (1) utilization immediately follows registration, (2) utilization comes from different regions at different times, and (3) utilization occurs at a specific time that can vary. Three experiments were conducted using a paradigm developed by H. E. Blanchard, G. W. McConkie, D. Zola, and G. S. Wolverton. Subjects were college students or graduates recruited through a college newspaper, who read text displayed on a video terminal. Results of the first two experiments showed that the crucial findings from the Blanchard and others paradigm were due to memory or other nonperceptual processes, thus ruling out the possibility that utilization always occurs immediately after new visual information is registered. The third experiment eliminated the possibility that visual information is used letter by letter in a left-to-right scan. The results are consistent with the proposal that utilization occurs at a specific time that varies, sometimes early and sometimes late in the fixation. (Extensive references and tables of data are appended.) (FL)

CENTER FOR THE STUDY OF READING

Technical Report No. 395

THE PATTERN OF UTILIZATION OF VISUAL INFORMATION DURING FIXATIONS IN READING

Harry E. Blanchard
University of Massachusetts

November 1986

University of Illinois
at Urbana-Champaign
51 Gerty Drive
Champaign, Illinois 61820

Bolt Beranek and Newman Inc.
10 Moulton Street
Cambridge, Massachusetts 02238

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The author is now at the University of Massachusetts. Reprint requests should be sent to him at the Department of Psychology, Tobin Hall, University of Massachusetts, Amherst, Massachusetts 01003.

Abstract

This series of experiments investigates the manner in which information is utilized during fixations in continuous reading. Utilization refers to visual informatio being used to further the comprehension of the text being read, in contrast to registration, which refers to visual information simply becoming available to the brain. Three possible patterns of utilization during fixations are considered: (a) utilization immediately follows registration, (b) utilization is from different regions at different times, and (c) utilization occurs at a specific time which can vary. Four experiments were conducted using a paradigm developed by Blanchard, McConkie, Zola, and Wolverton (1984). Experiments 1 and 2 ruled out the possibility that utilization always occurs immediately after new visual information is registered, by ruling out the possibility that the crucial findings from the Blanchard et al. (1984) paradigm are due to memory or other nonperceptual processes. Experiment 3 ruled out the possibility that visual information is utilized letter by letter in a left-to-right scan. The results are consistent with the proposal that utilization occurs at a specific time which varies, sometimes early and sometimes late in the fixation. Possible models for the control of utilization time are discussed.

The Pattern of Utilization of Visual Information During Fixations in Reading

During reading, the eye makes a series of short jumps, called saccades, across the line of text being read. Between each jump, there is a period of relative stability, the fixation, lasting approximately a quarter of a second. The visual information used in reading is acquired during fixations only, and not during saccades (Wolverton, 1979; Wolverton & Zola, 1983). The series of experiments reported here are directed toward answering the question: When during fixations is visual information put to use in furthering the reading process?

It is necessary to make a distinction between what McConkie (1983) called the <u>registration</u> and the <u>utilization</u> of visual information. Registration refers to the time at which the new information that is made available by fixating a new location becomes available to the brain. Utilization refers to the time at which the new visual information modifies the ongoing process of language comprehension. Registration involves neural impulses reaching the visual cortex and probably some early visual form recognition. Utilization involves comprehension processes. Some encoding processes are completed before the time of utilization. Utilization probably commences during some intermediate process, such as letter recognition or lexical access; however, it is not useful at this stage to indicate when utilization commences, as this needs to be determined empirically. When a fixation is made, the new visual information is available to the brain an estimated 60 ms after fixation onset (Russo, 1978). Information can potentially be utilized at any point after this time. The focus here is on when utilization typically occurs during fixations.

Three possible patterns of the time course of utilization are considered. First, utilization could immediately follow registration. It is commonly assumed that the first 50 ms of each fixation is devoted to information acquisition and the remainder to other processing activities (Gough, 1972; Just & Carpenter, 1980; Loftus, 1983; Rayner, Inhoff, Morrison, Slowiaczek, & Bertera, 1981; Smith, 1971). A second possibility is that information is utilized from different text segments at different times. There are many possible patterns of this kind, but the most widely discussed is the left-to-right scan of letters (Andersen & Crosland, 1933; Estes & Taylor, 1964; Geyer, 1968, 1970; Gough, 1972; Heron, 1957; Mewhort, 1984; Mewhort & Campbell, 1981; Mewhort, Merikle, & Bryden, 1969; McConkie, 1979; Neisser, 1967; and Sperling, 1963). The third possibility is that utilization occurs at a specific delimited point in time, as in the first alternative, but is not necessarily linked to the process of registration. That is, the time of utilization could vary, occurring sometimes early and sometimes later in the fixation. Blanchard et al. (1984) suggested that such a pattern occurs, and that the time of utilization is determined by higher level language processes.

Blanchard et al. (1984) examined the process of information utilization during fixations by manipulating the actual visual information available during fixations, through use of the eye movement contingent display control technique (McConkie & Rayner, 1975; McConkie, Zola, Wolverton, & Burns, 1978). Subjects' eye movements were monitored while they read from a cathode ray tube (CRT); the signal from the eyetracker was collected by a computer which determined, on line, whether the subject was fixating or making a saccade. The text on the CRT was changed at prespecified times when the subjects' eyes were in fixation. More specifically, a single letter in the text was changed partway through each fixation. The texts were written such that two words which differed by a single letter (referred to as critical words and critical letters, respectively), e.g., tombs and bombs, would both fit appropriately at a given position in the text, e.g., The underground caverns were meant to house hidden (tombs, bombs), but then the construction was stopped because of lack of funds. On fixations made near the critical word position, the word initially present, e.g., tombs, was changed to the alternative, bombs, at a prespecified time delay. During saccades, the initially presented word was returned. The overall result was that on each fixation in the region of the critical word, one word was present early in the fixation and one word was present later in the fixation. To determine what word(s) they had read, subjects were given a recognition test after reading each text. They were shown a series of four words in succession, which included the two critical words, and were asked to indicate, for each word, whether or not the word was in the text.

A difficulty with this manipulation is that the localized apparent movement associated with such a change attracts attention to the critical word location, away from its normal course in reading. A 30 ms mask consisting of a line of upper case Xs was used to introduce apparent movement at all points in the text. Thus, the complete sequence of changes during fixations near the critical word position was (a) a line containing the first critical word, (b) the mask, and (c) the line containing the second critical word.

The main finding was that only one of the critical words was reported in approximately two-thirds of all the changing-letter texts shown to all subjects. If utilization immediately follows registration, then subjects should have consistently reported the first critical word. However, subjects sometimes reported the first word, sometimes the second word, and sometimes both words (each approximately a third of the time). Thus, the results were inconsistent with the first pattern of utilization.

Further manipulations were conducted in order to test the possibility that different text segments are utilized at different times. The amount of time during the fixation in which the first critical word was present was varied among 50, 80, and 120 ms. There was a clear pattern in single word reports: The longer the first word was present, the more likely it was to be reported and the less likely the second word was to be reported. Another analysis revealed that the same relationship holds between the likelihood of reporting the second word alone and the amount of time the second word was present. Generally speaking, the longer a critical word was present during the fixation, the greater the likelihood that it would be the word that was reported. This will be referred to as the presentation time effect. It is consistent with a left-to-right sequence of utilization (in that, the longer a word is present, the more likely it is that a scan will reach the critical letter when that letter is present on the screen). However, further, more detailed analyses were not consistent with a left-to-right scan.

Blanchard et al. (1984) introduced the variable utilization time hypothesis to explain their results. According to this hypothesis, visual information is utilized at a specific time during the fixation. This time of utilization varies, sometimes being early and sometimes late in the fixation, thus producing the pattern of reporting sometimes the first word and sometimes the second word. (Cases where both words were reported are assumed to be due to incomplete masking of localized movement and errors on the reconition test.) Furthermore, the time at which utilization happens to occur is determined by the current need of ongoing language processing activity. The currently registered visual information is utilized by the concurrent comprehension activities when that information is needed to further advance comprehension.

The variable utilization time hypothesis accounts for the presentation time effect by a probabilistic process: The longer a word is present during the fixation, the more probable it is that the system is ready to utilize the information while that word was displayed. This process is probabilistic only in the sense that the time of utilization is determined by a multiplicity of factors connected with higher-level processing that are not under experimental control and not easily measurable.

The experiments reported here were competitive tests of the three patterns of utilization described above. Experiments 1 and 2 tested the variable utilization hypothesis against a version of the utilization-immediately-follows-registration hypothesis that was not considered by Blanchard et al. (1984). These last two experiments also determined whether the phenomenon of reporting only one of the critical words is due to memory or perceptual processes. Experiment 3 tested the predictions of their variable utilization time hypothesis against those of the left-to-right scan and related hypotheses. In addition, it attempted to determine whether or not the units of utilization are words. All the results were consistent with the variable utilization time hypothesis; however, some other possible hypotheses which are also consistent with the evidence are discussed later.

General Method

Subjects

Subjects were recruited through a campus newspaper advertisement and were paid for their participation. All of the subjects were good readers, as they were either university students or college graduates. Also, all subjects had normal uncorrected vision and were native speakers of English.

Apparatus

The text was displayed one line at a time, in upper and lower case characters, on a Digital Equipment Corporation VT-11 display unit. The refresh cycle of the display unit was approximately 3 ms, and display changes were made without interrupting that cycle. The distance between the subject and the CRT of the display unit was 68 cm, which made one degree of visual angle equivalent to four character positions. The subject was supplied with a button that called up the next line of text onto the CRT. This allowed subjects to read the multiline passages at their own pace, although it was not possible to reread a previous line. Eye movements were monitored with an SRI Dual Purkinje Image Eyetracker (Cornsweet & Crane, 1973). Head movements were minimized by fitting the subject to a headrest and a bitebar. The display unit and eyetracker were interfaced with a Digital Equipment Corporation PDP-1140 computer, which sampled eye position every millisecond and performed the display changes contingent upon eye movements.

Materials

Short texts two to three sentences long were used. Each text had two versions which were different in meaning but were physically different either by only one letter, or, in Experiment 3, by one word. The critical word position at which the two versions differed was always situated at least 16 character positions away from the beginning or end of a line. All critical words were five-letter words.

Design and Procedure

Each experiment had an experimental and a control condition. In both conditions, the text was masked during each fixation made on every line of text. After a certain preselected delay, ranging from 50 to 120 ms depending on the experiment, the text was replaced by the mask for 30 ms. After the mask, the text reappeared for the rest of the fixation. This manipulation divides every fixation into a premask, mask, and postmask period. The duration of the premask period is the <u>mask-onset time</u>.

The mask consisted of two overprinted lines of upper case Xs and Os. Each mask line had an X and an O overprinted at each character position on the line. One of these lines in the mask was at the same level as the text line, the other line was offset so that its lower edge was flush with the position at which descending letters extended. Both lines appeared simultaneously and printed over each other. This mask was developed to mask localized movement associated with the changing of descending letters with the same efficiency as other letters.

In the control condition, the text line present in the premask period was identical to the line present in the postmask period. In the experimental condition, the line present in the postmask period was different from the premask line during each fixation which fell within the immediate region of the critical word. The postmask line was the alternate version of the text, differing from the other version by only one letter or one word, depending on the experiment. During each saccade the line of text changed back to the premask version of the line. This causes the same sequence of text changes to occur for each fixation within the designated immediate region of the critical word. In other words, each fixation initiates a cycle of display changes: premask text, mask, postmask text, followed by a saccade during which the premask text returns. Outside of the immediate region around the critical word, the postmask text was identical to the premask text, just as in the control condition.

This immediate region around the critical word was defined in the following way. The alternate word or letter would be displayed during the postmask period only if (a) at least one fixation was made within 12 character positions of the left edge of the line, (b) the eyes were centered at a position that was within a region extending from 11 character positions to the left of the first letter of the critical to 11 positions to the right of the first letter, and (c) since initially entering this region the eye had not passed beyond the region to the right. Note that the postmask text was identical to the premask text on every fixation made between passing out of this region until the line was changed, even if the eye regressed back into this region.

In each experiment, the assignment of texts to the control or experimental conditions, to the mask-onset condition, and to other conditions was random and counterbalanced across subjects. The presentation order of the two alternate critical words during the fixation was also counterbalanced.

Subjects were informed of the display changes. They were told that, occasionally, a word might change as they were reading it. They were also asked not to purposely look for changing words, but to try and concentrate on reading for comprehension. Subjects first read a block of eight practice texts and then read the main set of texts, which were grouped into blocks of eight, with rests allowed in between the blocks.

After reading each text, four test words appeared individually one after another on the CRT. The subjects were instructed to indicate, for each word, whether or not the word had appeared in the immediately preceding text. They did this by pressing one of two buttons to indicate either yes or no. No feedback was given as to correctness. Two of the four test words were the two critical words. In Experiments 1 and 2, because the critical words differed by one letter, the other two test words were also five-letter words which differed by one letter. In Experiment 3, the critical words differed by every letter, so the other two test words also differed by every letter (although they were not necessarily five-letter words). In each experiment, one of the noncritical test words had been present in the text and the other had not been present. The presentation order of the test words was randomized across texts.

Experiment 1

Experiments 1 and 2 explore the reasons why a single word is sometimes reported. The finding that single words are reported is inconsistent with the hypothesis that utilization always immediately follows registration (Blanchard et al., 1984). However, a less simplistic version of this hypothesis could account for single word reports. Blanchard et al. (1984) assumed that the onset of fixation initiates registration, thus driving utilization. Therefore, the word present early in the fixation would be utilized, and the other visual information presented during the fixation, the mask and the second word, would not be utilized. But, utilization might be driven not by fixation onset but by the presence of newly registered information (whether or not that information comes from fixation onset). Under this assumption, subjects would be expected to report both critical words all the time; therefore, this hypothesis is also inconsistent with the reporting of single words.

This hypothesis can be made consistent with single word reports by invoking an explanation by memory processes: Both words present during a display-change fixation are utilized, but one of the words is more susceptible to forgetting. That is, perceptual processes are assumed to be identical for both-word and single-word reports; single-word reports are caused by forgetting processes which follow perception. (This is also consistent with the presentation time effect, in that the longer a word is presented, the better "consolidated" that word becomes in memory.) Although any hypothesis will allow some single-word reports as due to forgetting, this explanation seeks to account for <u>all</u> single-word reports by memory processes.

Experiment 1 tested the memory process explanation. Subjects indicated when they saw a letter change while they were reading by pressing a button. Subjects should indicate seeing a change when they later report both words. However, according to the memory process explanation, subjects should also frequently indicate seeing a letter change with single-word reports. In fact, a strong interpretation of the memory process explanation requires that indications of seeing a change should occur just as frequently with single-word reports as with both-word reports. If, however, single word reports are due to perceptual processes (as claimed by the variable utilization time hypothesis), then subjects' indications of seeing a letter change should correspond with choosing both words on the recognition test, and when they choose a single word they should not indicate seeing a change.

Method

The 16 subjects used in this experiment had previously participated in an experiment which used some variation of the Blanchard et al. (1984) paradigm. Before they read the main texts, subjects first read three blocks of practice texts, which included single letter switch materials, in order to make certain that they had seen some words change during reading. All subjects indicated that they knew what a letter change looked like.

The texts in this experiment were the same 96 texts used by Blanchard et al. (1984) which contained critical words differing in the first or fourth letter (a complete listing of the texts may be found in Blanchard, McConkie, & Zola, 1982). Subjects were instructed to press a button in their left hand if they saw a word change into another word while they are reading. (A right hand button was used for calling up a new line.) Subjects were not required to press their left button at the same instant they saw the change; they were free to press the button at or after they actually saw the change. These instructions were meant to reduce the demands of the dual task situation and prevent extended fixation durations or regressions in the area of the letter change due to processing demands associated with the button-press (rather than to the letter change itself).

Other than these instructions, the design was identical to Blanchard et al. (1984). Mask-onset time was either 50, 80, or 120 ms; 72 texts were presented in the experimental condition and 24 in the control condition. Within each presentation condition the three mask-onset times occurred equally often. Also, in half of the texts the critical letter was the first letter of the critical word and in half it was the fourth letter.

Results

Responses to test words and indications of seeing a change. Of all the responses made in the experimental condition, 38% were reports of a single critical word and 61% were reports of both critical words, 22% were reports of reading just the first critical word and 16% were reports of the second word. Subjects reported reading a single changing word less frequently by 27% in this experiment than in Blanchard et al. (1984); the difference is probably due to the task, because the texts were identical. Apparently, subjects can identify more instances of word changes when looking for them. In the control condition, 80% of all responses consisted of correctly reporting only the critical word that was presented, indicating that subjects performed accurately on the recognition test.

Figure 1 shows the frequencies of reporting the first, second, or both words for each mask-onset time in the experimental and control conditions. Also presented is the frequency with which subjects pressed the button to indicate they had observed a change on the line they were reading (if a subject pressed the button twice while reading one line, the second press was not counted). Two findings are evident: (a) there is substantial agreement between subjects' indications of seeing a letter change and their responses on the recognition test and (b) the presentation time effect is replicated.

Insert Figure 1 about here.

The presentation time effect was also found with the duration of the second presented critical word. The duration of the second word varies with fixation duration, so, to do this analysis, the fixations on which the critical word was acquired must be identified. As an approximation to this, instances where the critical word received only one fixation were selected for analysis. (McConkie, Zola, Blanchard, and Wolverton (1982) have shown that fixations which are the only ones made on a five-letter word are typically the fixation on which the word is acquired.) There are 299 fixations which fit the requirements for this analysis. Figure 2 shows the relationship between reporting the first, second, and both words and the time the second word was present, grouped into 100 ms intervals. The presentation time effect is evident.

Insert Figure 2 about here.

When subjects indicated seeing a change, they subsequently reported both words 92% of the time, and when they did not indicate seeing a change, they reported a single word 80% of the time. This is inconsistent with the memory process explanation, which claims that subjects actually perceive both words (or at least see a change) even when they report reading only one word on the recognition test. There is a phi correlation (see McNemar, 1969) of .73 between indications of seeing a change and reporting both words.

To evaluate the accuracy with which subjects indicated observing a change, the number of button presses on lines in which no letter change occurred (including lines prior to and following lines containing the critical word) were compared to lines in which a change took place. This treats the experiment as analogous to a psychophysical threshold detection experiment, where the no-change lines are catch trials. The probability of making a hit was .57 and the probability of a false alarm was nearly zero (12 false alarms were made out of 2940 no-change lines). The extremely low false alarm rate indicates that subjects used a very high criterion, suggesting that a subject's ability to detect a change may have been better than the hit rate implies. This would not be surprising, as subjects were instructed not to deliberately look for a change. On the other hand, it may also be incorrect to treat this situation as analogous to a threshold detection situation. The actual extent to which subjects were observing a change but not reporting it can be assessed by an analysis of fixation durations which is reported later.

General effects on fixation durations. Fixations were selected for analysis in four different ways. Before the selection process, fixations were excluded from the data set if they occurred during a disturbance in eye tracking, were longer than 1 ms in duration, were preceded by a regressive saccade, or were rereads (fixations on which the eye had already fixated farther to the right on the current line). The _single-fixation data_ consisted of fixations that were the only fixations made on the critical word. Again, these fixations are most likely to be the fixations during which the critical words are acquired (McConkie et al., 1982). The _first-fixation data_ consisted of fixations that were single fixations and fixations that were the first fixations of one or more on the critical word. The _prior-fixation data_ consisted of fixations that immediately preceded first fixations, and the _following-fixation data_ consisted of fixations that immediately followed first fixations.

Table 1 (top) presents the mean fixation durations for experimental and control conditions. Repeated measures analyses of variance were performed on each data set. Three factors were included: Presentation Condition (experimental versus control), Critical Letter Position, and Mask-Onset Time. To equalize the contribution of each subject, the analyses were performed on means for cells defined by the crossing of each factor with subjects. The main effect of Presentation Condition was significant in the single-fixation data ($F(1,15) = 11.23$, $p = .004$), the first-fixation data ($F(1.15) = 21.60$, $p \sim 0$), and the following-fixation data ($F(1.15) = 18.57$, $p = .001$). No other effects were significant. The results replicate Blanchard et al.

(1984), except that here the effect of Condition on following fixations reached significance.

Insert Table 1 about here.

Effects on fixation durations associated with type of response. Also in Table 1 (bottom) are mean fixation durations in the experimental condition classified by response made on the recognition test (cases where neither critical word was reported were excluded). Multiple comparisons using the Bonferroni _t_ test were done between the control mean and the both- and single-word means from the experimental condition. In the single-, first-, and following-fixation data, the both-word mean was significantly different from the control mean and from the single-word mean, while the control and single-word means were not different. Again, this replicates Blanchard et al. (1984) except for the addition of significant effects in the following-fixation data set. However, note the increases in mean fixation duration, relative to the control condition, when both words are reported in the experimental condition in the single- and first-fixation data. These two increases are greater than the corresponding increases found by Blanchard et al. (1984).

These two discrepancies can both be accounted for by the difference in task demands between the two experiments. In the current experiment, subjects were instructed to press their button when they saw a change, and when they did so they also usually reported both words on the recognition test. Subjects may have pressed their button during the first or following fixations, causing an increase in fixation duration. Or, simply directing greater attention to the critical word when subjects noticed both words may have also increased fixation durations to a greater degree than in Blanchard et al. (1984).

Effects on fixations durations associated with indications of seeing a change. An analysis was done to determine what effects there were on fixation durations when subjects had or had not indicated seeing a change while reading. If subjects had pressed their button on the line containing the critical word, then data from that line were included in the affirmative group, otherwise they were included in the negative group. The mean fixation durations for each group are presented in Table 2, along with the means for the control condition reprinted from Table 1 for comparison. The results of multiple comparisons using the Bonferroni t are also presented.

Insert Table 2 about here.

There is only a 3 ms difference between the experimental and control means when a change was not seen in the first and single fixation data, and a 13 ms difference in the following fixation data. This is substantially less than the difference between the control and single-word experimental condition means in Table 1. This confirms the claim that there are some instances in the single-word data where subjects see a change yet report a single word, and that this subset of data inflates the mean fixation duration relative to a population of "pure" single word instances.

More importantly, these findings bear on the problem of whether or not subjects sometimes observed a change, but, perhaps because of a conservative response criterion, did not press their button. If there were such cases where seeing a change was not reported, then there should be some perceptual disturbance, manifested in increased fixation durations, in the negative button-press group. There was no evidence of such disturbances. Instances where subjects' response biases affected the detection accuracy must be relatively rare. But if this is true, it contradicts the suggestion that subjects were using a very high criterion and hence often not reporting a change during cases where they did observe a change. Perhaps the analogy to a psychophysical threshold detection experiment is incorrect: Affirmative instances may be completely above threshold and negative instances completely below threshold.

Discussion

Subjects' indications of seeing a letter change while they were reading were almost always followed by reports of reading both words on the recognition test. This fails to support the memory process explanation, and is consistent with the claim that perceptual processes associated with single-word reports are different from perceptual processes associated with both-word reports. But, because it is not clear how the demands of this task may have altered eye movement, perceptual, and cognitive processes, another test of the memory process explanation was conducted using another kind of experimental manipulation, in order to provide converging evidence against this explanation.

Experiment 2

Experiment 2 combined the Blanchard et al. (1984) switching letter paradigm with the turn-off-the-text technique used by McConkie and Hogaboam (1985). While subjects were reading, the text was removed from the screen and replaced by a mask. The text was removed during a saccade taking the eyes away from the immediate region of the critical word, so that on the fixation following this saccade there was no text. When their reading was interrupted in this way, subjects were instructed to immediately report the last word or words they saw and whether or not they saw a letter change. The text was removed in 50% of the texts, including texts in the control and experimental conditions.

This technique eliminates non-immediate effects associated with memory processes. If forgetting is the sole cause of single word reports, then subjects should always report seeing both critical words when the text is removed after a word change. If perceptual processes are responsible, then essentially the same pattern of reports should occur in the verbal reports after text removal as occurs with the recognition test procedure (i.e., a combination of single- and both-word reports).

Method

Sixteen subjects participated in this experiment. All subjects had previously participated in Experiment 3 and in a pilot version of Experiment 1.

The texts were similar to those used in the Blanchard et al. (1984) experiment, except that the five-letter critical word pairs differed in either the second or third letter positions. There was a total of 80 texts (listed in Blanchard et al., 1982). Half of the control and half of the experimental texts were in the text removal condition. Two mask-onset times were used, 50 and 100 ms.

In both the experimental and control conditions, removal of the text was performed during the first saccade, which brought the eyes further than 11 character positions to the right of the critical letter. At the point at which the eye reaches its peak velocity during a saccade, it is possible to predict the locations of the following fixations within one or two character positions (McConkie, Wolverton, & Zola, 1984). If, after having fixated to the left of the critical word, a saccade was identified which would bring the eyes 11 or more character positions to the right of the critical letter, then the text was immediately replaced with the mask. Taking into account the typical point of maximum saccade velocity and the amount of time it takes to perform a display change, there was sufficient time for text removal to occur before the termination of the saccade.

Subjects were informed that the text would be removed from the screen while they were reading some of the texts. They were also informed that some words might change while they were reading. When the text was removed they were asked to report the last two or three words they remembered reading and to report any display changes they might have observed (although they were not prompted with the critical words). On cases where the text was removed, subjects did not read the rest of the text following the line on which the removal occurred, and they were not given the recognition test. Subjects then went on to read the next text. In cases where the text was not removed, subjects read the entire text and were given the recognition test, just as in Blanchard et al.'s (1984) procedure.

Results

Responses to test words. Overall responses (combining text removal and non-removal groups together) showed a pattern quite similar to that of Blanchard et al. (1984). Of all responses, 45% were single-word responses and 45% were both-word responses, and 20% were reports of reading only the first word and 25% were reports of only the second word. The percentage of single-word reports is still lower than the 65% found by Blanchard et al. (1984), but this could be due to the current subjects' experience with the switching letter manipulation. In the control condition, subjects gave accurate reports (reporting "yes" to only the critical word present) 76% of the time.

The data were then divided into verbal report and recognition test groups: Verbal report refers to the responses subjects gave when the text was removed, and recognition test refers to the usual procedure when the text was not removed. The results were very similar for these two conditions. For verbal reports, 45% were single-word reports (18% first word and 27% second word) and 41% were both-word reports. For the recognition test, 46% were single-word reports (23% first word and 23% second word) and 51% were both-word reports. In the verbal reports, 15% of the responses consisted of a miscellaneous category which were reports unique to this test procedure: 5% were reports which included a word similar to one or both critical words, 3% were reports from cases where the subject had not reached or had read beyond the critical word position, and 7% were cases where the subject could not recall any words at all. In the control conditions, subjects' accuracy was better in the verbal report procedure: 79% of the verbal reports and 72% of the recognition test reports included only the critical word that was presented. In sum, subjects showed the same pattern of responding, including reporting single words with the same frequency, whether they gave a verbal report immediately after a change occurred or were tested with the recognition procedure.

The presentation time effect is also the same, regardless of the testing procedure. Figure 3 shows the frequencies of reporting the first, second, or both words for each cell defined by crossing all levels of Presentation Condition, Mask-Onset Time, and Text Removal Condition (i.e., turn-off-the-text versus recognition test). There is very little difference between the frequencies as a function of Text Removal Condition.

Insert Figure 3 about here.

This was tested statistically using the method of loglinear models (Everitt, 1977; Fienberg, 1981). The loglinear model is a description of the relationships between the factors (dimensions) of a table. The model contains effects representing interactions between the factors. Models containing various factors can be compared. The most parsimonious model which provides an adequate fit to the data is chosen (Brown, 1976). Here, the response data were analyzed as a four-dimensional frequency table, where the dimensions were Mask-Onset Time, Critical Letter Position (second versus third letter), Text Removal, and Response (first word, second word, or both words). The result was that the model containing only the effect representing Mask-Onset Time by Response interaction provided a good fit ($X^2(18, \underline{N} = 16) = 15.28$, $\underline{p} = .64$). The conclusion is that the differences in observed frequencies can be accounted for without taking into account the Critical Letter Position or Text Removal dimensions. The effect of Mask-Onset Time on Response is the same whether immediate verbal report or the recognition test is used.

The presentation time effect can again also be shown using the duration of the second word. Single fixations on the critical word were selected, there were 242 acceptable fixations, second word durations were calculated and grouped into 100 ms intervals (Figure 4).

Insert Figure 4 about here.

Effects on fixation durations. Fixations were again classified into four data sets, as described previously. Table 3 (top) presents the mean fixations durations in the experimental and control conditions collapsed across both text removal conditions. Repeated measures analyses of variance were done, using cell means, with three factors: Presentation Condition, Text Removal, and Mask-Onset Time. The main effect of Presentation Condition was significant in the single-fixation data ($F(1,15) = 12.22$, $p = .003$), the first-fixation data ($F(1.15) = 13.86$, $p = .002$), and the following-fixation data ($F(1,15) = 11.96$, $p = .004$). This pattern of effects is comparable to Blanchard et al.'s (1984) findings, except for the significant effect on following-fixations. The main effect of Text Removal was significant in the following-fixation data, ($F(1,15) = 17.08$, $p = .001$). The reason for this effect is that following fixations were often located far enough to the right to have been made after the text was removed.

Insert Table 3 about here.

<u>Effects on fixations durations associated with type of response</u>. Fixations durations are presented in Table 3 (bottom) with fixations in the experimental condition classified according to the type of response made, i.e., one or both critical words reported (data for other types of responses, as found in the verbal reports, are not included). Multiple comparisons with the Bonferroni t shows that the pattern of significant effects for single and first fixations matches that of Experiment 1 and Blanchard et al. (1984). The both-word mean is significantly inflated relative to the mean for the control condition by 67 ms for the first fixations and 99 ms for single fixations. The

single word mean is not significantly different from the control mean, although there is a 20 and 21 ms inflation in the first- and single-fixation data, respectively. These inflations in single-word means are due to the influence of extreme values, as the differences disappear when medians are compared (medians are less sensitive to extreme values). For the first-fixation data, the control median is 248 ms and the single-word experimental condition median is 256 ms; the difference is not significant by a median test (Siegel, 1956), $X^2 = 0.89$, $p = .35$. For the single-fixation data, the control median is 255 ms and the single-word experimental median is 257 ms; the difference is not significant by a median test, $X^2 = 0.04$, $p = .85$.

Discussion

Two alternate ways of testing subjects for what critical words they read were compared in this experiment. The results showed substantial correspondence between the pattern of reports in the recognition test, which allowed memory process to have an effect, and the immediate verbal reports, which allows minimal time for nonperceptual processes. This suggests that perceptual processes are responsible for the pattern of reports observed in this experiment, and in the previous experiments as well. If the memory process explanation were correct, there should have been no single-word reports, or at least a reduction in them, in the immediate verbal reports. This did not occur. Along with the results of Experiment 1, these results provide evidence against the explanation by memory processes. This allows rejection of the hypothesis that utilization always immediately follows registration of any new visual input.

Experiment 3

Experiment 3 tested the assumption that words are the relevant textual segments which are utilized. The same procedure as Blanchard et al. (1984) was used, except that an entire word was switched during a fixation instead of just a single letter. If utilization occurs on word units, the same results should be found when every letter of the critical word is different after the mask as when only a single letter is different. If, on the other hand, letters are the units which are utilized, then changing every letter of a word should cause qualitatively different results than changing a single letter. When one letter is changed, the left-to-right scan may be "fooled" into utilizing information as if no change had taken place, because the sequence of letters perceived would still be an appropriate word. When a whole word is changed, however, scanning letters from left to right would cause a non-word sequence of letters to be utilized. In this case, the entire information acquisition process should be disrupted differently than in the single letter switch.

Because they assume different units of utilization, this experiment competitively tested the variable utilization time and left-to-right scan hypotheses. The variable utilization time hypothesis predicts that one word will be utilized and reported on the recognition test, just as in the Blanchard et al. (1984) single letter switch experiment. Also, just as in that experiment, there should be some subset of cases where both critical words are reported. However, switching more than one letter also creates more letter positions where localized movement may be noticed. It is possible, then, that the mask may fail to mask the movement on more occasions than in the single letter switch experiment. Therefore, there may be more instances of subjects reading both critical words and there may be more perceptual disruption (as observed in fixation durations), but the same basic pattern as observed in Blanchard et al. (1984) should be evident.

On the other hand, the left-to-right scan hypothesis predicts markedly different results between the word switch and single letter switch techniques. The only possible way a single word could be utilized is when the scan passes completely over the critical word before any change takes place or after all changes have occurred. Consequently, instances of reading a single word should be infrequent and should only be reported when the scan starts very near or very far from the critical word. Therefore, single words should be reported only when the location of fixations on which the critical words are acquired are maximally distant from the critical word position. Secondly, this hypothesis implies that subjects should sometimes perceive a non-word, because letters from one word may be scanned with letters from the alternate critical word. Because of possible top-down effects on perception, subjects may not become aware of non-words, but it is not clear whether a single critical word or both words will be consciously perceived. However, it seems reasonable to expect that perceptual disruption should be much greater, overall, in this experiment than in the single letter switch, due to processing time needed to reject the perceptual input and form a new percept.

Method

Nineteen subjects participated in this experiment, none of whom had ever previously participated in an eye movement contingent display change experiment. The display changes were essentially the same as in Blanchard et al. (1984), except that every letter of the critical word was different following the mask. Ninety-six pairs of five-letter words were chosen such that (a) each member of a pair had a different letter at each letter position and (b) the overall outline shape of the two words was the same, e.g., melon and cakes. The words appeared in one to three sentence texts, e.g., Sandy spent a long time preparing the (melon, cakes) for dessert and completely forgot about the hors d'oeuvres. (A complete listing of texts may be found in Blanchard, 1985, 1986.) Three mask-onset times were used: 50, 80, and 120 ms.

Results

Responses to test words. Of all the responses made in the experimental condition, 33% were reports of a single critical word: 17% were reports of the first presented word and 16% of only the second word. Another 66% were reports of both words. Subjects, then, did report reading only one word sometimes, but half as often as did subjects in the Blanchard et al. (1984) single letter switch experiment. In the control condition, 87%

of the responses consisted of correctly reporting only the word present on the CRT.

Insert Figure 5 about here.

The data were then examined for evidence of the same presentation time effect found in the single letter switch experiments. Figure 5 shows the frequencies of reporting the first, second, or both words for each mask-onset time in the experimental and control conditions. The frequencies for the three mask-onset times in the experimental condition were significantly different ($X^2(4, \underline{N} = 19) = 39.76$, $\underline{p} \sim 0$). The likelihood of reporting the first word increased when that word was present for 120 ms and the likelihood of reporting the second word decreased as the first word was present for a longer period of time. The pattern is less clear than that found by Blanchard et al. (1984), probably because of the smaller number of instances of single word reports. The presentation time effect can also be found for the duration of the second word. Single fixations on the critical words were selected, yielding 229 fixations. Figure 6, using 100 ms intervals, shows the presentation time effect for the duration of the second word: The longer the second word is present, the greater the tendency to report the second word and the less the tendency to report the first word.

Insert Figure 6 about here.

In general, there seems to be the same pattern of responses in the word switch as there is in the single letter switch, except for an increase in subjects' awareness of the changing word. The reporting of single words is consistent with the variable utilization time hypothesis. However, some single word reports would be expected under a left-to-right scan hypothesis, from instances where the word change occurred before or after scanning of the letters in the word was completed. These instances would occur when the scan begins maximally close to or distant from the critical word position. Therefore, the pattern of responses should vary systematically with the location of the fixation, with both critical words being reported more frequently as the location is closer to the critical word. Figure 7 shows the percentage of single and both word reports associated with all first pass fixations preceded and followed by forward saccades in intervals of two character positions. The probability of reporting both critical words does not vary as a function of fixation location. This is not consistent with the left-to-right scan hypothesis.

Insert Figure 7 about here.

Effects on fixation durations. Fixation durations were examined in order to assess the perceptual disturbance caused by the changing word. Fixations were segregated into four data sets exactly as described in Experiment 1: single, first, prior, and following fixations. Table 4 presents mean fixation durations in these four data sets. A repeated measures analysis of ·riance was performed on each data set, using cell means, with Presentation Condition (experimental versus control) and Mask-Onset Time as factors. Presentation Condition was significant for the first fixation data, $\underline{F}(1,18) = 37.45$, $\underline{p} \sim 0$, the single fixation data, $\underline{F}(1,18) = 30.84$, $\underline{p} \sim 0$, and the following fixation data, $\underline{F}(1,18) = 21.21$, $\underline{p} \sim 0$. In each case there was an increase in the experimental condition. No other effects were significant.

Insert Table 4 about here.

Fixation durations were also analyzed with data in the experimental condition classified according to the type of response, single or both words reported, made to the corresponding test items. For each data set, multiple comparisons using the Bonferroni $\underline{t}$ statistic were performed. As in the Blanchard et al. (1984) experiment, greater disruption occurred in those cases where two words were reported than those in which a single word was reported.

Although the pattern of effects in this word switch experiment was similar to Blanchard et al.'s (1984) letter switch experiment, there was a greater disruption in fixation durations. In both experiments, the inflation in the experimental condition was more pronounced when both words were reported during the recognition test, but, unlike the single letter switch experiment, there was also a significant inflation when a single word was reported.

The increase in mean fixation duration associated with single word reports could be due to a general inflation in the fixation duration of each and every case, or it could be due to a large increase in a few cases (cf. McConkie, Zola, & Wolverton, 1985). This distinction can be interpreted as important to the left-to-right scan hypothesis. Scanning may input a non-word sequence of letters in this experiment, causing extra processing to reinterpret the input as a sensible word. Most cases of reporting one word should therefore reflect this extra processing time. On the other hand, it is expected that in a few cases subjects actually observed both critical words but reported only one due to errors or forgetting. These few cases would resemble the both-word observations, thus increasing the mean fixation duration.

One way to distinguish the frequency and size of effects is to examine median fixation durations. The median is less sensitive to extreme values than the mean, so that if the inflation in mean fixation duration is due to extreme values, the medians will show a different pattern than the means. For the first fixation data, the single word median fixation duration was 255 ms and the control median duration was 246 ms; a median test identifies this as not significant, $X^2 = 0.92$, $p = .32$. For the single fixation data, the single word median was 270 ms and the control median was 256 ms, which is not a significant difference, $X^2 = 1.13$, $p = .29$. It is likely that the single word mean in this word switch experiment is increased due to a subset of long fixations rather than a general increase in every fixation.

<u>Discussion</u>

Experiment 3 resulted in a pattern of responses similar to the Blanchard et al. (1984) single letter switch experiment: Sometimes subjects reported reading only one of the presented words and sometimes they reported both. However, the word change is much more detectable than the letter change, resulting in twice as many both-word reports, and the change appeared to be much more disruptive to processing, as reflected in fixation durations. This can be accounted for by the greater discrepancy between the premask and postmask texts. Having five letters change allows a proportionately greater opportunity for the change to create apparent movement which failed to be eliminated by the mask.

The results are not consistent with the left-to-right scan hypothesis. First, single word reports were not associated with the eye having fixated at extreme distances from the critical word, as predicted by the left-to-right scan hypothesis. Second, even though there was much greater disruption in the word switch when compared to the single letter switch experiment, the increase still appears to be better explained as a result of processing after two critical words have been perceived, rather than as extra processing during perception, which would have been more consistent with the left-to-right scan hypothesis.

The other aim of this experiment was to determine what are the units of utilization. The rejection of the left-to-right letter scan implies that words are indeed the units of utilization. However, there is some counterevidence to the word unit hypothesis. If the units of utilization are segments of words (some units other than letters or whole words) then changing a whole word may produce a perceptual disturbance, a disturbance greater than that caused by changing a single letter. This is the case: The increase in mean fixation duration due to changing a word is greater than the increase due to changing a letter. Of course, this could also be explained in other ways, such as disturbances from processes during registration (i.e., before utilization), as explained above. Thus, the evidence for words as the units of utilization is equivocal.

General Discussion

The three experiments presented here rule out two of the possible patterns of utilization: the left-to-right scan hypothesis and the hypothesis that utilization always immediately follows the registration of new visual information. The results of Experiment 3 and a variety of other studies (Blanchard, 1985; Blanchard et al., 1984; McConkie, Underwood, Zola, & Wolverton, 1985; and Rayner, 1983) rule out the sequential acquisition of letters from left to right during fixations in reading. While letters may sometimes be acquired sequentially in the context of tachistoscopic presentations, the left-to-right scan is not a normal component of early visual processing in continuous reading. However, the evidence from this experiment only pertains to scans which proceed at a rate at least as slow as the 10-15 ms per letter proposed by Sperling (1963). The predictions tested do not hold for very fast scans. On the other hand, a very fast scan becomes difficult to distinguish from utilization at a delimited point in time as proposed in the variable utilization time hypothesis. If all the information to be utilized on a fixation is scanned very quickly, and the scan is completed in a time shorter than the fixation duration, then this approximates the utilization of visual information at a delimited point in time during a fixation.

One of the fundamental findings from this paradigm, that subjects sometimes report only one of the critical words present, indicates that utilization is registered in the brain. Experiments 1 and 2 replicated this fundamental finding and ruled out the possibility that this finding could be due to nonperceptual processes, viz. forgetting. An important implication of this is that visual information can be registered but not utilized. In other words, information can be processed to some level in the system and no further. Obviously, any word displayed on the CRT activates the retina and stimulates the visual cortex. However, the information associated with the unreported critical word remains unconscious (although note that this does not necessarily imply that there is any unconscious recognition of the meaning of the unreported word). It is not known to what level the unreported word is processed, that is, to what level of encoding registration automatically drives the visual input. The unreported word may stay in raw visual form, it may be represented as an array of visual features or letters, or lexical access may take place. This is a question for future investigation.

The general conclusion from this series of studies is that there is a specific, delimited time of utilization, which does not necessarily occur at the beginning of a fixation, or necessarily after new visual information is registered during a fixation. The results are consistent with Blanchard et al.'s (1984) variable utilization time hypothesis, but there are other possible explanations as well. Here, two will also be discussed: the gradual process hypothesis and the variable registration time hypothesis.

<u>Variable Utilization Time</u>

Visual information is utilized at a specific time during the fixation. This time varies, sometimes early and sometimes late in the fixation, and is determined by factors other than the presence of that information. The operation of a variable utilization time can be thought of in terms of a production system model (cf. Just & Carpenter, 1980; Newell, 1973). The result of perceiving a word is to place the representation of that word into a working memory. The working memory is accessible to productions which respond to a combination of word and other information to build knowledge structures.

There is one production which will be the first to use the word representation. At some point in time, the enabling conditions for this production will be fulfilled. Only at this point does the presence of the word have an effect on further processing; thus, this is what is referred to as the time of utilization. This time occurs when not only the word is present but also when the other conditions required for that production are fulfilled. Although the time of utilization is constrained by the time at which visual information becomes available through registration processes, it is nevertheless primarily determined by when the other enabling conditions for the production occur, i.e., by higher level cognitive processes. The word that is present in working memory at the time of utilization is the one which is perceived.

The Gradual Process Hypothesis

The gradual process referred to here is an alternative explanation for the presentation time effect. The gradual process is any process by which the length of time a word is present determines the "strength" of the visual encoding of that word. This can be discussed in terms of Morton's (1969) logogen model. As more information is accumulated, the activation level of the logogen rises until it reaches a threshold level, at which time the word is identified. This point is assumed to correspond to the time of utilization of the word. The longer a word is present during a fixation the more activation its logogen receives, and hence, the more likely it is that the logogen will reach its activation threshold and that word identification will consequently take place. The word which is utilized is determined by a kind of competition between the two words: The word which will reach threshold first through a combination of sensory activation and contextual facilitation will be the one which is utilized. This implies that the time of utilization occurs sometime after the input of information from both words in this experimental paradigm. Therefore, in the course of natural reading as well, the time of utilization would be set to take place at the end of each fixation (or even sometime after, during the saccade).

An explanation similar to the gradual process hypothesis treats a fixation as analogous to a tachistoscopic exposure and the mask during the fixation as a backward mask for the first presented word and a forward mask for the second presented word. The magnitude of a masking effect decreases with increasing exposure duration of the non-mask stimulus (Breitmeyer, 1984; Breitmeyer & Ganz, 1976; Kahneman, 1968). This finding can be used to explain the presentation time effect: The longer the first or second word is present during the fixation, the smaller the magnitude of the masking effect on that word, and so the more likely that word is to be reported. This is just a more general form of the gradual process explanation: The gradual process assumption is a beginning attempt to explain why the mask has an effect.

Variable Registration Time

This explanation combines an activation-based system with a variable time of utilization. Similar to the previous explanation, the point in time at which a logogen reaches a threshold level of activation is assumed to correspond to the time of utilization. However, the time of utilization does not occur rigidly at the end of a fixation, rather, the attainment of threshold sometimes occurs early and sometimes later in the fixation. In this way, the time of utilization is variable; however, it is the intrinsic variability of the time course of the registration processes which is responsible for the variable time of utilization. Such variability in registration may result from top down influences on the activation process (as in McClelland & Rumelhart, 1981). Variable registration time is the cause of variable utilization time here; utilization always immediately follows registration and yet still is variable.

Conclusion

In the three explanations above, it is the general principles, and not the specific assumptions, which are important for this discussion. The variable utilization time assumption could be expressed in terms of the activation of logogens or the gradual process hypothesis in terms of a production system. Also, these explanations do not have to be mutually exclusive. For example, pattern masking effects and a variable utilization time could be jointly responsible for the pattern of effects seen in experiments such as those reported here. Or, the time course of registration could be variable, as in the third hypothesis, but at the same time, utilization might also vary as a function of higher level processes, as in the first hypothesis. Using further variations of the Blanchard et al. (1984) paradigm, it is possible to further discriminate among these hypothesis about the pattern of utilization (see Blanchard, 1985, 1986).

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Table 1

Summary Statistics for Fixation Durations in Experiment 1

Condition Response	Prior fixation	First fixation	Following fixation	Single fixation
Control				
M	233	266 a	246 a	277 a
SD	77	86	82	72
N	279	319	252	177
Experimental				
M	234	312	288	336
SD	71	151	141	174
N	824	940	702	310
Single word				
M	230	268 b	260 b	278 b
SD	72	119	117	122
N	281	327	263	169
Both words				
M	238	338 ab	306 ab	421 ab
SD	71	162	150	201
N	498	563	399	122

Note. Fixation durations are in milliseconds. Means in a column that have a letter in common are significantly different ($p < .01$). The second panel was not included in this multiple comparison.

Table 2

Mean Fixation Durations in the Experimental Condition of Experiment 1 Classified by Whether Subjects Indicated Seeing a Change

Condition Response	Prior fixation	First fixation	Following fixation	Single fixation
Control				
M	233	266 a	246 a	277 a
SD	77	86	82	72
N	279	319	252	177
Experimental				
Negative				
M	228	269 b	259 b	280 b
SD	71	124	115	120
N	331	384	317	210
Affirmative				
M	237	341 ab	312 ab	455 ab
SD	71	161	155	206
N	493	556	386	100

Note. Fixation durations are in milliseconds. Means in a column that have a letter in common are significantly different ($p < .01$).

Table 3

Summary Statistics for Fixation Durations in Experiment 2

Condition Response	Prior fixation	First fixation	Following fixation	Single fixation
Control				
M	236	256 a	295 a	265 a
SD	70	87	189	75
N	444	506	414	319
Experimental				
M	237	304	347	320
SD	71	145	216	148
N	421	509	412	242
Single				
M	241	276 b	355 b	286 b
SD	78	121	236	120
N	178	220	176	134
Both words				
M	231	323 ab	331 ab	364 ab
SD	66	158	187	170
N	206	247	200	82

Note. Fixation durations are in milliseconds. Means in a column that have a letter in common are significantly different ($p < .01$). The second panel was not included in this multiple comparison.

Table 4

Summary Statistics for Fixation Durations in Experiment 3

Condition Response	Prior fixation	First fixation	Following fixation	Single fixation
Control				
M	231	254 ab	240 a	267 ab
SD	83	85	88	82
N	664	707	565	425
Experimental				
M	238	355	295	390
SD	109	186	149	198
N	667	746	547	229
Single				
M	239	310 ac	264 b	314 ac
SD	99	166	125	155
N	428	212	156	90
Both words				
M	237	373 bc	312 ab	444 bc
SD	99	191	160	208
N	428	480	352	123

Note. Fixation durations are in milliseconds. Means in a column that have a letter in common are significantly different ($p < .01$). The second panel was not included in this multiple comparison.

Figure Captions

Figure 1. Frequency of reporting the first, second, or both of the critical words in the 50, 80, and 120 ms mask-onset times of the experimental and control conditions of Experiment 1. Frequencies are given for all responses and also for only those responses which, prior to the response, subjects had pressed their left hand button during reading to indicate they had seen a letter change.

Figure 2. Probability of reporting the first, second, or both of the critical words at test for 100 ms intervals of the duration of the second word during fixations which were the only fixations on the critical words in the experimental condition of Experiment 1.

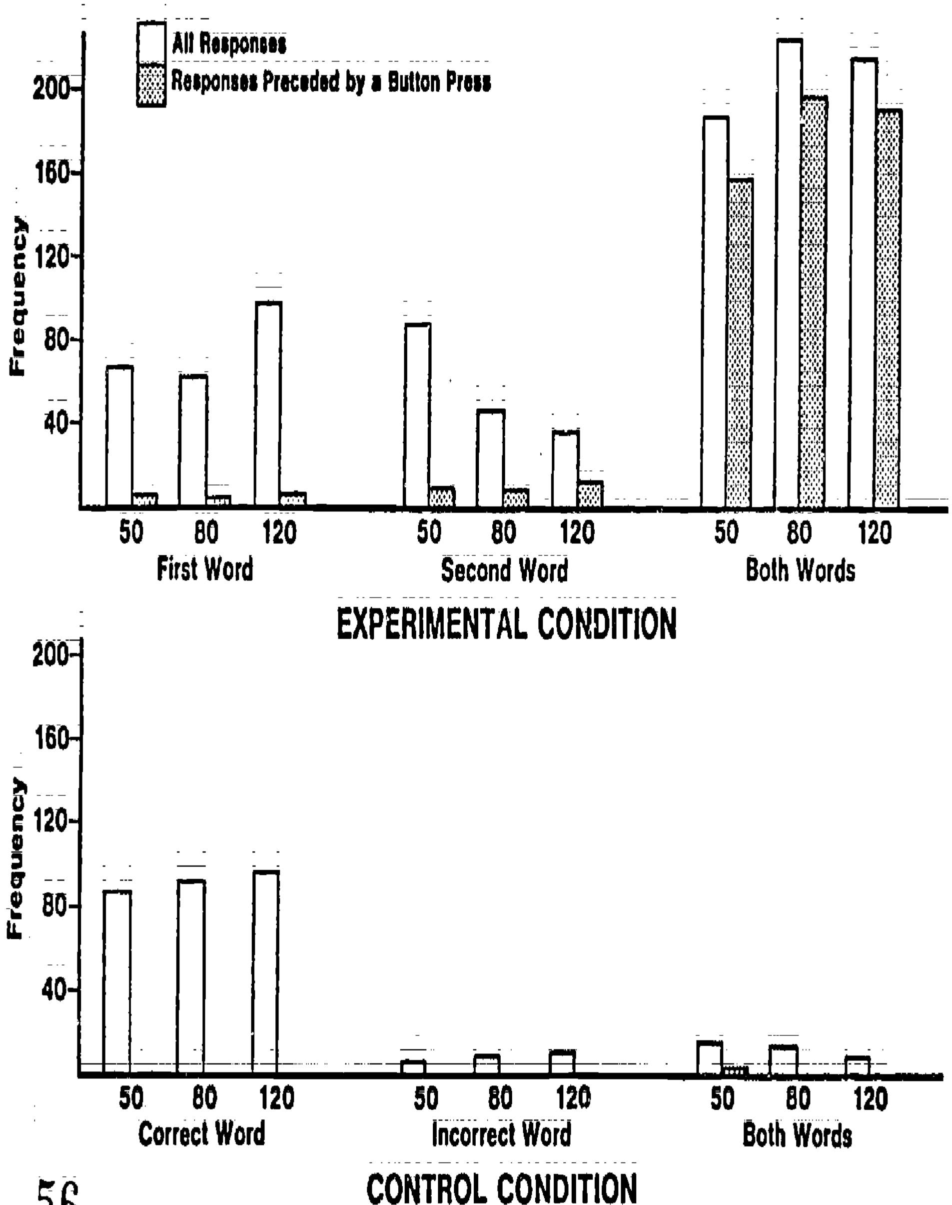
Figure 3. Frequency of reporting the first, second, or both of the critical words at test in the 50 and 100 ms mask-onset times of the experimental and control conditions of Experiment 2. Frequencies are given separately for the responses in the recognition test and turn-off-the-text conditions.

Figure 4. Probability of reporting the first, second, or both of the critical words at test for 100 ms intervals of the duration of the second word during fixations on the critical word in the experimental condition of Experiment 2. Numbers underneath the bars refer to midpoints of the 100 ms intervals.

Figure 5. Frequency of reporting the first, second, or both of the critical words at test in the 50, 80, and 120 ms mask-onset times of the experimental and control conditions of Experiment 3.

Figure 6. Probability of reporting the first, second, or both of the critical words at test for 100 ms intervals of the duration of the second word in the experimental condition of Experiment 3. Numbers underneath the bars refer to midpoints of the 100 ms intervals.

Figure 7. Percentage of reports of one or both of the critical words given after fixations centered at several different locations in Experiment 3. Fixations location values indicate the number of character positions away from the first letter of the critical words, where negative values are to the left of the first letter of the critical word.



All Responses
Responses Preceded by a Button Press
Frequency
200
160
120
80
40
50
80
120
First Word
Second Word
Both Words
EXPERIMENTAL CONDITION
Correct Word
Incorrect Word
Both Words
CONTROL CONDITION

Figure 1

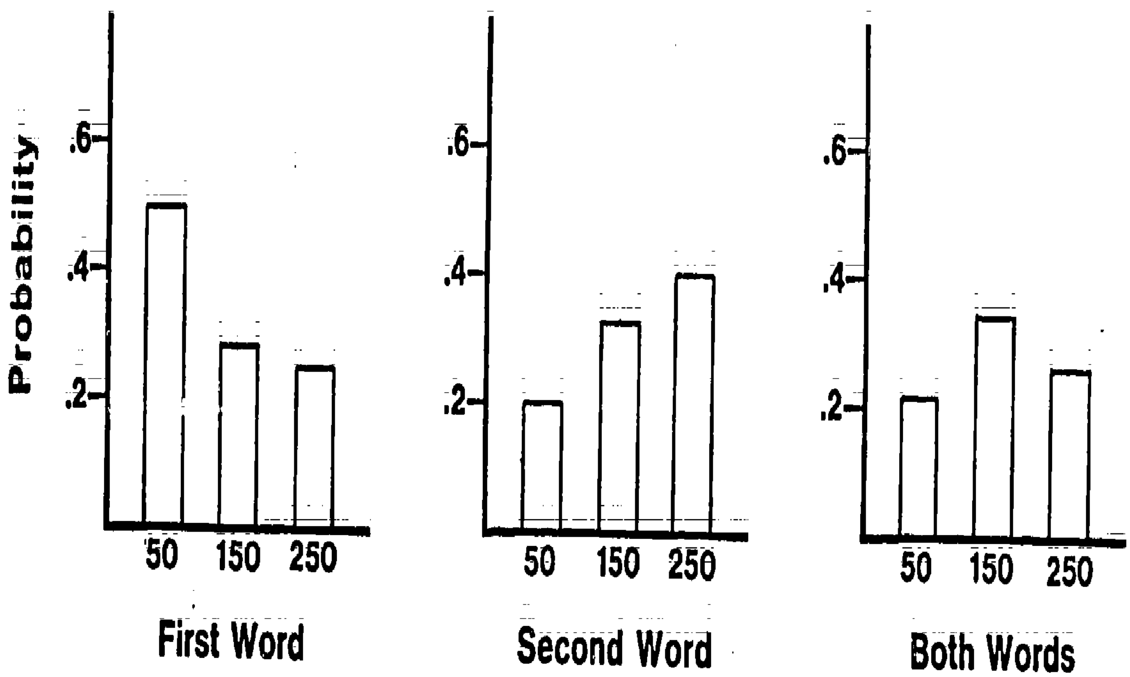
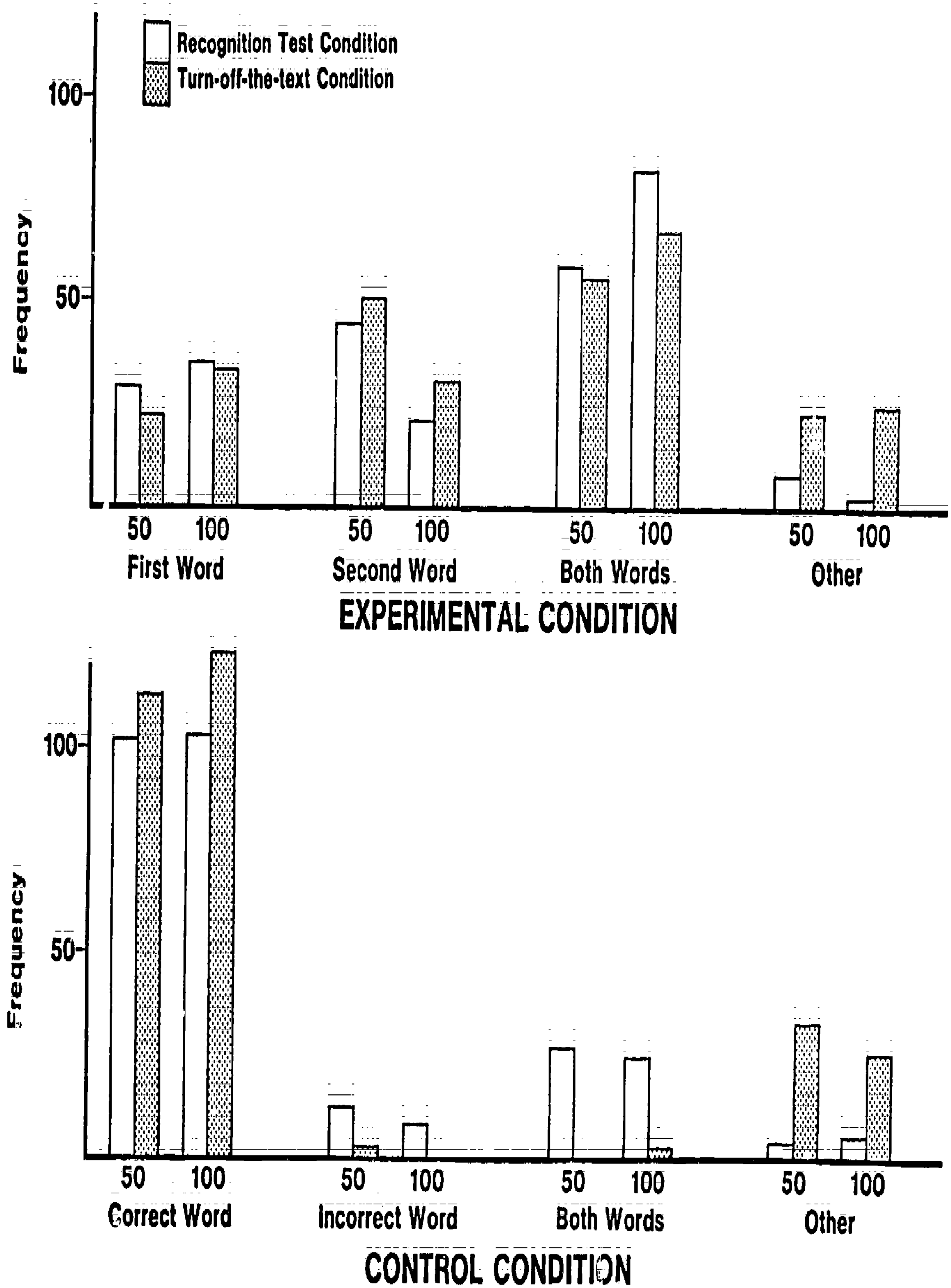

Probability
.6
.4
.2
50 150 250
First Word
.6
.4
.2
50 150 250
Second Word
.6
.4
.2
50 150 250
Both Words

Figure 2

Figure 3



Recognition Test Condition
Turn-off-the-text Condition
Frequency
100
50
50 100
First Word
50 100
Second Word
50 100
Both Words
50 100
Other
EXPERIMENTAL CONDITION
Frequency
100
50
50 100
Correct Word
50 100
Incorrect Word
50 100
Both Words
50 100
Other
CONTROL CONDITION

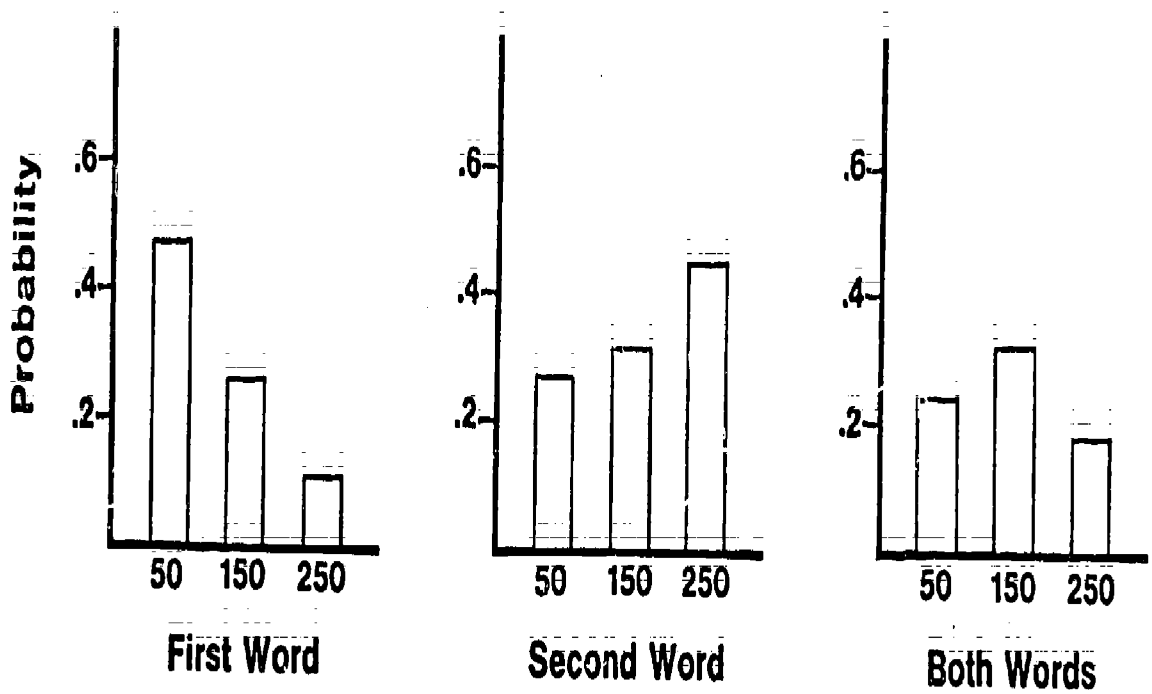

Probability
.6
.4
.2
50
150
250
First Word
Second Word
Both Words

Figure 4

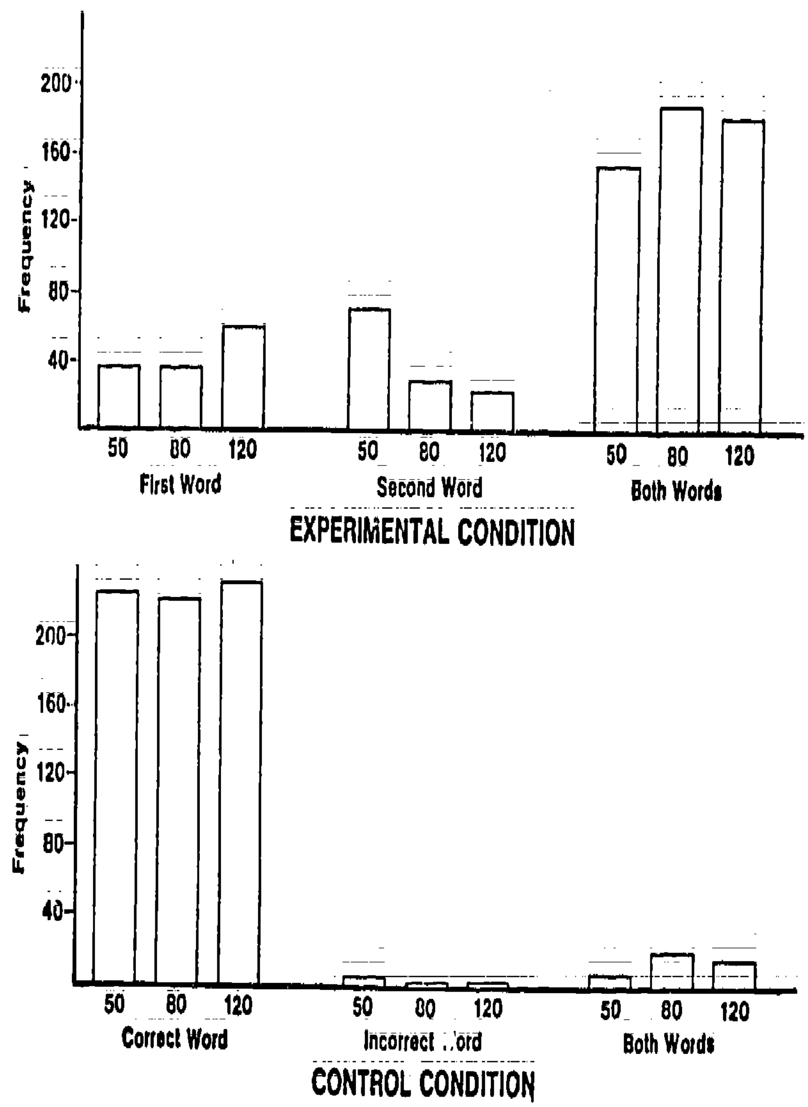
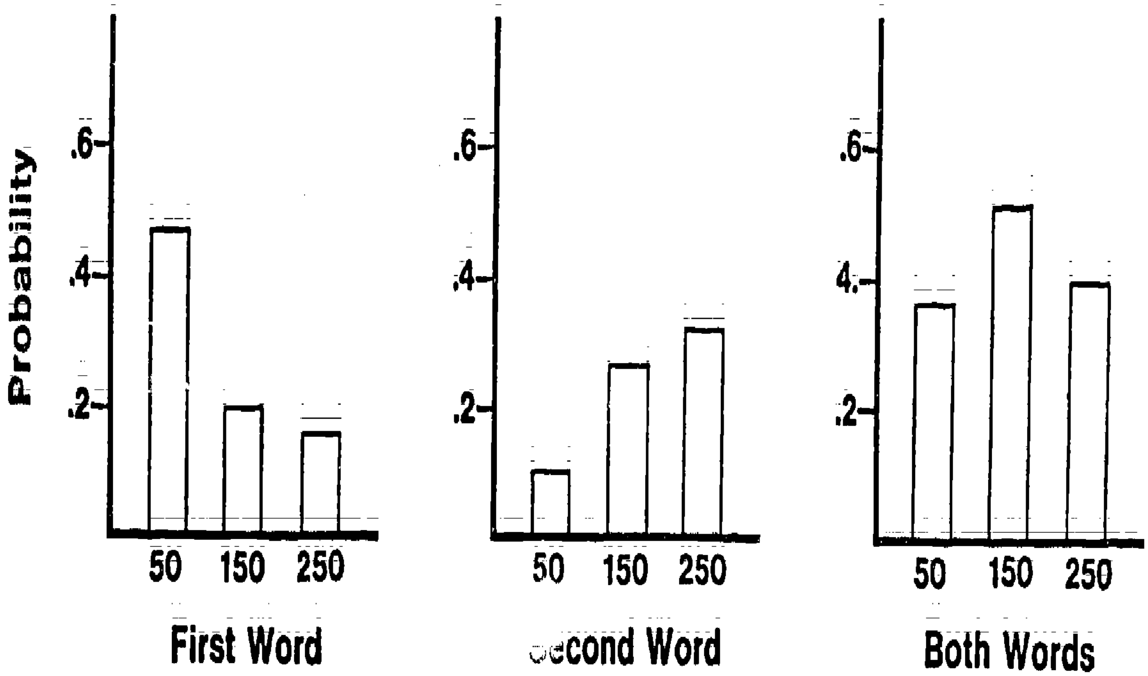

200
160
120
80
40
Frequency
50
80
120
First Word
50
80
120
Second Word
50
80
120
Both Words
EXPERIMENTAL CONDITION
200
160
120
80
40
Frequency
50
80
120
Correct Word
50
80
120
Both Words
CONTROL CONDITION

Figure 5

Figure 6



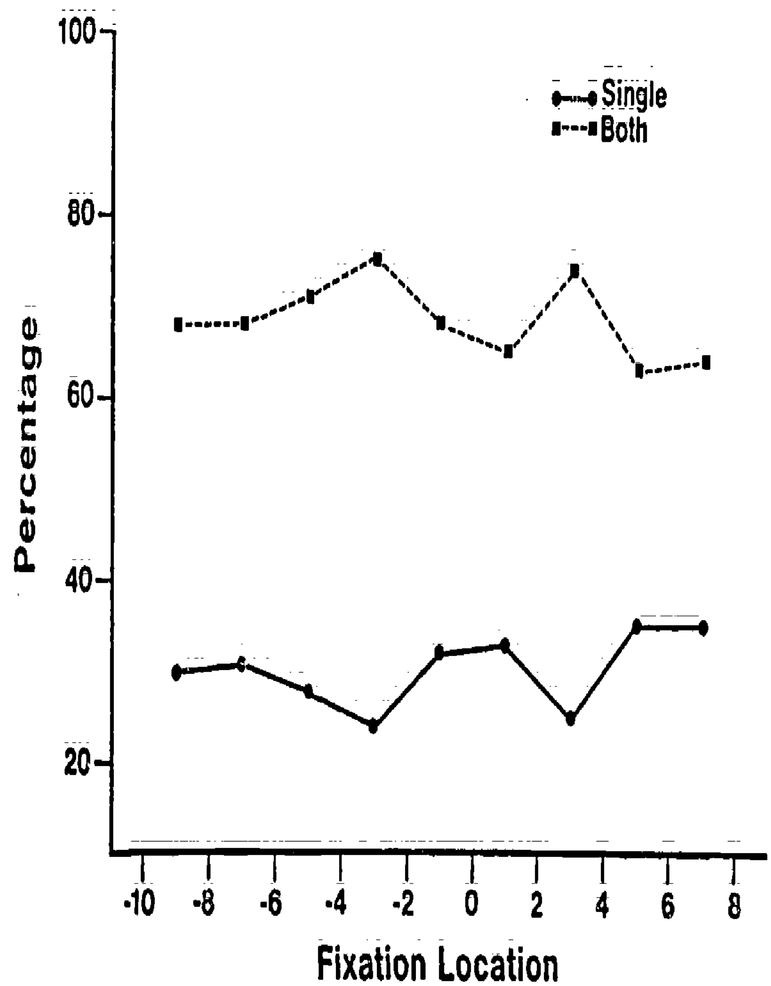

Single
Both
100
80
60
40
20
Percentage
-10
-8
-6
-4
-2
0
2
4
6
8
Fixation Location

Figure 7