Reading and visual search*

DENNIS F. FISHER†

University of Rochester, Rochester, New York 14627

Four experiments were conducted comparing the ways in which reading and search are affected by manipulations of word shape and word boundary. Word shape was manipulated by variations in type (normal, capitals, and alternating upper- and lowercase), while word boundary was manipulated by variations in spacing (normal, filled, and absent). The variations were combined factorially for nine space-type combinations. Experiments I and II were basic studies examining the effects of the manipulations on reading and on search, respectively. Search was found to be 2 to 2.5 times faster than reading. Reading and search both slowed to one-third of the normal speeds when spaces were removed and type altered. A significant interaction of Type by Space was found for reading but not for search. Experiments III and IV examined contextual and typographical effects on high-speed visual search through paragraphs. Form-class expectancy and target word predictability, respectively, were manipulated. In both experiments, subjects found the expected predictable words faster than the unexpected unpredictable words. The data were interpreted as providing support for the peripheral and cognitive search guidance processes hypothesized to be active in reading.

The purposes of this series of studies are to examine the effects of certain visual perceptual cues, namely, word boundary, word shape, and their interactions, on reading and visual speed search; to ascertain the degree of contextual awareness taking place during search by manipulating target expectancy and predictability; and to evaluate the contributions of peripheral and foveal processing during reading and search.

Hochberg and his associates (Note 1) manipulated word boundary cues by filling the spaces between words with *x*s and *&*s. In the filled space condition, they found that oral reading efficiency decreased. They interpreted the data as showing that the visual periphery picks up cues about word boundaries and that disrupting these cues by filling the spaces forces the reader to return to a more elementary (letter-by-letter or word-by-word) reading technique. In addition, Levin and Jones (Note 2) found a substantial reduction in the eyevoice span when spaces between words were filled. McConkie (Note 3) and McConkie and Rayner (Note 4) found that reading speed decreased and saccadic eye movements were more restricted in angular extent when the spaces between words were filled. In short, the findings indicate the importance of interword spaces; perturbing them

drastically reduces the ability of the visual periphery to detect word boundary information, leading to slower, less efficient reading.

Smith (1969) and Smith, Lott, and Cronnell (1969) examined word shape effects on reading and searching through paragraphs. They found that reading speed and multiple target search efficiency decreased significantly when text was typed in alternating large and small letters, irrespective of case, compared to normally typed text. Word shape, then, appears to be another important cue used during reading and search. It should be noted, however, that filling the interword spaces may reduce legibility because of factors other than word boundary cue disruption (e.g., masking of the initial and terminal letters) (cf. Woodworth, 1938, p. 720); however, the relative contributions of these various possible sources of interference remain to be determined.

Experiments I and II are methodological studies designed to extend the findings of the filled space studies and the studies by Smith and his associates by examining word shape, word boundary, and their interaction effects on reading and search speed. Contextual effects are of interest in Experiments III and IV, where target definition and subject's expectancy about target features are manipulated to examine their effects on search time.

EXPERIMENT I

Changing word shape and spacing between words have been shown to be reasonable manipulations for distinguishing the visual perceptual cues used in reading. Of particular interest is the possibility that these cues are interdependent. It is predicted that disrupting word shape (e.g., alternating upper- and lowercase letters) and eliminating spaces between words will slow reading speed significantly. Moreover, in those conditions where these two cues are combined, reading speed is expected to decrease even more.

*This paper is based on a dissertation submitted to the Department of Psychology, University of Rochester, in partial fulfillment of the requirements for the PhD. It was supported in part by National Institute of Mental Health Grant No. MH 07140, National Institute of Education Grant No. NE-G-00-3-0090, and U.S. Army Human Engineering Laboratory Contract No. DAAD-05-71-C-0407, all awarded to Ralph Norman Haber, Department of Psychology and Center for Visual Science, University of Rochester. This paper may be reproduced in full or in part for any purpose of the United States Government.

†The author is especially indebted to Ralph Norman Haber, who chaired his dissertation committee and provided valuable assistance throughout. Appreciation is also expressed to Irene Athey, Julian Hochberg, Richard A. Monty, and Clinton Walker for their valuable comments on earlier versions of the manuscript. Requests for reprints may be sent to Dennis F. Fisher, now at the Behavioral Research Directorate, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland 21005.

Method

Subjects. Eighty-one undergraduate introductory psychology students from the University of Rochester participated as part of a course requirement.

Materials. Nine paragraphs from the 1960 revised Nelson-Denny Reading Test⁵ were used as textual materials. This reading test was chosen because it had a very high degree of standardization from high school through college aged adults. The test has two forms, A and B. Paragraphs 3, 4, 6, and 7 were taken from Form A and Paragraphs 2, 3, 4, 6, and 7 from Form B. All paragraphs had 200 words.

Three spacing variations were chosen: *normal*—typical typewritten text, or a space between words equivalent to one letter width; *filled*—spaces replaced by either +s or @s which correspond closely to the size of lower and uppercase letters, respectively; *absent*—no spaces at all. Three type variations were also chosen: *normal*—upper- and lowercase letters as they would normally be used; *capital*—entirely uppercase; *alternating*—upper- and lowercase letters alternating throughout. These type and space variations are shown in Table 1. The type used was IBM Selectric Artisan 12 (Ball 053). A factorial combination of the three space and three type conditions produced nine space-type combinations. The nine conditions were combined with the nine paragraphs, giving 81 combinations. Booklets were prepared with the nine different paragraphs and a different space-type combination matched to each paragraph. Each paragraph and space-type combination occurred in each of the nine positions in the booklets an equal number of times. After each paragraph, a set of four multiple-choice questions was presented which had to be answered. The questions were taken from the Nelson-Denny Reading Test. A digital clock graduated in 1-sec steps provided a large visual display of the time to read and was clearly visible to all subjects.

Procedure. Each subject was given a test booklet of nine paragraphs and answer sheets. He was informed that the paragraphs were in different orders for different subjects and that he should work independently and as rapidly and accurately as possible. When subjects finished reading, they were to look at the time at the front of the room and write down the first number they saw. They were then to turn the page, answer the questions, and wait for instructions to go on to the next paragraph.

Results and Discussion

Analyses of variance (Bulter, Kamlet, & Monty, 1969), with paragraphs as a between effect and spacing (normal, filled, and absent) and type (normal, capital, and alternating) as within effects, were run on both the comprehension scores and reading rate data.

Comprehension Scores. Comprehension was emphasized both as an inducement to subject to read the paragraphs and as a control for paragraph difficulty. The mean number correct out of a possible 4.0 in the standardization of the Nelson-Denny Reading Test for Grades 9-16 and special adult was 2.89. During the reading test, the overall mean was 2.98 out of 4.0. There was no difference in the number of correct responses over the nine different paragraphs ($F = 1.0$), suggesting they were equally difficult in content. A difference between type variations was found [$F(2,144) = 3.61$, $p < .05$], with means of 3.08, 2.99, and 2.86 for normal, capital, and alternating type, respectively. Spacing as a main effect and other interactions concerning comprehension scores failed to reach

Table 1
Space and Type Combinations

1	The government of Henry the Seventh, of his son, and of his grandchildren was, on the whole, more arbitrary than that of the Plantagenets. Personal character may
4	The+government+of+Henry+the+Seventh,+of+his+son,+and+++of+his+grandchildren+was,+on+the+whole,+more+arbitrary++than+that+of+the+Plantagenets.+Personal+character+may++
7	Thegovernmentofhenrytheseventh,ofhisson,andofhisgrandchildrenwas,onthewhole,morearbitrarythanthatofthePlantagenets.Personalcharactermayinsomedegree
2	THE GOVERNMENT OF HENRY THE SEVENTH, OF HIS SON, AND OF HIS GRANDCHILDREN WAS, ON THE WHOLE, MORE ARBITRARY THAN THAT OF THE PLANTAGENETS. PERSONAL CHARACTER MAY
5	THE@GOVERNMENT@OF@HENRY@THE@SEVENTH,@OF@HIS@SON,@AND@@@OF@HIS@GRANDCHILDREN@WAS,@ON@THE@WHOLE,@MORE@ARBITRARY@@THAN@THAT@OF@THE@PLANTAGENETS.@PERSONAL@CHARACTER@MAY@@
8	THEGOVERNMENTOFHENRYTHESEVENTH,OFHISSON,ANDOFHISGRANDCHILDRENWAS,ONTHEWHOLE,MOREARBITRARYTHANTHATOFTHEPLANTAGENETS.PERSONALCHARACTERMAYINSOMEDEGREE
3	THE GoVeRnMeNt oF HeNrY THE SeVeNth, oF HiS SoN, aNd Of hIs gRaNdChILdReN wAs, On the wHoLe, MoRe aRbItRaRy ThAn tHaT Of the pLaNtAgEnEtS. PeRsOnAl cHaRaCtEr mAy
6	ThE@GoVeRnMeNt@oF@HeNrY@ThE@SeVeNth,@oF@HiS@SoN,@aNd@@@Of@hIs@gRaNdChILdReN@wAs,@On@the@wHoLe,@MoRe@aRbItRaRy@@ThAn@tHaT@oF@tHe@pLaNtAgEnEtS.@PeRsOnAl@cHaRaCtEr@mAy@@
9	ThEgOvErNmEnToFhEnRyThEsEvEnTh,oFhIsSoN,aNdOfhIsGrAnDChILdReNwAs,onThewHoLe,MoReArBiTrArYtHaNtHaToFtHePlAnTaGeNeTs.pErSoNaLcHaRaCtErMaYiNsOmEdEgReE

significance at the .05 level of confidence.

Reading Rate. The rate at which the paragraphs were read is of particular interest. Differences between the means for the main effect of spacing variation were highly significant [$F(2,160) = 792.3$, $p < .0001$], as were the differences between the means for main effect type variations [$F(2,160) = 396.7$, $p < .0001$]. The interaction of Spacing by Type Variation also proved significant [$F(4,320) = 61.20$, $p < .001$], and the data are shown in Figure 1. The numbers on the symbols refer to the stimulus designations in Table 1. The data confirm the predictions that reading rate decreases when word shape and boundaries are perturbed. In addition, the data extend the previous findings by showing a significant interaction of Type by Space Cues. Conditions 4-9 show increasingly greater reductions in reading speed as the text becomes more perturbed by eliminating more cues. This interdependence of cues causes a reduction in reading speed to nearly one-third of the speed of the separate (Conditions 1-3) cue manipulations.

It seems quite clear from the data that the conclusion

drawn by Smith (1969) regarding the importance of feature discriminability to word identification and the conclusion drawn by Coltheart and Freeman (1974) regarding the contribution multiletter visual features (total configuration) to word identification are inadequate descriptions of reading on at least two points. First, attempting to explain reading as a "static" word identification process does not explain the effect of the cues being examined or how meaning is being acquired. Second, the interdependence of word shape and word boundary cues tends to implicate higher order visual perceptual processing than might be required simply for word identification. Recent data collected by Spragins (1974) by eye movement recording indicate that recognition span or the number of character spaces per fixation for adults in conditions similar to Condition 1 of the present experiment is 5.63 spaces, whereas for Condition 9 the space is reduced to only 1.7 spaces. In the normal reading situation, multiple character units are processed within each fixation, whereas in highly perturbed conditions this process is nearly a letter-by-letter analysis. Whether or not the same typographical manipulations are interdependent in high-speed visual search is the primary concern of Experiment II.

EXPERIMENT II

Although tachistoscopic recognition tasks such as that of Coltheart and Freeman (1974) are often used to describe reading processes, they represent a static and relatively impoverished situation. Likewise, list search as described by Neisser (1967) represents an adequate examination of physical features, but notably lacks a contextual component and leads to a reliance on less familiar vertically displaced saccadic eye movements. Paragraph search tasks, e.g., Smith, Lott, and Cronnell (1969), are rarely described in the literature, but they do not seem to suffer many of these disadvantages and, therefore, show great promise as a means of studying reading and search processes. The manipulations of word shape and boundaries were found to interact and substantially reduce reading speed in Experiment I. Smith, Lott, and Cronnell found that the reduction in search efficiency closely resembled the reduction in reading speed performance found by Smith (1969). There is, then, the possibility that the same visual perceptual processes active in reading are active in visual search. If these processes are the same or similar, then the space-type manipulations that disrupted reading speed should similarly disrupt search speed. In addition, it is expected that space-type manipulations are interdependent, leading to increasingly greater reductions in search times as the cues are successively eliminated.

Figure 1. Reading rate in milliseconds per word and words per minute for the nine space-type variations.

Method

Subjects. Thirty-six undergraduate introductory psychology students from the University of Rochester participated as part of a course requirement.

Materials. Each paragraph was the same as described in Experiment I, except that each line was now numbered in the right and left margins. The subjects were seated approximately 2.75 m from the projection screen. The paragraphs were approximately 12 to 13 deg wide and long. An average five-letter word subtended 1.2 deg. Lower- and uppercase letters subtended .25 and .38 deg, respectively. The sizes correspond quite favorably to normal reading conditions, where the subject is about 40 cm from the text. Normally, the paragraphs are approximately 15 deg wide and long. An average five-letter word subtends 1.4 deg. Lower- and uppercase letters subtend .28 and .43 deg, respectively.

Nine sequences of paragraphs given in Experiment I were used. Paragraphs and space-type variations occurred equally often over the nine trials. Each of the nine paragraphs was divided into 20 10-word sequences. A target word was chosen from each 10-word sequence, except the first and the last, to assure an even distribution of targets within the paragraph. A target word appeared only once in the paragraph and once as a target across paragraphs. Of the 162 target words chosen, 44 had fewer than six letters and 58 had more than seven letters. Six- and seven-letter words were equally represented. The words ranged in frequency and familiarity and were exclusively nouns, verbs, adjectives, and adverbs. No targets were proper nouns, pronouns, conjunctions, interjections, or short verbs, e.g., *is*. For data reduction purposes, times taken to find the target were combined for every two 10-word sequences. That is, times to find target words in Sequences 2 and 3 were averaged and now termed "Location 1." Similarly, Sequences 4 and 5 were

Table 2
Mean Search Time in Milliseconds Per Word

Spacing	Type		
Normal	135	Normal	177
Filled	247	Capitals	188
Absent	230	Alternating	247

averaged and now termed "Location 2" and so on throughout the paragraphs, for a total of nine locations.

Procedure. Four subjects were run simultaneously. Each subject was given a response button that stopped one of four electronic stopwatches. A sheet of nine targets (one for each paragraph) was given to each subject. Each subject received a different target list. Stimulus paragraphs were presented in a dimly lit room by means of opaque projection onto a white screen. On each trial, E lifted the shutter on the projector and simultaneously started all of the clocks. As soon as the subjects found the target word, they were to push the response button and write the number of the line in which the word appeared on the response sheet. If the target was not found the first time through the paragraph, subjects were instructed to go through the paragraph again until it was found. The response measure for the search experiments was milliseconds per word taken to find the target. This procedure was followed in each of the search experiments.

If the subject failed to find the target by the time he reached the end of the paragraph, the trial was scored as an error. He was told to go through the paragraph until he found the target or until a 180-sec criterion time had been exceeded. If the subject took two passes to find the target on three or more of the nine paragraphs, the entire paragraph-target sequence was rerun with another subject. Two-pass data were scored by dividing total time by total number of words searched.

Results and Discussion

The search time data were collapsed across subjects and an analysis of variance was performed on the data in milliseconds per word, with one between effect (target location) and two within effects (spacing and typing). The main effects of spacing and type were found to be highly significant [$F(2,54) = 40.09$ and $F(2,54) = 14.44$, respectively, both beyond the .001 level of confidence]. The data for the main effects are shown in Table 2. Unlike Experiment I, the interaction of Spacing by Type did not prove to be statistically significant [$F(4,108) = 2.03$, $p < .10$]. No interactions of space or type with target location reached the .05 confidence level. The fastest search times occurred when spacing was normal, as was the case in reading. In search it apparently does not matter whether word boundaries are destroyed by filled characters or by deleting the spaces—both are equally deleterious; the space absent condition was found to be read significantly slower than the space filled condition. Increases in search speed progressed across type and spacing manipulations as they had during reading.

Of 324 trials, 47, or 14.5%, required two passes (errors). In general, errors tended to be randomly distributed, as analysis of the errors by condition and locus failed to reveal any significant trends or differences in errors for space or type.

In summary, the average time taken per word to search all paragraphs and space-type variations was 205 msec. If subjects were reading, this would give an average of 295 words/min, considerably faster than the average of 120 words/min found in Experiment I. It appears that reading and search processes are sensitive to and slowed down by the same typographical manipulations. That is, with only slight deviations, rate changes were consistent over manipulations; however, during search a significant interaction, indicating interdependence between space and type, was not found. Search is two to three times faster than reading. In addition, Spragins (1974) recently showed that in Condition 1 recognition span was 10.13 character spaces, while in Condition 9 the span was 3.9 character spaces. This means that during search larger units are available during each fixation than during reading and even at the slowest search speeds the searcher may be examining more than one word during each fixation. Both speed and recognition span decrease as a function of task (search vs. reading) and typography.

The following two experiments examine the effects of contextual and typographical manipulations on visual search.

EXPERIMENT III

In reading a text, the reader must pick up substantive information or meaning. It is very likely that a sensitivity to grammar aids the reader in selecting high-information words and phrases as he progresses through the paragraph. It is not at all clear whether this is also true for search.

Roydes and Osgood (1972) examined the effects of form-class expectancy in a tachistoscopic recognition task. They hypothesized that, if subjects are given a set to a form class (e.g., nouns or verbs), threshold would be lower for the set compatible words than for the incongruent words. Their data showed no difference in recognition based on form class, but they did find that recognition thresholds increased for unexpected words. Another way of examining the effects of expectancy is by asking the subject to search for a word in a paragraph that he expects to be used in its correct form class. An example of an unexpected target is *conduct*, defined to the subject as *to lead*, which appears in that usage in the paragraph. An example of unexpected form class is *conduct*, defined to the subject as *to lead*, but used in the paragraph as *conduct*, as in *deportment*. Differences in search time for expected and unexpected target words cannot be attributed to physical featural differences because the same letters define the target in each case. Differences must be attributed to contextual effects stemming from inappropriate form-class expectancy. It is predicted that expected targets will be found more rapidly and more accurately than unexpected targets.

Assuming that search proceeds word by word in the

Table 3
Stimuli Used in Experiment III

Para-graph	Stimulus Phrase	Form Class	Frequency [†] (Percent)	Msec/Word	Use in Paragraph
1	a royal <i>subject</i>	N*	10	146	rights of the <i>subject</i>
	to <i>subject</i> oneself	V	9	186	
2	<i>state</i> of affairs	N*	16	152	certain <i>state</i> of things
	to <i>state</i> a point	V	8	191	
3	to <i>conduct</i> the orchestra	V*	N.A.	168	must <i>conduct</i> the administration
	his <i>conduct</i> was poor	N	N.A.	195	
4	scientific <i>progress</i>	N*	6	184	his initial <i>progress</i>
	to <i>progress</i>	V	7	182	
5	to <i>sink</i>	V*	58	170	tropical countries <i>sink</i>
	kitchen <i>sink</i>	N	N.A.	167	
6	to be <i>present</i>	V*	5	314	pottery is <i>present</i>
	Christmas <i>present</i>	N	2	251	
7	parade <i>ground</i>	N*	2	172	familiar with the <i>ground</i>
	he <i>ground</i> his teeth	V	1.5	185	
8	to <i>spring</i> forth	V*	15	157	ready to <i>spring</i> upon them
	bed <i>spring</i>	N	7	191	

*Expected: as used in the paragraph

[†]From West (1964): percentages of total word use

slow search conditions, as indicated by the search rate data and eye movement data (Spragins, 1974), the physical features of the target words are most likely to be subjects' primary cues for locating the target, whereas form-class expectancy should affect target identification. If this is the case, few or no search time differences should distinguish expected and unexpected targets in the word-by-word or slow search conditions, e.g., Variations 6 and 9 (see Table 1). Large differences in search times should distinguish expected and unexpected targets in the rapid search conditions, where large units of letters, words, or phrases are examined during each fixation, increasing the likelihood of unexpected targets being overlooked.

Method

Subjects. Thirty-six undergraduates from the University of Rochester served as paid volunteers.

Materials. Eight of the original nine paragraphs were used. Each of the nine space-type variations was used in the experiment. In four of the paragraphs, a noun in context was the target. In the other four, a verb in context was the target. All targets could be used as noun and verb. Each target was defined to the subject embedded in a phrase. The targets, the defining phrase, and the actual phrase in the paragraph are shown in Table 3. Frequency of usage estimates were taken from West (1964) whenever possible.

Procedure. The procedure was the same as that described in Experiment II.

Results

The search time data in milliseconds per word were subjected to an analysis of variance with one between effect (paragraphs) and three within effects (type, spacing, and expectancy).

It can be noted from Table 3 that Paragraph 6 yields search times quite discrepant from the other seven paragraphs. The analysis including Paragraph 6 showed a

highly significant main effect of paragraphs [$F(7,8) = 15.086$, $p < .001$]. This main effect was eliminated ($F < 1.0$) when Paragraph 6 was excluded from the analysis. The reason for the discrepant search times is not known; therefore, the data from Paragraph 6 will be excluded from all subsequent comparisons. The main effects of type and spacing were highly significant [$F(2,14) = 45.2$ and 90.0 , respectively, $ps < .001$]. The interaction of Type by Spacing was also found to be significant [$F(4,28) = 7.15$, $p < .01$], and again no difference was found between the filled and absent space conditions across type ($F < 1.0$).

As predicted, target expectancy affected search time [$F(6,7) = 9.3$, $p < .025$]. The search times for expected and unexpected targets were 164 and 186 msec/word, respectively. Thus, the sensitivity to grammatical features during search seems confirmed. Whether a word was a verb or a noun did not affect search time ($t < 1.0$), with mean search times per word of 175 and 174 msec for verbs and nouns, respectively. Neither the interaction of Space by Target Expectancy [$F(2,14) = 1.6$] nor the interaction of Type by Target Expectancy ($F < 1.0$) proved statistically significant. This leads to a rejection of the hypothesis that physical feature comparisons are predominant in slow search conditions. In fact, the absolute differences between the expected and unexpected targets for rapid and slow search conditions provide at least some support for an alternate hypothesis. That is, context probably becomes more important as speed decreases. Additional experimentation is needed to confirm this latter possibility.

There were 47 errors, or 14%, of the total possible. The errors again appeared to be equally distributed across conditions. Analyses of the error distribution failed to reveal any significant trends or relationships.

In short, expected targets were found faster than unexpected targets. The spatial manipulations of the text did not affect detection of expected or unexpected targets. The data not only provide evidence for the presence of contextual awareness during search, they also provide an indication of the possible locus of the effect. That is, manipulating cues relevant to the periphery does not affect the detection of expected or unexpected targets. On the other hand, these data and those of Roydes and Osgood (1973) are in harmony. Their task, tachistoscopic recognition, relied solely on the foveal identification of words. It could then be argued that threshold and search times are lower for set-compatible expected targets because of foveal identification processes. Experiment IV further examines the possibilities of functional differences between peripheral and foveal processing depending upon how the targets are defined.

EXPERIMENT IV

The targets in Experiment III looked exactly the same whether expected or unexpected. Having targets look the same eliminates distinguishing physical features. Therefore, it appears that the faster search of expected over unexpected targets is largely due to contextual effects rather than simply to physical feature sensitivity. Experiment IV is a further examination of typographical manipulations and context, namely, target predictability. The targets will be *different* words placed in identical locations in the paragraphs. Hypotheses similar to those examined in Experiment III will be examined here. That is, predictable targets are expected to be found more rapidly than unpredictable targets and space-type variations will slow search speed.

In addition, the results of Experiment III were interpreted as indicating that typographical manipulations did not affect search times for expected and unexpected targets. Similarly, if contextual and typographical factors do not interact, few or no differences should arise between search times for predictable and unpredictable targets in the fast and slow search conditions.

Method

Subjects. Twenty-four undergraduates from the University of Rochester served as paid volunteers.

Materials. Only Paragraphs 1, 2, and 3 were used in this experiment. From each paragraph, four target words were chosen. Each paragraph had two versions, each version having two semantically predictable and two unpredictable target words. All target words had either four or five letters. Unpredictable alternatives were words that were targets in one of the six other paragraphs not used in this experiment that matched the predictable words in length but not shape. Stimuli and their use in the paragraphs are shown in Table 4. Subjects saw each paragraph three times and each looked for a *different* target in a *different* location in a *different* typography.

Procedure. The procedure was the same as that described in Experiment II.

Table 4
Stimuli Used in Experiment IV

	Predicted Target	Unpredicted Target	Use in Paragraph
Paragraph 1	whole	ensue	on the whole
	palace	afford	their palace was guarded
	point	later	beyond a certain point
	common	corpse	were common to all
Paragraph 2	spirit	raised	influence on the spirit
	grown	fatal	those who have grown up
	order	think	part of the order
	denied	speedy	warmly denied by some
Paragraph 3	place	light	resolve to place the king
	sacred	thrown	most sacred principles
	prison	enable	opposition into prison
	legal	prize	show of legal right

Results

An analysis of variance was run on search time in milliseconds per word, with trials (exposures of the same paragraph), type, spacing, and target predictability as within effects. There was no significant improvement in search time over the three exposures to the same paragraph ($F < 1.0$), with means of 163, 154, and 161 msec. The main effects of type and spacing were again found to be highly significant [$F(2,22) = 4.08$, $p < .05$ and $F(2,22) = 17.98$, $p < .001$, respectively]. The means for these main effects are shown in Table 5. The interaction of Space by Type failed to reach statistical significance ($F < 1.0$).

The main effect of target predictability was found to be significant [$F(1,11) = 13.1$, $p < .005$], with means of 152 and 170 for predictable and unpredictable words, respectively. Neither the interaction of Type by Predictability [$F(2,22) = 1.7$] nor the interaction of Space by Predictability ($F < 1.0$) proved significant. In both interactions, larger absolute differences between predictable and unpredictable target search times occurred in the slow search condition. If the differences had proved significant, their direction would tend to favor a contextual rather than a physical feature hypothesis.

In addition, the interaction of Type by Space by Predictability was found to be significant [$F(4,44) = 3.56$, $p < .025$]. The data are plotted in Figure 2. Concerning the data directly, it can be seen that during high-speed search (normal spacing) predictable words are found faster. This is consistent with the hypothesis of faster search for predictable words. The data show a large difference between predictable and unpredictable

Table 5
Mean Search Time in Milliseconds Per Word

Type	Spacing	
Normal	153	129
Capitals	153	181
Alternating	177	172

Figure 2. Search time in milliseconds per word as a function of spacing, type, and semantic use.

words in the filled spacing/alternating type condition, but unpredictable and predictable words are searched at about the same speed in the normal and capital type/filled spacing condition. This trend is clearly in a direction opposite to that predicted. The mean difference in the high-speed search condition was 15 msec; in the word-by-word condition (space absent), it was 23 msec. For some unknown reason, the time is unusually fast in the alternating type/filled space/predictable target condition. The expected time would be at least 240 msec, considering comparable conditions in Experiments II and III. The data generally support the alternate position that the slow search condition shows a higher degree of contextual sensitivity than the high-speed search condition.

There were 36 errors, or 16.7% of the total possible. Analysis of the distributions of these errors failed to show a significant trend across any of the variables or their interactions.

In summary, predictable targets were found faster than unpredictable targets, once again confirming the effects of context on visual search. Type and spacing manipulations slowed search as in previous experiments; however, here an interdependence was found indicating that search for predictable or unpredictable targets differed with typography.

Discussion: Experiments III and IV

The reason for the significant increase in search times for unexpected and unpredictable target words in Experiments III and IV remains unresolved. One means of further examination is to look at the total search time differences. In Experiment III, search for expected words was 1.9 sec faster, on the average, than for unexpected words. In Experiment IV, the predictable words were searched 2.1 sec faster than the unpredictable words. A difference was predicted, but 2 sec seems too large.

A number of possibilities exist to account for the large differences. First, the subject might have skipped over the target and then had to go back for it. This

would have accounted for a time difference in search, but hardly up to 2 sec. Two seconds in search time could mean eight words or more were searched after the target, which intuitively seems to be too many. Second, the subject may simply have been going slower through the entire paragraph. This possibility would have necessitated the subject's having prior information about the target, the context, and recognizing the incongruity. This possibility also seems unlikely, because the search times are faster than would be expected with a general speed reduction. Third, subjects might have had to go through the paragraph more than once because the unexpected and unpredictable targets were harder to find. This possibility is also highly unlikely, because error analyses failed to show differences between expected-unexpected and predictable-unpredictable target words. Fourth, subjects simply took longer to respond to an unpredictable word because of a lack of certainty or confidence about their decision of whether the target word was correct or incorrect. The possibility that search time differences may depend upon response processes seems quite reasonable. Such a response lag might be analogous to typical *same-different* decision time differences found in matching tasks. Fifth, assuming that the subject has at least minimal contextual awareness as he goes through the paragraph and the context is congruent with the target words, the target may "stand out," allowing the subject to saccade to the target more quickly. In the final analysis, eye movement recordings must be relied upon for defining the saccadic eye movement sequencing process and describing how it relates to contextual awareness.

THEORETICAL IMPLICATIONS

Reading does not seem to be strictly a foveal process. Poulton (1962) noted the importance of peripheral vision by showing that reading speed decreased when the width of a line of text was narrowed. More recently, Bouma (1971, 1973) found that peripheral visual acuity is high out to 5 and 6 deg from fixation, especially for

initial and final letters of words and the right visual field. This high peripheral visual acuity provides a basis for a mechanism in the visual system that is physical feature sensitive. This mechanism could possibly perform an initial screening of the text for important cues and features that can be examined in depth by the fovea following a saccadic eye movement.

Recently, Hochberg (1970) and Hochberg and Brooks (1970) have proposed a two-process model for reading as a special type of search. *Peripheral search guidance* was hypothesized to be a process that is activated during eye movements and tuned to pick up contours (physical cues and features) in the periphery. Information about important cues and features is sent to a higher order processing unit, *cognitive search guidance*, for integration and meaning extraction. As meaning increases, the peripheral search guidance process interrogates larger areas of the text.

The applicability of the two processes to reading and search seems to be well documented in Experiments I and II, where slower reading and search speeds resulted when word shape and word boundaries (important cues to the periphery) were degraded. The data are interpreted as providing additional confirmation of peripheral processing. However, the data in Experiments III and IV are more difficult to interpret.

Hochberg, Levin, and Frail (Note 1) speculated that reducing the discriminability of word boundaries leads to more elemental, word-by-word, and letter-by-letter reading. Granted, they were describing reading, but their claim led to the prediction in Experiment III that when search is rapid (normal type/normal spacing) there would be a greater difference in expected-unexpected search time than in space-type manipulations that forced search to proceed word by word. The differences did not receive statistical verification. Similarly, the data from Experiment IV for Spacing by Predictability and Type by Predictability interactions failed to confirm expectation.

One possibility for the lack of confirmation is that the hypothesis is *not* a fair test of peripheral search guidance. The reason for this may be consistent with a two-stage peripheral to central information processing model. Assume that search is primarily a physical feature dependent process and secondarily dependent upon contextual features. Peripheral search guidance assumes the major role in search and a minor role in reading. Cognitive search guidance assumes the opposite roles. The overall rate differences between reading and search are probably caused by comprehension demands.

Search and reading proceed very rapidly whenever word shape and word boundary cues are available but on a word-by-word or letter-by-letter basis whenever they are lacking. Contextual effects differed slightly between reading and search. During reading (Experiment I), comprehension decreased with type. During search

(Experiment III), if targets looked the same but differed in form-class expectancy, the main effect of expectancy (cognitive search guidance effect) proved significant, but there were no interactions found between type or space with expectancy that would implicate peripheral search guidance effects. In addition, the data are in close agreement with those of Roydes and Osgood (1972). They used a recognition threshold task with total foveal presentation. In Experiment IV, when targets looked different and differed on predictability, the expected main effect of predictability (cognitive search guidance effect) as well as the Space by Type by Predictability interaction proved significant. When both context and physical feature discriminability are crucial to the task, the complimentary nature of peripheral and cognitive search guidance seems demonstrated. When physical features cannot distinguish the target, the processes are capable of operating more or less independently.

Such a conceptualization of these two processes demonstrates why cognitive search guidance is probably responsible for the expectancy-predictability target search time advantage. It is simply *not* the responsibility of peripheral search guidance to handle contextual information beyond the point of feature discrimination. Rayner (1974) has also expressed this belief. Moreover, it is likely that once peripheral cues can no longer be discriminated, peripheral search guidance is rendered dysfunctional and search and reading become totally foveal activities. Recently, using eye movement recordings, Spragins (1974) has confirmed a lack of Type by Space interaction during search and has shown a dramatic decrease in recognition span between search and reading and between perturbed and normal text.

REFERENCES

- Bouma, H. Visual recognition of isolated lowercase letters. *Vision Research*, 1971, 11, 459-474.
- Bouma, H. Visual interference in the parafoveal recognition on initial and final letters or words. *Vision Research*, 1973, 13, 767-781.
- Butler, D. H., Kamlet, A. S., & Monty, R. A. A multipurpose analysis of variance FORTRAN IV computer program. *Psychonomic Monograph Supplements*, 1969, 2, 301-319.
- Coltheart, M., & Freeman, R. Case alternation impairs word identification. *Bulletin of the Psychonomic Society*, 1974, 3, 102-104.
- Hochberg, J. Components of literacy: Speculation and exploratory research. In H. Levin and J. P. Williams (Eds.), *Basic studies on reading*. New York: Basic Books, 1970. Pp. 74-89.
- Hochberg, J., & Brooks, V. Reading as an intentional behavior. In H. Singer and R. B. Ruddell (Eds.), *Theoretical models and processes of reading*. Newark, Del: International Reading Association, 1970. Pp. 304-314.
- Neisser, U. *Cognitive psychology*. New York: Appleton-Century-Crofts, 1967.
- Poulton, E. C. Peripheral vision, refractoriness and eye movements in fast oral reading. *British Journal of Psychology*, 1962, 53, 409-419.
- Rayner, K. The perceptual span and peripheral cues in reading. Unpublished dissertation, Cornell University, 1974.
- Roydes, R. L., & Osgood, C. E. Effects of grammatical form-class set upon perception of grammatically ambiguous English words. *Journal of Psycholinguistic Research*, 1972, 1, 165-174.
- Smith, F. Familiarity of configuration vs. discriminability of

- features in the visual identification of words. *Psychonomic Science*, 1969, 14, 261-262.
- Smith, F., Lott, D., & Cronnell, B. The effect of type size and case alteration on word identification. *American Journal of Psychology*, 1969, 82, 248-253.
- Spragins, A. B. Eye movements in examining spatially transformed text: A developmental examination. Unpublished dissertation, University of South Carolina, 1974.
- West, M. *A general service list of English words*. London: Longmans, Green and Co., 1964.
- Woodworth, R. S. *Experimental psychology*. New York: Holt, 1938.
- span. In H. Levin, E. J. Gibson, and J. J. Gibson (Eds.), *The analysis of reading skills: A program of basic and applied research*. Ithaca, N.Y.: Cornell University, 1968.
3. G. McConkie, personal communication, April 12, 1974.
4. McConkie, G. W., & Rayner, K. The span of the effective stimulus during fixations in reading. Paper presented at the American Educational Research Association, New Orleans, Louisiana, 1973.
5. The author wishes to express his gratitude to the Houghton-Mifflin Company for the use of the Nelson-Denny Reading Test, copyright 1960, Houghton-Mifflin Company, Boston, Massachusetts. The paragraphs were reproduced with permission of the publisher, Houghton-Mifflin Company, and were a particularly fine source for textual material because of the very great lengths taken to standardize and qualify the paragraphs.

NOTES

1. Hochberg, J., Levin, H., & Frail, C. Studies of oral reading: VII. How interword spaces affect reading. Mimeographed, Cornell University, 1966.
2. Levin, H., & Jones, D. Filled interword spaces and eye-voice

(Received for publication March 17, 1974;
revision accepted July 30, 1974.)