Peripheral and cognitive components of eye guidance in filled-space reading

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Five undergraduates read aloud three pages of text a day for 10 days. One page of text each day had interword spaces filled with a black letter-like filler, one with a red filler, and one was normal (control). Results showed that (1) red fillers produced a reading rate significantly below normal text, (2) black fillers yielded a significantly lower reading rate than red fillers, and (3) with practice, the reading rate for the black-filled condition rose significantly. Testing on Day 11 with an alternative filler form showed that a specific form was being learned with practice. Results were interpreted as support for both peripheral guidance of eye movement by physical cues and cognitive guidance involving reader-generated hypotheses about the text.

Considerable speculation in reading research has centered around the topic of models of eye-movement control. Possible models range from random control of eye movements to models requiring integration of the reader's knowledge of syntactic and semantic patterns with information acquired in both the foveal and peripheral visual fields. Several summaries and discussions of the range of models are available (see Haber, 1976; McConkie & Rayner, 1976; Rayner & McConkie, 1976). The models presented vary somewhat from description to description, but all are basically derived from combinations of random, peripheral, and cognitive components of eye-movement control.

Random control models propose that movement is unrelated to the text that the eye is moving over; the eye simply moves ahead some average distance with each saccade. Experimental findings, however, are not consistent with this hypothesis. Haber (1976) cites Buswell's (1922) eye-movement data which show that difficult words embedded in less difficult text tend to draw multiple fixations. Rayner and McConkie (1976) present data indicating that the probability of fixating any given letter is related to the length of the word it is in. Finally, Abrams and

Zuber (1972) and Rayner (1975a) have found that the blank areas in text receive fewer fixations than words do. While there may be some degree of randomness in eye movement arising simply from inaccuracies in muscle control, these findings suggest that randomness cannot be the only factor in eye movement.

One possibility is that guidance is based on information picked up in the periphery of the visual field. Fixations may be guided by peripheral cues such as word lengths and interword spaces (McConkie & Rayner, 1976; Rayner & McConkie, 1976). These cues may be used to guide eye movements toward the longer and more informative words and away from the uninformative blank spaces. Evidence for more detailed peripheral processing is reported by Rayner (1975b), who found that readers could detect word shape and final and initial letters of words up to 7-12 character spaces beyond the point of fixation, and McConkie and Rayner (1976), who found that readers were able to derive information about phrase structure from word length alone. The latter finding suggests that some syntactic information may be picked up in the periphery.

Not inconsistent with the above findings is a recent proposal by Hochberg (1970) which states that readers use peripheral information in conjunction with hypotheses or expectations about what is to be encountered next to allow more efficient reading. The skilled reader can take advantage of the predictability and redundancy of language to sample the text selectively for only enough information to confirm or disconfirm hypotheses and decode the unpredicted, informative words. The reader does this by using "cognitive search guidance" (Hochberg, 1970) to predict in which words important information is

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likely to be found, and "peripheral search guidance" (Hochberg, 1970) to guide the eyes to the spot by means of the available peripheral cues. Reading efficiency is increased as eye fixations are guided to the specific regions which require more detailed analysis.

Hochberg (1976) has presented evidence of peripheral and cognitive search guidance, but evidence for the latter was obtained from search tasks rather than from normal reading. The present experiment approximated normal reading and sought to investigate peripheral and cognitive guidance components using text in which interword spaces were filled.

Hochberg, Levin, and Frail (Note 1) found that filling the blank spaces between words with a filler consisting of a c with an x typed over it greatly reduced the speed at which fifth and sixth grade readers read aloud. First and second graders, on the other hand, were not impaired by the fillers. Hochberg et al. concluded that skilled readers make use of peripheral cues which are eliminated by the presence of fillers, forcing them to resort to a word-by-word reading process. Similar results were obtained by Fisher (1975) using college students as subjects. Filling interword spaces clearly makes the process of reading much more difficult than usual. It would appear, however, that in addition to the lack of normal peripheral cues, filled text also imposes upon the reader an additional stimulus (i.e., the filler) for processing in a limited-capacity system. The reader's mode of dealing with this unfamiliar and noninformative, letter-like stimulus may provide the basis for more detailed knowledge of how the reader guides eye movements. The present experiment, by examining variables that produce reading disruption, may help clarify the role of peripheral cues in eye movement within the framework of Hochberg's (1970) components of guidance.

If it is assumed that peripheral cues provide a significant source of guidance for eye movements and that skilled readers are hampered when interword spaces are filled with a filler which matches the gross visual characteristics of the text (Hochberg et al., Note 1), the degree of interference should be attenuated if an alternative physical cue is made available for separating fillers from text. Providing the reader with text in which interword spaces are filled with a contrasting color filler should result in performance superior to that of text with same-color fillers if peripheral physical cues are used.

Evidence for a source of eye-movement guidance using other than exclusively physical cues may be found if readers are able to adjust eye movements to deal effectively with filled text when all physical cues are absent. If readers show improvement with practice in reading filled-space text, it would appear that they are learning something of importance with regard to the nature of the filled text. Two possibil-

ities suggest themselves. First, the reader may be learning a generalized strategy such as shortening saccade length to avoid missing information that is no longer detectable in the periphery. This kind of adjustment would imply that the reader can monitor the overall difficulty of abstracting information from the visual display and make a gross adjustment in placing fixations to suit the material. Alternatively, something may be learned about the filler itself. The form of the filler may be learned as a noninformative stimulus which does not require fixation. The reader may then be able to use this knowledge to direct the eye past the filler. Such a strategy would lend support to the notion of the involvement of cognitive guidance in eye movement. It is possible to determine which type of learning may be occurring by giving subjects extended practice reading text with one form of filler and then testing with a filler that differs in form.

The two suggested types of learning lead to separate predictions about performance with the novel interword filler. If subjects learn a general strategy over the extended practice period, then this strategy should be transferable across forms of fillers (provided the alternative form of filler preserves such gross characteristics as size and color). If, however, subjects learn that a specific filler is noninformative, their performance with a different filler should drop to prepractice level. This latter result would suggest that the previous improvement in reading performance was based on cognitive search guidance.

METHOD

Subjects

Five Wesleyan University undergraduates served as volunteer subjects over 11 daily experimental sessions.

Materials

Stimuli were pages of newspaper text retyped in black elite type on standard white 21 × 28 cm typing paper. Each page contained an average of 250 words of text and approximately the same number of interword spaces.

Interword spaces for the first 10 days' reading were either blank (normal text) or filled with a red or black typed filler consisting of a lowercase x with a lowercase c typed over it (from Hochberg et al., Note 1). Thus, daily testing over the first 10 sessions consisted of three pages of text: normal, black-filled and red-filled.

The 11th session consisted of four pages of text: (1) normal text; (2) text with interword spaces filled with a black o and a black s typed over it; (3) text with interword spaces filled with a red o and a red s typed over it; and (4) text with interword spaces filled with a solid red square the size of a typed lowercase letter.

Texts were drawn from issues of a local newspaper (*The Hartford Courant*). Each day's texts consisted of one article from each of three separate sections of the newspaper: front page, sports, and features. Conditions were rotated across sources each day to eliminate any regular discrepancies in reading material difficulty due to source.

Procedure

Subjects were given three pages of text a day for 10 days. Each subject read one normal page, one page with black fillers,

and one page with red fillers per day. On the 11th day, the subjects read four pages of text, as described above. Order of presentation was random for each subject each day.

The subjects were instructed to read each page aloud as quickly and as accurately as possible. The subjects were timed on a stopwatch from first to last word read. Reading times were recorded for each page and a count was made of the number of errors per page. Any word that was omitted, misread, or misread and then corrected was counted as an error.

Because pages of text varied in length, it was necessary to obtain a standardized measure of amount read per unit of time. Actual word counts for each page appeared to be an inaccurate estimate of amount read, since some articles tended to contain a larger number of short words than others, thereby inflating words-per-second calculations in relation to other pages. The number of syllables read was thought to be a more accurate and consistent measure of the amount read. Therefore, the number of syllables per page was counted and reading times were converted to syllables per second.

RESULTS AND DISCUSSION

The principal findings on reading speed and accuracy are shown in Figures 1 and 2, respectively. Comparison of the black-filled condition on the initial test day to the normal text for that day shows that the results of Hochberg et al. (Note 1) have been replicated. Filling interword spaces with a black letterlike form drastically reduces reading speed and increases reading errors. It is also clear that variables of color, practice, and form of filler have major effects on the level of disruptiveness imposed by the filler. Each of the variables will be discussed individually.

Color

The presence of a physical color cue in the interword filler significantly facilitated reading when compared with the black-filled condition. An analysis of variance on the mean syllable-per-second reading scores for the three conditions shows that the

Figure 1. Mean reading rates for normal (solid line), red-filled-space (dashed line), and black-filled-space (dotted line) conditions as a function of number of practice sessions.

Figure 2. Mean error rates for normal (solid line), red-filled-space (dashed line), and black-filled-space (dotted line) conditions as a function of number of practice sessions.

difference among conditions is highly significant, $F(2,8) = 67.87$, $p < .001$. After 10 days of practice, the average reading rate for all subjects for black fillers remained significantly below that for red fillers, $t(4) = 4.64$, $p < .01$, indicating that readers appear to utilize the physical cue of color to reduce the disruptive effects of the interword filler. This finding indicates that readers are capable of using physical cues with no semantic or syntactic content to facilitate reading.

Practice

It is interesting that the red-filled condition does not show any substantial improvement over 10 days of practice. The performance from Day 1 to Day 10 is not significantly different, $t(4) = .20$, $p > .05$, and reading speed on Day 10 for the red condition is still significantly below that for normal text, $t(4) = 6.32$, $p < .01$. Color may only partially compensate for the procedures acquired over a lifetime for encoding letterlike forms. The black condition, however, lacks a physical basis for discrimination; if performance is to improve over time, it must be based on the learning of some other aspect of the text that is not dependent upon gross physical cues.

The hypothesis that readers can guide eye movements in the absence of word length, boundary, and shape cues is confirmed by performance for the black-filled condition over the 10 days. It is clear from the large practice effect seen for the black condition that subjects learn something related to the interword filler that makes the task substantially easier with practice. The decrease in error rate shown in Figure 2 indicates that subjects are not sacrificing accuracy for speed, nor are they reading faster while maintaining a fixed error rate; they are becoming more accurate as they gain skill in reading the black-

filled condition. The practice effect seems to consist of both a lowered error rate and an increased reading rate. Some of the increase in reading speed is obviously attributable to a reduction in errors which usually involved time-consuming pauses and corrections as subjects realized their mistakes. But this cannot be the principal cause of faster reading rates, as the error rate for Days 6-10 remained fairly stable while reading speed continued to rise.

Form

The effect of changing the form of the interword filler is a revealing manipulation with regard to the disruptive effect and what is being learned over the 10 days' testing sessions. The high level of performance in the condition consisting of a red square between words demonstrates that it is not the simple presence of an unaccustomed stimulus that produces disruption of normal reading. Rather, it appears that the filler becomes distracting when it incorporates a letter-like form, a form which when detected in the peripheral visual field may appear to be potentially informative. The significant drop in performance for the red letter-like filler for Day 11 as opposed to the red letter-like filler for Day 10 performance, $t(4) = 5.94$, $p < .01$, shows that form is attended to even when the color cue is available for easy detection in the periphery. This supports the notion advanced in the previous section that some processing of form is occurring even with the presence of the color cue. If form were not attended to, it would be expected that a change in the form of the red letter-like filler would have no effect.

Most importantly, results from the 11th day's test indicate strongly that the improvement shown over the course of the 10 days of testing is due to the learning of a specific form rather than to the acquisition of a general response to filled spaces. Performance drops significantly when the black letter-like filler is changed from Day 10 to Day 11, $t(4) = 13.65$, $p < .01$. Despite the large improvement that 10 days of practice has caused in performance on the original filler, the new filler produces a reading level as low as the first day's rate for the original filler. In addition, the error rate for the new filler is as high as the first day's error rate for the other filler. Subjects clearly did not learn a generalized strategy for dealing with filled interword spaces. Instead, the form of the filler was learned, presumably as a nonmeaningful stimulus, thereby permitting the eye to identify it in the periphery as such and move to areas of higher information value without detailed processing of the filler.

GENERAL DISCUSSION

The major results of this study have shown that when readers are confronted with an unbroken string

of potentially informative stimuli, they will use any available physical cues to aid in selective direction of eye movement. In the absence of physical cues, readers appear to direct eye movement based on knowledge of specific forms and their information value.

The fact that color is a significant aid to selectively guided eye movements supports previous studies implicating the importance of peripheral physical features for guiding eye movements. Even when two texts present identical space fillers between words, the addition of a color cue to one allows the disruptive effect of the filler to be greatly reduced in comparison to the other. Thus, a significant component of peripheral guidance seems capable of being based on gross visual characteristics of the text.

Most importantly, in the absence of any peripheral cues to help guide the eyes, another component of guidance seems to be available. The improvement for the black-filled condition appears to be based on the learning of the specific form of the filler. This finding lends support to the proposal that eye guidance is partially cognitive; the reader is able to guide the eye to areas that are potentially informative on the basis of acquired knowledge and expectations.

REFERENCE NOTE

1. Hochberg, J., Levin, H., & Frail, C. *Studies of oral reading: VII. How interword spaces affect reading*. Mimeographed manuscript. Cornell University, 1966.

REFERENCES

- ABRAMS, S. G., & ZUBER, B. L. Some temporal characteristics of information processing during reading. *Reading Research Quarterly*, 1972, 12, 41-51.
- BUSWELL, G. T. Fundamental reading habits: A study of their development. *Education Monograph Supplement*, 1922, 21.
- FISHER, D. F. Reading and visual search. *Memory & Cognition*, 1975, 3, 188-196.
- HABER, R. N. Control of eye movements during reading. In R. A. Monty & J. W. Senders (Eds.), *Eye movements and psychological processes*. Hillsdale, N.J.: Erlbaum, 1976.
- HOCHBERG, J. Components of literacy: Speculations and exploratory research. In H. Levin & J. P. Williams (Eds.), *Basic studies on reading*. New York: Basic Books, 1970.
- HOCHBERG, J. Toward a speech-plan eye-movement model of reading. In R. A. Monty & J. W. Senders (Eds.), *Eye movements and psychological processes*. Hillsdale, N.J.: Erlbaum, 1976.
- MCCONKIE, G. W., & RAYNER, K. Identifying the span of the effective stimulus in reading: Literature review and theories of reading. In H. Singer & R. B. Ruddell (Eds.), *Theoretical models and processes of reading*. Delaware: International Reading Association, 1976.
- RAYNER, K. Parafoveal identification during a fixation in reading. *Acta Psychologica*, 1975, 39, 271-282. (a)
- RAYNER, K. The perceptual span and peripheral cues in reading. *Cognitive Psychology*, 1975, 7, 65-81. (b)
- RAYNER, K., & MCCONKIE, G. W. What guides a reader's eye movements? *Vision Research*, 1976, 16, 829-837.

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