DOCUMENT RESUME

ABSTRACT
        The eye movements of two college graduates were
monitored in a study of flexible reading, which is defined as the
ability to adjust one's rate and approach to reading according to the
purpose of reading, the difficulty of the material, and one's
knowledge of the subject matter. The subjects were told to read an
excerpt from a tenth grade biology textbook as if it were a homework
assignment. They were tested with detailed essay and multiple choice
questions after reading the selection twice. The first-reading data
showed that subjects slowed down for ideas that tended to be
recalled, for important ideas, for ideas that contained new or
unfamiliar information, and for ideas containing a high number of
prepositions essential to the gist of that idea. Analyses of the
changes between first and second readings showed that the difference
rate was correlated with meaning unit importance ratings, the average
importance of propositions in an idea, the propositions essential to
the gist of an idea, and serial position. The overall pattern of
correlations showed that the subjects read important ideas 51 words
per minute slower and unimportant ideas 84 words per minute faster on
the second reading than they did on the first reading. These data
support the notion that macro and micro variations in eye movement
patterns resulted from flexible reading strategies under voluntary
control. (RL)

Eye Movements Reveal Components of Flexible Reading Strategies

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When asked to characterize superior readers, educators single out flexible reading, "the ability to adjust one's rate and approach to reading with the purpose of reading, with the difficulty of material, and with one's background or knowledge of the particular subject matter" (Weintraub, 1977, p. 169; see also Fisher & Montanary, 1977; Harris & Sipay, 1975; and Tinker, 1947). Despite its importance, very little is known about adaptable reading strategies and as a result, educators have not developed effective lesson plans for teaching it. One reason is that flexibility has been treated as a modulating single strategy when it is in fact a compound of fundamental component strategies representing successive stages in the acquisition process. In the present paper we use eye movement records to analyze and parse out components of flexible reading.

Some researchers have examined flexibility as a between passage strategy using total reading time over an entire passage as their main response measure where typography and content were varied (cf. Fisher, 1976; Rankin, 1974). We, on the other hand, follow the lead of Shebilske and Reid (1979) who used eye movement records to analyze components of flexible reading within passages. Shebilske and Reid based their analysis on a reading model according to which eye movements are controlled by recognition and comprehension. Recognition processes map light patterns onto surface structural units corresponding to letters, syllables, sentences, and paragraphs. (Several recent reaffirmations of the influence of recognition processes on eye movements have been made (cf. Just and Carpenter, 1980; Rayner, 1978). Comprehension processes map the output from recognition processes onto conceptual representations and build conceptual units into structured internalized representations.

Shebilske and Reid provided support that the comprehension processes influence eye movements by showing that students reading a 2000 word narrative slow down when reading sentences that are indirectly related to higher-order conceptual units than they do over sentences that are directly related, but when these same sentences were read out of-context, no difference was found. They argued that their contextual effects represented components of intra-passage flexibility. When they compared intra- with inter-passage flexibility they found a significant positive correlation. The present study extends eye movement measures of the hypothesized flexibility and adaptability to textbook reading.

Two problems must be solved in order to measure components of flexible reading: 1) defining units of analysis, and 2) specifying relevant characteristics of those units. The acid test for any recommended solution is whether or not the units and characteristics can be used to shed light on adaptable reading. In the present study we tested units and their characteristics that were developed by a multipdisciplinary team effort.[1] The units and characteristics were defined from the point of view that what is read is as important as what an author has written and therefore the ways ideas are segmented, and characteristics like importance and familiarity are expected to be revealed in changes in eye movement dynamics like fixation duration, frequency and distance between subsequent fixations.

Methods

Subjects. Two technical staff employees at the Human Engineering Laboratory volunteered to participate in our experiment. Both had received undergraduate college degrees in areas other than biology.

Apparatus and Materials. We measured eye movements with the oculometer located at the Behavioral Research Directorate, Human Engineering Laboratory, at Aberdeen Proving Ground, Maryland. Further details on this free viewing system are reported by Monty (1975). Reading material was projected onto a 24" X 40" screen located 1.7 meters in front of readers who sat in an easy chair without head restraints. Since all recording equipment was located in a separate room, subjects were not aware that their eye movements were being monitored. Calibration was accomplished in tasks that did not give away its true purpose. Horizontal eye position was measured with an accuracy of approximately 1° (4 letter word), and vertical eye position was measured with an accuracy of approximately 1° (one line). This TV based monitoring system utilizes a PDP 11/20 and PDP 11/50 for pupil/iris acquisition and on-line analysis. A Tektronix hard copy unit provides scan-patterns of segmented fixations.

The text was a 2866 word excerpt from a tenth grade biology textbook (BSCS, Green Version, 2nd edition), typed in pica and double spaced with about 15 lines per page.

Procedure. Subjects were told to read the excerpt as they would ordinarily read such a passage for a homework assignment. They proceeded at their own pace pushing a button to advance slides to new pages. They were told that they would be tested with detailed essay and multiple choice questions and that they would have an opportunity to reread the text before the test. Tests of paraphrastic recall and multiple-choice followed the second reading.

Results

Several preliminary analyses assessed the representativeness of our two readers. Recalls proved comparable to those given by University of

Virg[illegible]duates in our previous experiments and that reading rates were c[illegible] to college student norms. One reader averaged 232 words per m[illegible] first reading and the other averaged 335 words per mi[illegible] average reading rates for college students is about 280 words per minute for easy material (Taylor, Frankenpohl, & Pette, 1960).

Scan paths and digital records, like those in Figure 1, of critical parameters of each fixation like duration, location and distance from previous fixation were analyzed. Each reader produced more than twelve thousand data points for each reading. To overcome a potential overwhelming problem a hierarchical method of data analysis was devised. First analyzed were macro-level aggregates of eye movements, then the micro-parameters of individual fixations.

The macro-level analysis measured modulations in reading rate as a function of meaning unit characteristics. For each meaning unit three scores were averaged over both subjects: reading rates for the first and second readings, and the difference in rate between the first and second reading. These data were then correlated with the first reading rate and the difference rate with the 18 meaning unit characteristics shown in Table 1.

Insert Table 1 about here

The results of the analysis of the first reading data showed that subjects slowed down for ideas that tended to be recalled ($r = -.12$, $p = <.15$), for important ideas ($r = -.17$, $p = <.07$), for ideas that contained new or unfamiliar information ($r = .22$, $p = <.03$), and for ideas containing a high number of prepositions essential to the gist of that idea ($r = .11$, $p = <.17$).

Analyses of the changes between first and second readings showed that the difference rate was correlated with meaning unit importance ratings (r = .44, p<.001), the average importance of propositions in an idea (r = .50, p<.001), the propositions essential to the gist of an idea (r = .30, p<.01), and serial position (r = -.28, p<.01). The correlation with serial position indicates that on a second reading subjects slowed down more towards the end of the passage. One possible explanation for this is that there was more important information near the end of this passage.

The overall pattern of correlations show that readers modulate their rate in accord with the familiarity (old or new)/of information on the first reading, spending more time on new information, and to whether information is viewed as important or unimportant on the second reading. The mean reading rates for important vs. unimportant ideas are of special interest. On the first reading, the subjects read important and unimportant ideas at rates of 280 wpm and 288 wpm respectively. On the second reading, they read important ideas at the rate of 229 wpm and unimportant ideas at the rate of 372 wpm. That is, these subjects read important ideas 51 wpm slower and unimportant ideas 84 wpm faster than they did on the first reading. Even with two subjects, the test of this interaction with a t test with idea units as the random variable, resulted in a positively biased but significant, t (72) = 3.60, p<.001, effect giving power to our finding.

Since importance was the most influential meaning unit characteristic in our macro-analysis of aggregated eye movements, a micro-analyses of individual eye fixations comparing fixations on important and unimportant ideas followed. Differences in fixation duration, number of regressions, and interfixation distance were analyzed. On first and second readings

similar trends appeared. Readers had longer fixations and more regressions

on important ideas while interfixation distances were relatively constant.

More specifically: 1) mean fixation durations of 276 msec. for important

ideas vs. 240 msec. for unimportant, 2) 4 regressions per important unit

vs. 1 regression per unimportant unit, and 3) average interfixation

distances of 4.28 degrees for important ideas vs. 4.46 degrees for

unimportant ones. It was not infrequently that readers finished a meaning

unit before deciding to slow down and take another look at it. This

verification process was also evident when they came to the last word in a

unit (most likely an important unit) and then made a large regression,

sometimes back to the first word in the idea. This result not only reveals

an interesting reading strategy and provides support for comprehension

effects, but also adds construct validity to our meaning units.

Discussion

The data reported support the notion that macro and micro variations

in eye movement patterns result from flexible reading strategies under

voluntary control. At times the variations correspond to and seem

determined by the text, while at other times variations reflect the

subject's view of important information. That is, subjects could have read

important and unfamiliar material faster if they had chosen to do so.

This interpretation will be further tested in future experiments that will

manipulate variables like the purpose for reading, background knowledge,

text redundancy, and end of sentence/idea unit integration time.

The prospects for future research are especially bright considering

that adaptability and generality of our reader-based procedures for

utilizing and characterizing reading in applied content area settings.

Karmiohl (1979) recently showed that reader-based procedures can detect

variations in perceived text structure that occur in a wide range of contexts like reading a passage on marketing to business students or to psychology students. Recent preliminary studies using Karmiohl's materials showed that readers move their eyes differently depending upon how they perceive the text structure. The adaptability of our reader-based procedures contrast sharply with the limitations of formal text grammars being used to unitize and characterize texts in other laboratories (e.g. Just & Carpenter, 1980). Formal grammars measure only the structure that an author puts into a text; they do not measure the structures the readers see in a text (cf. Shebilske, 1980).

While a formal text grammar applies to one discourse style, others in our research group have identified and measured a variety of discourse styles in textbooks (cf. Deese, 1980). The adaptability and generality of our approach makes it particularly well suited for studying individual differences based on background. Background effects were shown in the present study when students regulated their eye movements according to whether information was old or new. Individuals also differ in their familiarity with various styles of discourse and in their ability to discover modifiers and to make inferences. The present study represents a starting point from which to move toward comprehensive analyses of individuals' performance.

Specific recommendations for teaching may be premature, but some suggestions for application are appropriate and timely. This project is based upon the critical assumption that the mechanics of reading are largely controlled by the level of understanding and not the other way around. Therefore, the path of previous attempts to improve reading by improving the mechanics of eye movements (cf. Tinker, 1958) goes counter to

our purpose. For the most part, eye movement measures will remain in the laboratory and provide one of several converging operations used to infer effective, flexible reading strategies. Our goal will be to encourage the use of flexible strategies on the part of the reader and to inform the text writer and producer about the facilitory aspects of more efficient text analysis. At the classroom level we are coordinating our research efforts with teachers in an attempt to make our data a sound empirical foundation for developing effectual lesson plans for teaching flexible reading.

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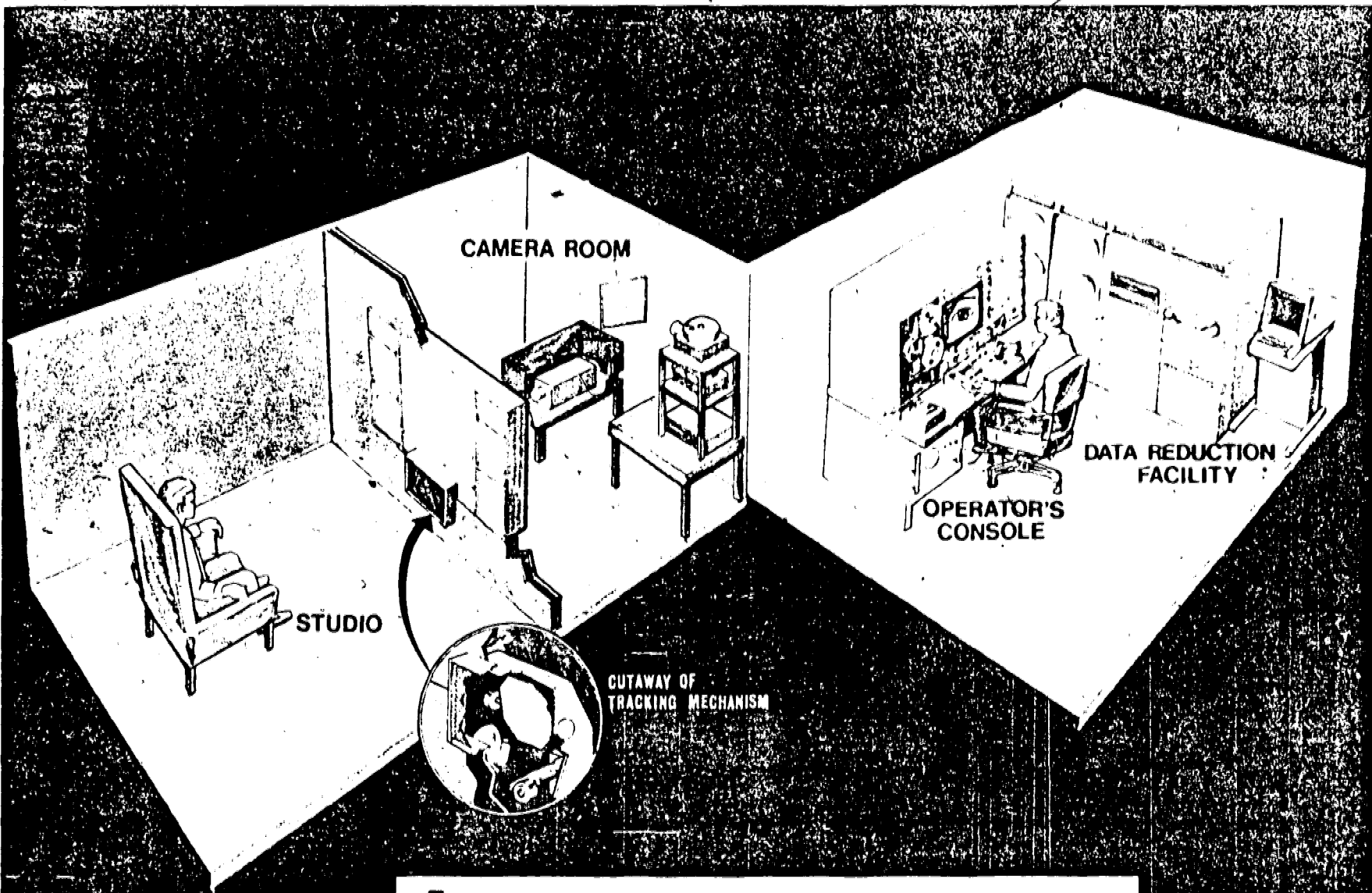Weintraub, S. Research. The Reading Teacher, 1977, 21, 169-173.

Footnote

Members of this team are James Deese, John Rotundo, Thomas Estes, and

Mary Wetmore in addition to the authors.

Table 1

MEANING UNIT CHARACTERISTICS

1. MU Recall = Proportion of Subjects Recalling MU.

2. MU Importance Rating.

3. Average Importance of Propositions in MU.

4. Number of Propositions in MU.

5. Number of Words in MU.

6. Number of Propositions Essential to Gist

7. Number of Important Propositions.

8. Proportion of Propositions Essential to Gist

9. Proportion of Important Propositions

10. Serial Position in Text

11. Serial Position from Beginning of Text

12. Serial Position from End of Text

13. Serial Position from Beginning of Paragraph

14. Serial Position from End of Paragraph

15. Number of _ _ _ _ _ _ _ _ _ _ _ _

16. Proportion of Subjects Having Segment Boundary

17. Proportion of Subjects Having Segment Boundary, _ _ and _ _

18. _ _ _ _ _ _

CAMERA ROOM

STUDIO

DATA REDUCTION FACILITY

OPERATOR'S CONSOLE

CUTAWAY OF TRACKING MECHANISM

EG&G - HEL OCULOMETER SYSTEM