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**THE EFFECTS OF COMPUTER-MEDIATED TEXTS ON THE
VOCABULARY LEARNING AND COMPREHENSION OF
INTERMEDIATE-GRADE READERS**

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ABSTRACT

The authors investigated whether intermediate-grade readers' vocabulary learning and comprehension would be affected by displaying texts on a computer screen that provided the meanings of difficult words. Sixty sixth-grade subjects read two informational passages containing several target words that had been identified as difficult. Subjects were assigned to four treatment conditions. In two of the conditions they read the passages on printed pages accompanied by either a standard dictionary or a glossary comprised of the target words. In the remaining two conditions they read the passages on a computer screen that provided either optional or mandatory assistance with the meanings of the target words. The results indicate that subjects who read passages with computer assistance scored significantly higher on a vocabulary test that measured subjects' knowledge of the target words. Subjects who read the passages on the computer screen with mandatory assistance also outperformed other subjects on a test measuring comprehension of the experimental passages. In addition, subjects free to select which of the target words they would investigate chose to do so more often when the computer provided assistance. The authors conclude that these results support and help explain previous studies that have found increases in comprehension when computer-mediated texts have been used to expand or control readers' options for acquiring information.

Recent research suggests that the vocabulary development of school-age children may be due in part to the incidental learning of word meaning during independent reading (Herman, Anderson, Pearson, & Nagy, 1987; Nagy, Herman, & Anderson, 1985). Paradoxically, other studies suggest that deriving a word's mean-

ing during independent reading may require considerable skill and effort on the part of a reader. McKeown (1985), for example, found that low-ability readers had difficulty deriving the meaning of a new word despite the fact that the word was presented in multiple contexts specifically designed to elucidate the word's meaning. She concluded that the acquisition of a word's meaning from context is difficult for many readers, even under optimal conditions. Likewise, Jenkins, Stein, and Wysocki (1984) found unexpectedly that intermediate-grade subjects learned the meanings of relatively few words when the experimental task created conditions especially favorable to deriving word meaning contextually.

Other than using contextual clues, readers who endeavor to learn the meaning of an unfamiliar word during independent reading must rely on reference aids such as a dictionary or glossary. Determining the meaning of a word in a particular context with the aid of a dictionary or glossary is limited by a number of factors, however (see Miller & Gildea, 1985). For example, in addition to having access to an appropriate reference aid, readers must be able to apply skills necessary to locate the word. Some readers, especially young readers, may not have adequate reference skills to carry out this task effectively or efficiently. In addition, when a word is located in a reference aid such as a dictionary, a reader must frequently match one of the word's several given meanings to the context in which it was encountered. Thus, the reader must again employ context to determine the word's meaning. The time and cognitive effort required to carry out these tasks may interfere with a reader's processing of other information in a text. Furthermore, the relatively short, general meanings typically used in dictionaries are frequently inadequate because the use of a word in a particular text may have a context-specific meaning not fully elucidated by the meaning found in a dictionary (McKeown, *in press*).

The difficulties inherent in using context and reference aids to determine the meaning of an unfamiliar word encountered while reading may lead readers to circumvent difficult words. For example, few readers consult a dictionary during independent reading unless compelling circumstances motivate them to do so. Underlying metacognitive strategies may be similarly evasive when a reader encounters low-frequency words. Freebody and Anderson (1983) postulated the minimum effort principle to explain the results of their study investigating the effects of difficult words on reading comprehension. Their study indicated that it was necessary to substitute a relatively high percentage of low-frequency synonyms for high-frequency words to produce a statistically significant decrease in reading comprehension. They reasoned that readers may focus strategically on more familiar aspects of a text for comprehension rather than expend the considerable effort required to deal with the difficult words.

Computer-mediated texts (texts displayed electronically under the immediate control of a computer) may represent a viable means for addressing the limitations inherent in determining the meanings of difficult words during reading because

they provide new options for acquiring information from written texts (Daniel & Reinking, 1987; Duchastel, 1986, 1988; Reinking, 1987, 1988; Reinking & Bridwell-Bowles, 1991; Reinking & Schreiner, 1985). In the present study, computer-mediated texts were employed to assist readers by providing immediate access to the definitions of difficult words. Unlike conventional reference aids, the computer provided immediate access to context-specific definitions without requiring readers to employ reference skills such as the ability to locate words alphabetically and to determine which of several meanings apply to a given context.

The ease with which readers of computer-mediated texts can access word meanings may affect their propensity to seek out the meanings of difficult words. Increased attention to difficult words during independent reading may lead to an increase in a reader's vocabulary knowledge, which may in turn increase the comprehension of texts (see Anderson & Freebody, 1981, for a discussion of the possible relations between a reader's vocabulary and comprehension). This relation may be especially relevant for those texts in which comprehension is dependent on the knowledge of technical terms. Although adjacent-to-text glosses indicating word meaning may have similar advantages, there is some evidence that using the computer to stimulate reader-activated glosses may be superior to glosses on printed pages (Blohm, 1982). One purpose of this study, therefore, was to investigate whether using computer-mediated texts to provide readers with the definitions of difficult words would increase (a) attention to the meanings of these words, (b) knowledge of their meanings, and (c) comprehensions of the texts in which they appear.

Several studies have used computer-mediated texts to enhance readers' options for acquiring word meanings during independent reading. For example, Reinking (1983, 1988; Reinking & Schreiner, 1985) has investigated the effects of using computer-mediated texts to provide readers with several options for assistance during independent reading. One of several options available to the reader was the capability to request context-specific meanings of difficult words in a text. Comprehension increased in these studies when readers selected among the options for assistance and when the computer required readers to view all of the options for assistance. In one study (Reinking, 1983) statistically significant differences were found on vocabulary test scores in favor of subjects who were able to request all forms of assistance including the meanings of difficult words. Likewise, MacGregor (1988b) developed a computer-mediated text system (CTS) designed to encourage third-grade students to ask questions while reading texts displayed on a computer screen. Questions were clarification questions pertaining to the meanings of difficult words or focus-of-attention questions pertaining to literal information in the text. Average readers using CTS made significantly greater gains in their knowledge of word meanings and in comprehension, while good readers made greater gains in the ability to predict their performance on a vocabulary test.

From these studies it is difficult to draw conclusions about the effects of the

computer-based assistance for deriving the meanings of difficult words, because this assistance was accompanied by several other types of computer-based assistance. These other types of assistance may have affected subjects' knowledge of word meanings and their comprehension of a text. For example, readers could choose to read a less technical version of the original passage in which, among other adaptations, high-frequency words were substituted for low-frequency words that appeared in the original passage (see Reinking, 1988; Reinking & Schreiner, 1985). MacGregor (1988a) used computer-based assistance with vocabulary words to study the effects of motivation, learner control, and collaboration on third-grade readers' vocabulary learning, passage comprehension, and time on task. She found differences in vocabulary learning but her treatments varied as to the type of motivation (extrinsic vs. intrinsic) and the social environment for learning (independent vs. students working in pairs at the computer). In addition, because her study focused on making recommendations for designing computer-mediated text systems, she did not use an off-line group for comparison to the computer-based treatment conditions. In previous studies, therefore, it has not been possible to assess unequivocally the effects of computer-based assistance with difficult words during independent reading on the knowledge of those words and on the comprehension of the texts in which they appeared. A second purpose of the present study, therefore, was to clarify the results of previous research by focusing exclusively on the availability of on-line or off-line assistance with difficult words during independent reading.

Another issue that has emerged from the studies investigating computer-mediated texts is the degree to which the reader or the computer controls the assistance provided by the computer. Unlike conventional texts, for example, computer-mediated texts can restrict a reader's access to a text based on contingencies specified in a computer program (Wilkinson, 1983). The research pertaining to the issue of learner control has produced mixed findings across a wide range of content and instructional activities (see Carrier, 1984) including learning from computer-mediated text (Reinking & Bridwell-Bowles, 1991). In some studies comprehension has increased significantly only when the computer has required readers to view specified textual manipulations (e.g., Reinking & Schreiner, 1985). In other studies comprehension also increased when readers were permitted to select freely from among several options for computer-based assistance (e.g., Reinking, 1988). There is some evidence that mature readers do not accurately monitor their own learning of word meanings presented via computer-based instruction (Balajthy, 1988). MacGregor (1988a) also found increased vocabulary learning, but not increased comprehension, when a computer-mediated text required third-grade subjects to review specific vocabulary words prior to reading experimental passages. A third purpose of the present study, therefore, was to investigate the effects of providing readers with optional or required computer-based assistance in determining the meanings of difficult words.

METHOD

Subjects

The subjects in this experiment were 60 sixth-grade students who attended a suburban public school in an upper-middle class community. The sample was racially heterogeneous, though predominantly Caucasian, and included 33 girls and 27 boys. Prior to their participation in this study, subjects had frequently used computers to complete academic tasks in their school and many had computers in their homes. None of the subjects' reading performance was more than one grade level below their assigned grade level as determined by their placement in a developmental reading program; placement in the reading program had been determined by an informal evaluation conducted by each subject's teacher at the end of the previous school year. Poor readers were not included in this study in order to reduce the possibility that decoding difficulties would affect experimental outcomes. In addition, in several previous studies focusing on computer-mediated texts reading ability has not interacted with the variables included in this study (MacGregor, 1988a, 1988b; Reinking, 1988; Reinking & Schreiner, 1985).

Materials

Stimulus materials. Two passages from the sixth-grade textbook in the Scott, Foresman Science series (Cohen, Del Giorno, Harlan, McCormack, & Staver, 1984) were used in this study. Readability estimates computed with the Fry formula indicated that both passages were at the sixth-grade level. Each passage was an intact subsection from two chapters related to the human body. One passage entitled *Bones in Your Body* was 404 words long; the other passage entitled *Food Digestion in Your Body* was 615 words long. Each passage was followed by 10 multiple-choice comprehension items. Upon completion of both passages and the multiple-choice items, subjects completed a 32-item vocabulary test.

These passages were selected for several reasons. First, they were representative of informational reading materials that subjects in the experiment were required to read in school. Second, like many texts that are required reading in school subjects, they contained several notable low-frequency words; most of these words were technical terms related to the content (e.g., marrow, ligaments, cartilage, enzymes, hydrochloric acid, pancreas, etc.), but others were not (e.g., absorbed, contract, durable, etc.). Several of these words had explicit contextual clues to their meaning available in the text (e.g., the statement "glands make enzymes that further digest proteins" from the passage is an explicit clue as to the function of enzymes). Lastly, subjects had not read the passages previously and the topics had not been presented to subjects during the previous two years of science instruction.

Thirty-two difficult words were identified across both of the experimental passages (14 words from the passage about bones and 18 from the passage about

digestion). These target words were selected by a panel of eight middle-school science teachers who were asked individually to read the experimental passages and to identify the words that they believed might hinder the understanding of a typical sixth-grade student assigned to read the passages independently. A word selected by four or more of the teachers was considered a difficult word. For each target word, the experimenters wrote a definition that fit the context of the experimental passage in which the target word appeared. These definitions ranged from a single-word synonym to a 15-word phrase. The text of the experimental passages, the target words in each passage, and sample definitions are included in Appendix A.

Four versions of the stimulus materials corresponding to the four treatment conditions were prepared as follows:

1. *Dictionary condition:* Passages were presented on typed pages and were accompanied by a Scott, Foresman, Intermediate Dictionary. Each of the target words (or a root of the target word) was included in the dictionary, as was a definition appropriate to the context of the respective experimental passage.
2. *Glossary condition:* Passages were presented on typed pages and were accompanied by a separate typed glossary page containing the target words and their meanings as used in the passages. Subjects were directed to circle any words that they looked up on the glossary page.
3. *Select-definitions condition:* Passages were presented on a computer screen. Subjects could request that the computer provide a context-specific definition for any or all of the target words. Each computer screen displaying a section of the text enabled readers to request the definitions of words on that screen. Subjects were able to move freely among the individual computer screens.
4. *All-definitions condition:* Passages were presented on a computer screen. Subjects were required to view the context-specific definition of each target word immediately after the screen on which it appeared. That is, subjects could not proceed to a subsequent segment of the text until they had viewed the meanings of the target words in the previous segment. After each screen, subjects were permitted to review any of the previous text or the meanings of any of the previous target words.

Dependent measures. A 10-item, multiple-choice test developed by the experimenters was administered after subjects had finished reading and studying each passage. Five of the 10 items were text explicit and 5 were text implicit as defined by Pearson and Johnson (1978). Items were ordered randomly by item type but they were presented in a fixed order to all subjects. The experimenters also developed a 32-item vocabulary test containing one item for each of the 32 target words. The vocabulary test used a modified cloze format consisting of sentences containing a blank space, each followed by three words. The subjects' task on this test was to select among the three words to fill the blank space in each sentence. Distractors

were words that were clearly incorrect, but that were syntactically appropriate in the sentence and that appeared in the same passage as the correct word. The modified cloze format was selected because we wished to avoid testing vocabulary learning with the definitions provided in the treatment conditions. Anderson and Freebody (1981) have also argued that multiple-choice sentence completions in which distractors maximize the discriminating power of items are useful for measuring relative (as opposed to absolute) vocabulary learning as was our interest in this experiment. The comprehension test and the vocabulary test were administered off-line in all treatment groups because at least one study (Heppner, Anderson, Farstrup, & Wiederman, 1985) has found statistically significant differences when comparing scores on a standardized reading test that was administered on-line or off-line. Sample items from the comprehension test and the vocabulary test for the passage about bones are included in Appendix A.

Apparatus. On-line treatment conditions were carried out at two work stations each equipped with a standard Radio Shack TRS-80 system consisting of a TRS-80 Model IV computer (64K), a disk drive, and a monochrome monitor. Having completed a variety of educational activities at these work stations prior to the experiment, subjects were familiar with the work stations. The texts consisted of upper- and lowercase letters and were displayed on alternate lines available on the computer screen. In addition to displaying the texts and providing access to the definitions of the target words, the computer was programmed to record which of the target words subjects in the select-definition condition requested to be defined. The computer programs were written in TRS-DOS BASIC.

Procedure

After being assigned randomly to one of the four treatment conditions, the subjects were scheduled for participation in the study. The subjects were dismissed four at a time from their regular classroom activities (one subject from each treatment condition) and reported to the school's media center, a corner of which contained two computer work stations. When subjects reported to the media center, they were informed that their participation in the experiment would not affect their school grades, but they were encouraged to do their best in order to help the experimenters learn more about reading. General directions given to all subjects included informing them that they were to read and to study two passages and that they would be asked some questions about what they had read when they were finished. They were also informed that the passages might contain some unfamiliar words, but that they would not be permitted to ask anyone for help with these words. These general directions were followed by a practice passage that familiarized subjects with the conditions of their respective treatment conditions. Subjects (except for those in the all-definitions condition) were encouraged individually to investigate the meanings of unfamiliar words with the resources available to them.

The experimenters inconspicuously monitored subjects' reading and were available to offer assistance with procedures or equipment; little assistance was necessary. When subjects had completed reading both passages (presented in counter-balanced order within treatment conditions) and had responded to the comprehension items that followed each passage, they signaled an experimenter who then asked them to complete the vocabulary test. Subjects were separated physically so that they could not easily attend to the work of other subjects. The experimental activities required approximately 50 minutes and upon completion of these activities subjects were thanked for participating in the experiment and were dismissed to their regular classrooms.

RESULTS

Vocabulary Test

Each subject's vocabulary score represented the total number of correct responses on the 32-item vocabulary test. Across the four treatment conditions the means and standard deviations were, respectively: (a) 26.4 and 2.2 for the dictionary condition, (b) 26.5 and 2.2 for the glossary condition, (c) 28.7 and 1.6 for the select-definitions condition, and (d) 29.4 and 1.8 for the all-definitions condition. A one-way analysis of variance (ANOVA) was employed to test for statistically significant differences among means across treatment conditions.

The results indicated a significant effect for treatment condition, $F(3, 56) = 9.15, p < .001$. Newman-Keuls post hoc comparisons of means for treatment conditions indicated that the mean for the all-definitions group ($M = 29.4$) was statistically different from the means of the dictionary group ($M = 26.4$) and the glossary group ($M = 26.5$). The mean for the select-definitions group ($M = 28.7$) was also statistically different from the means of the dictionary group and the glossary group. These results suggest that treatment was a factor that affected subjects' learning of the meanings of the target words. The all-definition and select-definitions groups learned more of the target words' meanings than did the dictionary or glossary groups.

Definitions Selected

Because the computer was programmed to record the words that subjects in the select-definition condition requested to be defined, it was possible to determine the number of target words that were selected by each subject in that condition. Similarly, subjects in the glossary condition circled words that they looked up in the glossary. We did not direct subjects in the dictionary condition to identify words they had looked up because we believed that such a direction might lead them to look up more words than they ordinarily would have looked up on their

own. On the other hand, directing subjects in the glossary group to identify the words they looked up created off-line conditions approximately equivalent to the select-definitions group, which permitted us to determine if any effects might be due to using printed pages or the computer to access word meaning. For the glossary condition the mean number of words selected was 2.1 and the standard deviation was 1.5. For the select-definitions condition the mean number of words selected was 4.8 and the standard deviation was 4.2. Means were compared using a *t*-test for uncorrelated samples. The results indicated a statistically significant difference between the two treatments, $t(28) = 6.59, p < .01$. These data suggest that across both passages, subjects in the on-line, select-definitions condition investigated the meanings of more words ($M = 4.8$ per passage) than did subjects in the off-line, glossary condition ($M = 2.1$ per passage).

Comprehension Test

Each subject responded to five text explicit and five text implicit multiple-choice items after each of the two experimental passages. The number of correct responses to these items represented a subject's comprehension score. Means and standard deviations for comprehension scores by treatment condition, passage, and item type are given in Table 1. These means were compared using a three-way ANOVA for a $4 \times 2 \times 2$ (Treatment \times Passage \times Item Type) mixed factorial design in which treatment condition was the between-subjects factor and passage and item type were within-subjects factors.

The results indicated a main effect for treatment condition, $F(3, 56) = 3.00, p < .05$, and for item type, $F(1, 56) = 21.50, p < .001$. Newman-Keuls post hoc

Table 1

Means and Standard Deviations for Comprehension Scores

Question Type	Treatment							
	Dictionary		Glossary		Select-Definitions		All-Definitions	
	Bones	Digestion	Bones	Digestion	Bones	Digestion	Bones	Digestion
Text Explicit								
<i>M</i>	3.9	3.3	3.8	2.9	4.0	3.7	4.0	3.9
<i>SD</i>	.9	1.2	.9	.8	.9	1.0	.7	1.1
Text Implicit								
<i>M</i>	2.7	2.6	2.8	3.3	2.8	3.5	3.5	3.8
<i>SD</i>	1.4	1.0	.9	1.1	1.4	.6	1.1	.9

Note. Maximum score = 5. $n = 15$ for each cell.

comparisons yielded a statistically significant difference between the all-definitions treatment condition ($M = 3.8$) and the dictionary treatment condition ($M = 3.1$). The interaction effect for passage and item type was also statistically significant, $F(1, 56) = 13.79, p < .001$. Newman-Keuls post hoc comparisons yielded a statistically significant difference between the number of correct responses to text explicit items ($M = 3.93$) and to text implicit items ($M = 2.98$) for the passage on bones but not for the passage on digestion. These data suggest that treatment condition affected comprehension of the experimental passages. The all-definitions group scored higher on the comprehension test than did the dictionary group. As expected, text implicit items were apparently more difficult than were text explicit items. However, the interaction effect suggests that although text explicit items were easier across both passages, the main effect for item type was due primarily to the statistically significant difference between text explicit and text implicit items on the passage about bones.

DISCUSSION

The results of the present study suggest that providing intermediate-grade readers with the meanings of difficult words while reading short, informational texts presented by a computer may affect positively their vocabulary learning and comprehension. Subjects reading computer-mediated texts that provided definitions of words identified by teachers as being difficult scored higher on a vocabulary test over these words than did subjects reading the same texts displayed conventionally on printed pages, even though the latter subjects had access to a dictionary or a glossary defining the difficult words. Subjects reading computer-mediated texts also scored higher on a comprehension test than did subjects reading the texts off-line, but this was the case only for subjects required by the computer to view the definitions of every target word.

There is evidence in this experiment that the superior performance on the vocabulary test among subjects reading computer-mediated texts was due to increased attention to the target words' meanings during reading. Subjects in the all-definitions condition were required to view the definition of every target word and subjects in the select-definitions condition chose to investigate on the average approximately 9 of the 32 target words identified in the experimental passages. Based on their self-reports, subjects in the off-line glossary condition, on the other hand, investigated on the average only about 2 of the 32 target words.

The lack of a significant difference in vocabulary scores between the two on-line groups indicates that when considering vocabulary learning alone there was little advantage to requiring all subjects to view a definition of every difficult word. Apparently, the subjects in this experiment who were free to choose among the difficult words to investigate were effective in selecting those words for which

computer-based assistance was most useful for increasing vocabulary learning. These results add to the mixed findings reported in previous studies investigating the effects of reader versus computer control of computer-based assistance during reading. MacGregor (1988a), for example, found that third-grade students' vocabulary learning increased only when the computer required students to view vocabulary words prior to reading. Similarly, Gillingham, Garner, Guthrie, and Sawyer (1989) found that fifth-grade subjects reading science texts comprehended more when the computer prescribed assistance including the meanings of difficult words highlighted in the text. They also found that subjects frequently chose not to use the computer-based assistance even when the selection of particular forms of assistance appeared to be useful. Other studies suggest that the apparent advantages of computer control may be due in part to increases in reading and study times (cf. Reinking, 1988; Reinking & Schreiner, 1985). Cumulatively these findings suggest that recommendations about reader vs. computer control may need to take into account a variety of factors including the type of assistance available, the effects of assistance on reading and study times, text-specific factors such as topic and difficulty, characteristics of the reader such as background knowledge, age, and metacognitive skill and whether comprehension or vocabulary learning is considered.

An important question raised by the results of this study relates to the difference between the number of words investigated by subjects in the glossary and the select-definitions conditions. Both groups had immediate access to context-specific definitions of the target words, yet subjects using the computer investigated the meanings of significantly more words. One explanation is that subjects in the offline, glossary condition did not report every word investigated. This explanation is contradicted, however, by the superior performance of the select-definitions group on the vocabulary test. Another explanation is that the computer was a novelty that encouraged more activity among subjects in the select-definitions condition. Subjects in this experiment, however, had used the computer frequently prior to this experiment and it is unlikely that it was a novelty. The experimental task (i.e., using the computer to investigate word meanings) was novel, however, and this may have contributed to differences. Learners' attributions to various instructional media have also been shown to affect learners' expectations about learning and subsequently the cognitive effort they devote to learning tasks (Salomon, 1984). Subjects may have devoted more attention to difficult words in the computer condition because they attributed different characteristics to reading and learning from texts presented by a computer. More research is necessary to shed light on these possible explanations.

When compared to the results of the vocabulary test, the results of the comprehension test are also difficult to interpret unequivocally. A reasonable explanation for the higher comprehension scores among subjects in the all-definitions group is that they had also learned the meanings for more of the difficult words. This

explanation, however, implies that the select-definitions subjects would have also had higher comprehension scores, due to their greater knowledge of the meanings of the target words, but this was not the case. Although these findings appear to be contradictory, they are consistent with previous research investigating the relation between vocabulary knowledge and comprehension. Familiarity with the appropriate meaning of words used in a text has been shown to be a necessary, but not sufficient, condition for comprehending that text (Anderson & Freebody, 1981). Perhaps the presentation of difficult words at the end of each screen in the all-definitions condition stimulated deeper processing of the text on that or subsequent screens. In this regard, it is important to note that one might have expected this textual presentation to be intrusive and to produce a decrease in comprehension. Apparently, it did not have this effect. Another possible explanation is that requiring subjects to make decisions concerning which words to investigate may interfere with other comprehension processes. Thus, for subjects in the select-definitions condition there may have been a trade-off between comprehension gains due to increased vocabulary knowledge and a loss of comprehension due to this interference. The subjects in the all-definitions group, on the other hand, may have benefitted from their increased knowledge of the difficult words without this interference because they were not required to make decisions about which words to investigate.

These findings may also be interpreted in terms of Freebody & Anderson's (1983) minimal effort principle. This principle states that when a text contains difficult words, readers prefer to compensate for the difficulty of these words by focusing on other, more familiar aspects of the text for comprehension. Subjects in three treatments were free to investigate any of the target words and they may have adopted a usual strategy of selecting a minimal number of words, while depending primarily on more familiar aspects of the text for comprehension. The comprehension of subjects required to view the definition of every target word may have increased because their treatment condition required them to deal more directly with critical concepts, even if this requirement conflicted with their usual inclinations.

Several considerations limit the interpretation and generalization of the present findings. Subjects' prior knowledge was controlled only by the fact that the topics of the experimental passages had not been presented to subjects in their science classes during the two years prior to the experiment. Research published after the completion of the present study suggests that prior knowledge may be especially important in comprehending science texts discussing topics about which readers have misconceptions (Hynd & Alvermann, 1989). Another consideration is the effect of the treatment conditions on the time subjects devoted to reading and investigating words. The present study did not investigate differences in the time subjects devoted to the experimental tasks. Previous research indicates that com-

puter-based textual manipulations such as those used in this study do affect reading and study times but that these differences do not have a statistically significant effect on measures of comprehension (Reinking, 1988).

In the present study it is not possible to deduce the rationale subjects used for selecting and attending to the target words. Did they choose to investigate a word specifically to increase their knowledge of the word's meaning, to remove a barrier to comprehension, or for other reasons? It is also likely that subjects' criteria for selecting a word would be influenced by directions or instruction given prior to reading. For example, many teachers follow the recommended practice of building background knowledge and introducing difficult words prior to having students read an informational text. In the present study subjects were only informed that the texts might contain some difficult words. Providing subjects with a different orientation to the experimental task via directions or instruction may affect the results reported here.

The present study adds to a growing research literature suggesting that reading comprehension can be increased when computer-mediated texts are used to expand or to control options for acquiring information in ways that are not feasible without a computer. The results of the present study suggest that increases in comprehension found in other studies employing such texts may be due in part to the requirement that subjects view the meanings of difficult words (e.g., Reinking, 1988; Reinking & Schreiner, 1985). Furthermore, the present study suggests that the learning of difficult words during the independent reading of informational texts may be enhanced with the aid of a computer. The limited availability of computer-mediated texts such as those used in this experiment suggests that for the present vocabulary learning during independent reading will remain associated with printed texts. Nonetheless, the findings of this and related studies support the belief that computer technology will lead to important new options for enhancing learning during reading.

REFERENCES

- Anderson, R. C., & Freebody, P. (1981.) Vocabulary knowledge. In J. T. Guthrie (Ed.), *Comprehension and teaching: Research reviews* (pp. 77-117). Newark, DE: International Reading Association.
- Balajthy, E. (1988). An investigation of learner-control variables in vocabulary learning using traditional instruction and two forms of computer-based instruction. *Reading Research and Instruction*, 27, 15-25.
- Blohm, P. (1982). Computer-aided glossing and facilitated learning in prose recall. In J. A. Niles & L. A. Harris (Eds.), *New inquiries in reading research and instruction*. Thirty-first yearbook of the National Reading Conference (pp. 24-28). Rochester, NY: National Reading Conference.
- Carrier, C. (1984). Do learners make good choices? *Instructional Innovator*, 29, 15-17.

- Cohen, M. R., Del Giorno, B. J., Harlan, J. D., McCormack, A. J., & Staver, J. R. (1984). *Science*. Glenview, IL: Scott, Foresman.
- Daniel, D. B., & Reinking, D. (1987). The construct of legibility in electronic reading environments. In D. Reinking (Ed.), *Reading and computers: Issues for theory and practice* (pp. 24–39). New York: Teachers College Press.
- Duchastel, P. (1986). Computer text access. *Computer Education*, 10, 403–409.
- Duchastel, P. C. (1988). Display and interaction features of instructional text and computers. *British Journal of Educational Technology*, 19, 58–65.
- Freebody, P., & Anderson, R. C. (1983). Effects on text comprehension of differing proportions and locations of difficult vocabulary. *Journal of Reading Behavior*, 25, 19–39.
- Gillingham, M. G., Garner, R., Guthrie, J. T., & Sawyer, R. (1989). Children's control of computer-based assistance in answering synthesis questions. *Computers in Human Behavior*, 5, 61–75.
- Heppner, F. H., Anderson, J. G. T., Farstrup, A. E., & Weideman, N. H. (1985). Reading performance on a standardized test is better from print than from computer display. *Journal of Reading*, 28, 321–325.
- Herman, P. A., Anderson, R. C., Pearson, P. D., & Nagy, W. E. (1987). Incidental acquisition of word meaning from expositions. *Reading Research Quarterly*, 22, 263–284.
- Hynd, C. R., & Alvermann, D. E. (1989). Overcoming misconceptions in science: An on-line study of prior knowledge activation. *Reading Research and Instruction*, 28, 12–26.
- Jenkins, J. R., Stein, M. L., & Wysocki, K. (1984). Learning vocabulary through reading. *American Educational Research Journal*, 21, 767–787.
- MacGregor, S. K. (1988a). Instructional design for computer-mediated text systems: Effects of motivation, learner control, and collaboration on reading performance. *The Journal of Experimental Education*, 56, 142–147.
- MacGregor, S. K. (1988b). Use of self-questioning with a computer-mediated text system and measures of reading performance. *Journal of Reading Behavior*, 20, 131–148.
- McKeown, M. G. (in press). Learning word meanings from definitions. In P. Schwanenflugel (Ed.), *The psychology of word meanings*. Hillsdale, NJ: Erlbaum.
- McKeown, M. G. (1985). The acquisition of word meaning from context by children of high and low ability. *Reading Research Quarterly*, 20, 482–496.
- Miller, A. G., & Gildea, P. M. (1985). *How to misread a dictionary*. Unpublished manuscript, Princeton University, Princeton, NJ.
- Nagy, W. E., Herman, P. A., & Anderson, R. C. (1985). Learning words from context. *Reading Research Quarterly*, 20, 233–253.
- Pearson, P. D., & Johnson, D. D. (1978). *Teaching reading comprehension*. New York: Holt, Reinhart & Winston.
- Reinking, D. (1988). Computer-mediated text and comprehension differences: The role of reading time, reader reference, and estimation of learning. *Reading Research Quarterly*, 23, 484–498.
- Reinking, D. (1987). Computers, reading, and a new technology of print. In D. Reinking (Ed.), *Reading and computers: Issues for theory and practice* (pp. 3–23). New York: Teachers College Press.
- Reinking, D. (1983). *The effects of computer-mediated text and reader study behavior on measures of reading comprehension*. Unpublished doctoral dissertation, University of Minnesota, Minneapolis.
- Reinking, D., & Bridwell-Bowles, L. (1991). Computers in reading and writing. In R. Barr, M. L. Kamil, P. B. Mosenthal, & P. D. Pearson (Eds.), *Handbook of reading research* (Vol. 2). New York: Longman.
- Reinking, D., & Schreiner, R. (1985). The effects of computer-mediated text on measures of reading comprehension and reading behavior. *Reading Research Quarterly*, 20, 536–552.
- Salomon, G. (1984). Television is "easy" and print is "tough." The differential investment of mental effort in learning as a function of perceptions and attributions. *Journal of Educational Psychology*, 76, 647–658.

Wilkinson, A. C. (1983). Learning to read in real time. In A. C. Wilkinson (Ed.), *Classroom computers and cognitive science* (pp. 183–199). New York: Academic Press.

APPENDIX A

Experimental Passages*

Bones in Your Body

You might not think of your bones as living *tissue*, because bones seem so *durable*. But your bones are as alive as your brain. Your bones work together to form a living system that gives you *support*, helps you move, and makes blood cells.

There are three parts of a living bone. The outer layer is a tough, *protective* coat for your bones. If a bone breaks, this coating helps mend it. Just inside the outer layer is the bone itself. Bone is made of bone cells. Blood vessels from the outer coat *penetrate* the bone. The bone cells take *minerals* from the blood and arrange the minerals in rings. These rings of minerals make your bones *sturdy*. The center of your blood cells are made by the *marrow*.

Bones have different shapes. The shape of a bone is a clue to what the bone does. Your curved skull bones *enclose* your brain and protect it from injury. The curved shape of the bone is perfect for giving protection. The hip or pelvic bone supports the weight of the upper body. Its wide, dish-like shape is perfect for giving this support. Your long, thin arm bone acts as a *lever*. The arm bone's shape makes it easy for you to lift and move things.

Your bones are connected to each other at the joints. Fixed joints do not allow your bones to move. The bones in a fixed joint fit together like puzzle pieces. The skull bones join at fixed joints.

Other kinds of joints allow your bones to move in different ways. Your lower arm can swing back and forth like a door hinge. The hinge joint in your elbow allows this back and forth motion. Your upper arm can *rotate*. The ball-and-socket joint in your shoulder allows this circular motion. All moving bones are connected at joints by *ligaments*.

Cartilage is found at the ends of many bones. It keeps the bones from rubbing at joints. Your bones were made almost entirely of cartilage when you were very young. As you grow, bone cells replace most of the cartilage in your bones.

Food Digestion in Your Body

Think of what you ate for lunch yesterday. Perhaps you had a peanut butter sandwich, a glass of milk, and an apple. You eat a wide variety of foods.

Foods are made of *nutrients* that your body needs. Carbohydrates are one kind of nutrient. Bread is made mostly of *carbohydrates*. Peanut butter contains other nutrients, such as *fats* and *proteins*. Most foods also contain vitamins and minerals. Water is another nutrient found in most foods. Your body needs carbohydrates, fats, proteins, vitamins, minerals, and water to work properly and stay healthy.

Most nutrients are *complicated chemicals*. Digestion is the process of breaking down

complicated chemicals in nutrients into forms that the body can use. *Enzymes* aid digestion by speeding up the chemical breakdown of your food.

Digestion begins in your mouth. When you chew, your teeth break your food into smaller pieces. *Saliva* mixes with the food to make it soft and moist. An enzyme in saliva begins breaking down the carbohydrates in the food. Your tongue moves the food around and forms it into a soft ball that you swallow.

When you swallow, food moves from your throat down the *esophagus* to your stomach. Your stomach is a thick-walled muscular pouch that stretches when full and folds up when empty. The wrinkled inner surface of the stomach stretches and becomes smooth when the stomach is full of food.

Glands in the walls of your stomach release different substances that help you digest your food. Some glands release *hydrochloric acid* that kills any harmful organisms in your food. It also clumps proteins together and begins breaking them down. Other glands make enzymes that further digest proteins.

The muscular walls of your stomach *contract* and relax, mixing your food with fluids from your stomach's glands. The lining of your stomach is coated with mucus which protects your stomach from strong acids and enzymes.

After digesting in your stomach for several hours, your food becomes a paste-like mixture. Muscles in your stomach squeeze a small amount of the mixture into the small *intestine*.

Glands in the walls of your small intestine make enzymes that continue the breakdown of carbohydrates and protein that began in the mouth and stomach. The *pancreas* releases other enzymes into the small intestine. These enzymes help digest carbohydrates, proteins, and fats. The liver releases *bile* into the small intestine which helps digest fats.

The breakdown of food in the small intestine takes four to eight hours. When digestion is completed, food materials are in a thin, watery form that can be *absorbed* into the blood stream. Each of the tiny *fibers* on the inner surface of the small intestine has tiny blood vessels that absorb nutrients.

Food that is not absorbed from your small intestine moves on to the large intestine. Vitamins, minerals, and water from your digestive *fluids* are absorbed by the large intestine. Much water is used to make digestive fluids. If your large intestine did not absorb the water, your cells would dry up, and you would die.

The remaining unabsorbed materials are in the form of solid *wastes*. Your large intestine passes the waste out of the body.

*Note: Target words are italicized, but they were not italicized in the experimental materials.

Sample Definitions

durable: able to withstand much wear
 ligaments: material that holds bones together

Sample Items from the Comprehension Test

In what part of the bones are blood cells made?

1. in the center

2. in the outer coat

3. in the bone itself

How does an adult's bone compare to a baby's bone?

1. The adult's bone has more cartilage.

2. The baby's bone has more cartilage.

3. They both have the same amount of cartilage.

Sample Items from the Vocabulary Test

A hard _____ shell shields a turtle from injury.

connective

protective

supportive

The football player tore _____ in his knee.

marrow

minerals

ligaments