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Computer-mediated text and comprehension differences: The role of reading time, reader preference, and estimation of learning

DO READERS comprehend a text better when it is displayed electronically by a computer (computer-mediated) than when displayed conventionally, on printed pages? Previous studies have suggested that computer presentations that offer the reader access to additional information, or control the reader's processing of the text, do facilitate comprehension. The author attempted to replicate these findings. In addition, he investigated whether computer presentations of texts would affect readers' passage preference, their estimation of their own learning, and the time taken to read the text, and whether these factors in turn would contribute to comprehension differences. Thirty-three good and poor readers in fifth and sixth grade read expository passages on a printed page and in three computer presentations that varied as to the availability of computer assistance, and whether the computer or the reader controlled the computer manipulations. As in previous studies, subjects' comprehension increased when they read computer-mediated texts that expanded or controlled their options for acquiring information. As expected, reading time was longer for the computer-mediated texts with options for assistance, but even after the effect of reading time was removed statistically, comprehension scores remained significantly higher for readers of the computer-mediated texts that offered computer assistance. Based on the results, the author attempts to clarify which factors associated with computer-mediated texts may affect reading comprehension.

Différences dans la compréhension de textes sur ordinateur: Effets du temps de lecture, des préférences du lecteur et de l'auto-évaluation de l'apprentissage

EST-CE QUE les lecteurs comprennent plus facilement un texte présenté sur ordinateur que sous la forme imprimée? Des recherches antérieures ont semblé montrer que la compréhension de texte était meilleure sur ordinateur en raison des possibilités qu'offre l'ordinateur d'accéder à des informations complémentaires ou de contrôler les processus de traitement du lecteur. L'objectif d'auteur était, d'une part, de tester ces conclusions, d'autre part, de voir dans quelle mesure la présentation de textes sur ordinateur influencerait les préférences du lecteur, l'auto-évaluation de l'apprentissage et le temps pris pour lire le texte et finalement de voir dans quelle mesure ces trois facteurs influencent la compréhension. Trente-trois enfants de cinquième et de sixième année, divisés en bons et mauvais lecteurs,

ont lu des extraits de textes informatifs dans une situation sans ordinateur (texte imprimé) et dans trois conditions qui variaient selon l'aide disponible sur ordinateur et selon que la présentation du texte était contrôlée par le lecteur ou par l'ordinateur. A l'instar des recherches précédentes, la compréhension a été meilleure dans la condition contrôlée par ordinateur et dans la condition avec aide. Tel que prévu, le temps de lecture fut plus long pour la condition assistée par ordinateur mais même une fois enlevé l'effet du temps de lecture, la compréhension est restée meilleure pour la condition assistée par ordinateur. S'appuyant sur ces résultats, les auteurs tentent d'approfondir la question et de cerner quels autres facteurs sont susceptibles d'intervenir dans la lecture de textes assistée par ordinateur.

Texto presentado a través de computadoras y diferencias en la comprensión: El rol del tiempo de lectura, preferencias del lector y la estimación del aprendizaje

¿ES CIERTO que los lectores comprenden mejor un texto cuando este es presentado electrónicamente por una computadora (por medio de computadora) que cuando es leído de una página impresa? Estudios previos han sugerido que las presentaciones en la computadora que ofrecen al lector acceso a información adicional, o que controlan el procesamiento del texto por el lector, sí facilitan la comprensión. El autor intentó replicar estos hallazgos. Además, investigó si la presentación de textos por computadora afectaría las preferencias del lector, su estimación del aprendizaje propio, y el tiempo que les llevaría leer el texto, y si estos tres factores a su vez contribuirían a entender diferencias en la comprensión. Treinta y tres buenos y malos lectores de quinto y sexto grado leyeron pasajes expositivos en una página impresa y en tres condiciones experimentales que variaron según el acceso a la ayuda por computadora, y dependiendo de si la computadora o el lector controlaba las manipulaciones de la computadora. Como en estudios anteriores, la comprensión de los sujetos aumentó cuando leyeron textos por medio de la computadora si esta expandía o controlaba sus opciones para adquirir información. Como se esperaba, el tiempo de lectura fue mayor para los textos por medio de computadora, pero aún después de que el efecto del tiempo de lectura fue removido estadísticamente, las calificaciones de comprensión permanecieron significativamente más altas para los lectores de textos por medio de la computadora que ofrecían asistencia de la computadora. Basado en los resultados, los autores trataron de clarificar cuáles factores asociados con los textos presentados por medio de la computadora pueden afectar la comprensión de la lectura.

Computervermittelter Text und Unterschiede beim Verstehen: Die Rolle der Lesezeit, Lesematerialbevorzugung und Lernbeurteilung

VERSTEHEN LESER einen Text besser, wenn er elektronisch durch einen Computer (computervermittelt) dargestellt wird oder wenn er als gedruckter Text gelesen wird? Jüngere Forschungen haben angedeutet, daß Computerdarstellungen, die dem Leser Zugang zu weiteren Informationen anbieten oder die Textverarbeitung seitens der Leser steuern, ein Verstehen tatsächlich erleichtern. Der Autor dieses Beitrags versucht, jene Resultate zu reproduzieren. Der weiteren untersucht sie, ob die Textdarstellungen anhand eines Computers die Lesematerialbevorzugungen der Leser, deren eigene Lernbeurteilungen und die zum Lesen aufgewendete Zeit beeinflussen würden, und ob diese drei Faktoren wiederum zu Unterschieden im Verstehen beitragen. Dreiunddreißig gute und schlechte Leser der fünften und sechsten Klasse lasen Abschnitte aus Erörterungstexten unter kontrollierten Bedingungen (gedruckter Text) und unter drei experimentellen Bedingungen, die in bezug auf drei Punkte variierten: war Computerunterstützung vorhanden, wurden Computermanipulationen durch den Computer kontrolliert, oder wurden sie durch den Leser

kontrolliert. Wie bereits in jüngeren Forschungen festgestellt wurde, verbesserte sich das Textverständnis der Teilnehmer, wenn sie computervermittelte Texte lasen, die die Möglichkeiten eines Informationserwerbs erweiterten oder kontrollierten. Wie erwartet war die Lesezeit für die computervermittelten Texte länger; aber auch dann, als die Auswirkung der Lesezeit statistisch neutralisiert wurde, waren die Leistungen bei Leseverständnistesten für die Leser der computervermittelten Texte, die Computerunterstützung zur Verfügung stellten, wesentlich besser. Aufgrund der Ergebnisse versuchen diese Autoren klarzustellen, welche Faktoren, die auf computervermittelte Texte zutreffen, ein Leseverstehen beeinflussen können.

A number of researchers have compared readers' comprehension of text displayed electronically by a computer (computer-mediated text) with their comprehension of text displayed conventionally, on printed pages. The results of several studies indicate that presenting a text with the aid of a computer may increase comprehension (Anderson et al., 1974; Blohm, 1982; L'Allier, 1980; Reinking & Schreiner, 1985). In other studies computer presentation of text has had no apparent effect on comprehension (Fish & Feldmann, 1987; Gambrell, Bradley, & McLaughlin, 1985; Muter, Latremouille, Treurniet, & Beam, 1982). Other studies suggest that computer presentation of text may have a negative effect on factors associated with reading comprehension (e.g., Haas & Hayes, 1985a, 1985b; Heppner, Anderson, Farstrup, & Weideman, 1985).

In studies that have found increases in reading comprehension, the computer has been employed to expand or control readers' options for acquiring information from the text in ways that are not feasible without a computer. For example, Blohm (1982) investigated the effects of a computer presentation that permitted college students to request information helpful to understanding the text they were reading. He found that subjects who had an option to use these "computer-aided glosses" recalled more idea units than did subjects who did not have this option. L'Allier (1980) employed a computer to adapt the organizational structure of text. The computer automatically adapted the text for individual readers based on their reading time, response times for interspersed questions, and performance on comprehension probes. He concluded that when the computer

adapted the text to accommodate individual needs, high school students who were poor readers comprehended text as well as good readers who read the same text on printed pages.

In an earlier study (Reinking & Schreiner, 1985), we used computer-mediated text to provide intermediate-grade readers with assistance when they experienced difficulty in comprehending short expository passages. These readers could request four options for assistance: a less technical version of the passage, definitions of key vocabulary, additional background information, and the main idea of each paragraph in the passage. We compared good and poor readers in four experimental conditions that varied as to the medium of presentation (the computer or the printed page), the availability of options for assistance, and whether the computer or the reader controlled selection of these options. We found that both good and poor readers would freely select textual manipulations during their reading. However, we also found that comprehension for both high- and low-difficulty texts was increased when the computer controlled readers' interactions with the text.

In these studies, increases in reading comprehension have been attributed to the unique technological characteristics of the computer display, which can be employed to affect readers' processing of text. In addition, several writers have proposed theoretical frameworks that highlight those characteristics of computers that may influence comprehension by effecting richer interactions between a reader and a text (Daniel & Reinking, 1987; Duchastel, 1986; Reinking, 1986, 1987). Current research, however, has not directly addressed which attributes

of computer presentations of texts may account for increases in reading comprehension, or how these attributes may interact with other factors related to comprehension.

Clark (1983) has argued that research does not support the idea that attributes of an instructional medium directly affect learning. Differences in learning, for example, may be attributed to a learner's perceptions about learning via a particular medium, rather than the characteristics of the medium itself. In an investigation of this theoretical position, Salomon (1984) compared subjects assigned to learn instructional content via either television or print. He found differences in subjects' perceptions of the difficulty in learning from these media, and these differing perceptions affected subjects' investment of mental effort and consequently their learning.

This finding and the issues raised by Clark (1983) suggest that increases in reading comprehension when texts are displayed by a computer may be confounded with readers' preconceptions about reading with the aid of a computer. Or, it is possible that readers might be more interested in reading material presented electronically by a computer, and this increased interest might account for differences in comprehension. Readers' interest in the content read has been shown to be a factor affecting reading comprehension (Wigfield & Asher, 1984). In fact, although they detected no difference in comprehension, Gambrell, Bradley, and McLaughlin (1985) found that third- and fifth-grade readers more often liked and enjoyed stories presented by the computer, even though these stories were identical to those presented on printed pages. Subjects also indicated, however, that the computer-mediated text was more difficult to read. The effect of these factors on the comprehension of other types of text, or texts presented in varying computer formats, is unknown.

Reading time is another factor that may affect comprehension of computer-mediated texts as compared with printed texts. Several studies have found that readers read texts displayed electronically more slowly than conventional texts. Gould and Grischkowsky (1983) found that reading times were longer for subjects who

read text displayed on a cathode-ray tube (CRT) than for subjects who read the same text displayed on printed pages. Hansen, Doring, and Whitlock (1978) found that students who completed an examination on a computer screen required more time than students who completed it on printed pages. Haas and Hayes (1985a) found that college students required more time to retrieve specific information from texts displayed on a computer screen than did subjects who read the same texts on printed pages. The time difference was not statistically significant, however, when each screen displayed more text and text-editing functions were added (such as the capability to search the text for a particular word).

More research is needed to determine whether variations in reading time may explain comprehension differences in studies comparing computer-mediated and conventional text. For example, Muter, Latremouille, Treurniet, and Beam (1982) found that the reading rate of subjects who read text from a video screen was 28.5% slower than when the same text was displayed in a book. Although no difference was found on a reading comprehension test, they described this test as "relatively insensitive." Blohm (1987), on the other hand, found no difference in reading and study times between subjects who read computer-mediated texts with "look-up" aids available and those who read computer-mediated texts in which these aids were not available. Comprehension was greater, however, for subjects using the look-up aids. In an earlier study (Reinking & Schreiner, 1985), we suggested that increased comprehension in one of the treatments involving computer-mediated text may have been due to increased reading and study times. One purpose of the present study was to investigate whether comprehension differences between conventional and various computer-mediated texts are related to reading time.

Another factor that may affect comprehension of computer-mediated text is whether the reader or the computer is more in control of the textual manipulations designed to aid comprehension. This factor is unique to computer-mediated texts. Conventional printed materials do not typically provide readers with an opportu-

nity to enhance their comprehension by overtly manipulating textual information; nor do they provide mechanisms for an investigator to control reliably what readers may attend to during independent reading. Computer-mediated texts, on the other hand, can provide overt textual manipulations that are either optional or required, depending upon predetermined contingencies.

For example, a computer-mediated text could allow a reader to request that a difficult term be defined or that an ambiguous sentence be rephrased. Based on an analysis of this or other requests for assistance, the computer might then require the reader to view the definitions of related terms prior to the display of subsequent text. Wilkinson (1983) has suggested that the basis of this control is the computer's capability to limit readers' access to text. A computer screen can be considered a "window" through which the reader may have selective access to a text (see also Daniel & Reinking, 1987; Reinking, 1987).

Little research has addressed how control by either the reader or the computer may affect comprehension of computer-mediated texts. In our earlier study (Reinking & Schreiner, 1985), we found that the comprehension of fifth- and sixth-grade subjects increased when the computer required the students to view all textual manipulations made available by the computer. The comprehension of subjects free to select the same textual manipulations also increased, but the comprehension of these subjects did not differ significantly from that of subjects reading texts without any manipulations. Our conclusions were also limited by an unexpected interaction between treatment and passage difficulty.

We hypothesized that this finding could be explained by evidence that younger readers may not have well-developed metacognitive skills (Baker & Brown, 1984). Readers in the intermediate grades may not be adept at determining what manipulations would be most helpful to aid their comprehension of the text, and thus they might benefit by the external control provided by the computer. There is also evidence that learners may not make efficient choices when they direct their own learning of unfamiliar content (Carrier, 1984). An alternative explanation, however, is that the subjects in the

study were unfamiliar with the computer or inexperienced in selecting appropriate textual manipulations provided by a computer.

Several factors, therefore, may affect comprehension when text is displayed by a computer. The purpose of the present study was to clarify the role of these factors. Specifically, the study addressed three objectives: (a) to attempt to replicate findings that comprehension increases when computer-mediated texts are used to expand or control readers' options for acquiring information from text, (b) to investigate whether readers' preferences, estimation of their own learning, and reading time are affected by type of textual presentation, and (c) to investigate whether these factors, in turn, contribute to comprehension differences when textual presentation varies.

These objectives were addressed by replicating in part a previous study (Reinking & Schreiner, 1985). Several modifications were implemented in the present investigation, however, in order to address limitations described in the earlier study. These modifications and the specific limitations they address will be discussed in the remaining sections of this report.

Method

Subjects

Subjects were 33 fifth- and sixth-grade boys and girls in an urban elementary school. The sample was racially heterogeneous. From school records I obtained each subject's score on the reading subtest of the California Achievement Tests. Scores ranged from the 3rd to the 95th percentile, and there was a normal distribution between these extremes. Subjects who scored below the 50th percentile were designated poor readers ($n = 19$, mean percentile = 29.5). Subjects scoring at or above the 50th percentile were designated good readers ($n = 14$, mean percentile = 68.2).

All subjects had participated previously in a regular program of computer-based instruction. During the school year prior to this study, subjects had attended a weekly class taught by a computer teacher in a room containing 15 Apple IIe computers. This class required subjects

to complete various educational activities using a computer, sometimes individually and sometimes in small groups. Data in the present study were gathered during one of these regular class periods in the second year of the program. Thus, two assumptions are reasonable concerning subjects in this study. First, subjects were proficient at using the Apple IIe computer that was employed. Second, due to their extensive previous use of the computer, their performance on the computer-based tasks required in this study was not greatly influenced by the novelty of using a computer to complete the tasks.

Because the present study replicates in part a previous study (Reinking & Schreiner, 1985), subjects were selected carefully in order to compare the results of the two studies. As in that study, subjects in the present study were fifth- and sixth-grade boys and girls in a racially heterogeneous, urban elementary school. However, subjects in the present study had much more experience in using Apple IIe computers in school. This is an important distinction because several of the findings in the earlier study might have been affected by subjects' lack of experience in working with a computer. For example, Kunz, Schott, and Hovekamp (1987) found that subjects who were trained to use computer-mediated text read faster and comprehended more than subjects who did not receive training.

Materials

Stimulus materials. The stimulus materials used in this study were adapted from those used in the earlier study (Reinking & Schreiner, 1985). The original materials in that study consisted of six 140- to 180-word passages, each followed by a 6-item multiple-choice test. The presentation of these passages to subjects varied according to treatment condition. The four treatment conditions in the earlier study, which were basically replicated in the current study, were as follows:

1. Subjects read passages on printed pages. No options for assistance were available (*off-line condition*).
2. Subjects read passages displayed by the computer. No options for assistance were available (*test-only condition*).

3. Subjects read passages displayed by the computer and were free to choose from among several options for assistance that were deemed useful for enhancing comprehension of the passage (*select-options condition*).
4. Subjects read passages displayed by the computer and then were required to view all the options for assistance before being allowed to continue (*all-options condition*).

Although the same treatment conditions were used in the present study, several modifications were made to the computer programs that presented the passages. First, to record subjects' reading and study times, I inserted a subroutine developed by Cooney (1984) into each computer program. This subroutine was activated when subjects pressed a key either to access the text or to continue when they had finished reading; thus, subjects were unaware that they were being timed. For all treatment conditions, reading time was defined as the time between the initial presentation of a passage and a subject's decision to begin working on questions that followed the passage. A second difference was that two questions were displayed after a subject had completed reading a passage:

1. How much did you like this passage?
2. How much did you learn from reading this passage?

Subjects responded to each question by selecting a number on a scale that ranged from 1 ("did not like at all/learned nothing") to 5 ("liked very much/learned very much"). Third, in the present study subjects were not required to achieve a criterion score on the comprehension test for a passage before being allowed to continue. In the earlier study, this requirement was included in order to measure the number of trials it took each subject to reach the criterion. This measure was not included in the present study because I reasoned that it might have influenced subjects' motivation to read, their interest in the text, or their estimation of their own learning.

Four of the six passages from the earlier study were used in the present study. Prior to gathering data, I used the remaining two pas-

sages to teach students how to interact with the on-line versions of the passages and to provide them with individual opportunities to become familiar with selecting options while reading. The topics of the four experimental passages were the Great Salt Lake, the value of pots and pans in early England, the rotation of the planet Mercury, and how the need for salt led to the development of early trade routes. We considered the first two passages somewhat more difficult because their mean readability estimates (computed from the results of six widely-used formulas) were 9.6 and 11.2, respectively. Mean readability estimates for the second two passages were 6.2 and 5.7 (Reinking & Schreiner, 1985).

Several options for assistance were available to subjects who read passages in the select-options condition. They could request that the computer provide them with an easier, less technical version of the passage, a definition of a difficult word or phrase, important background information (often in the form of a graphic aid), and the main idea of each paragraph in the passage. Subjects who read passages in the all-options condition were required to view the material presented in each of these options, after which they could choose to review any of them. Subjects in both of these conditions could view the information provided in these options for as long as they wished prior to attempting the comprehension test.

Measure

A six-item multiple-choice test followed the presentation of each passage. These items were developed in the earlier study from an item analysis including a study of each item's passage dependency. The data for these analyses were gathered from an independent sample of subjects not used in the experiment. The split-half reliability coefficient for the 36 items across the six passages was .90 (Reinking & Schreiner, 1985). The items were textually implicit as described by Pearson and Johnson (1978). Twenty-four of these items (all six original items from each of the four experimental passages used here) were used to measure comprehension of passages in the present study. A

post-experiment analysis of subjects' scores on these 24 items indicated a split-half reliability estimate of .86 using the Spearman-Brown formula.

Apparatus

Students read the computer-mediated texts at 15 work stations in a regular classroom that had been converted to a computer lab. Each work station consisted of a standard Apple IIe system, including an Apple IIe computer (64K), two disk drives, and an Apple color monitor. Prior to reading the passages displayed on the computer screen, subjects were directed to turn the color adjustment to its lowest setting and to adjust the contrast and brightness controls to a comfortable level for reading a screen displaying directions. Color was not used in any of the programs, and turning down the color adjustment improves the legibility of text presented on an Apple IIe system.

Procedures

First, subjects were introduced to the materials and procedures. I presented a demonstration passage on a large monitor to three groups of subjects during three regularly scheduled class periods in the computer lab. Following this introduction, subjects practiced completing the experimental tasks. Practice included working in small groups on the demonstration passage, completing a second practice passage individually, and moving from a computer station to a station for reading off-line (printed) passages.

The experiment was conducted two days later during another regularly scheduled class period in the computer lab. Each subject was seated at one of the computer stations and was handed a disk with his or her name on the label. Students who had been absent during the earlier practice session were not included in the experiment and were given an alternate computer-based activity to complete in a separate room. When all subjects had received their disks, they were directed to insert these disks into the Apple disk drive. A master power switch that controlled all of the computers in the lab was then turned on. Students proceeded to follow the di-

rections displayed on their computer screens, as they had practiced earlier. These directions informed subjects about the conditions under which they would read the first passage. Similar information preceded subjects' reading of each of the four experimental passages.

Because all subjects read one passage under each of the four treatment conditions, they were directed to leave the computer temporarily and to move to a separate reading station for the off-line passage. This station had been set up in an inconspicuous corner of the computer lab directly behind the computer stations. At this station subjects were given a passage face down on the table in front of them. They turned the passage over to signal that they were starting to read and turned it face down again to signal that they were finished reading and that they were ready to answer the comprehension items. A trained assistant standing inconspicuously behind and to the side of the subject used a digital stop watch to measure reading time based on these signals.

Reading in the off-line condition was carried out in a manner that closely approximated on-line conditions. For example, off-line versions of each passage were printed using the same character set as the computer display, and each page of the printed text corresponded to one computer screen. Thus, turning a page of the printed text was analogous to pressing the return key to see a new portion of the computer-mediated text. Care was taken to ensure that subjects were unaware that their reading was being timed, as was the case in the on-line conditions. Prior to the experiment, the trained assistants also practiced using a digital stopwatch to time the reading of on-line passages, and these results were compared with the time reported by the computer program. The mean discrepancy was less than 1 second for reading times that averaged 1.9 minutes as measured by the computer program.

In each treatment the experimental task involved completing the following sequence of activities:

1. Read directions specifying the conditions under which the passage would be read.
2. Read and study the passage.

3. Respond to a question concerning preference for the passage.
4. Respond to a question concerning the estimation of the amount learned from reading the passage.
5. Respond to six multiple-choice comprehension items based on the passage's content.
6. Proceed to next passage (treatment) until four passages (treatments) have been completed.

Subjects in the select-options condition could select from among the options for assistance after reading the passage and before responding to the questions. Subjects in the all-options condition were required to view all of the available options for assistance (and any options that they wished to view again) at the same point in the sequence. Subjects were not permitted to view the text while they were responding to items on the comprehension test.

When subjects had finished responding to the comprehension items following the last passage, the computer displayed several multiple-choice questions unrelated to the purpose of this experiment (e.g., "What kinds of books do you like to read most?"), but which occupied their time while they were waiting for the other students to finish their passages. When I determined that all subjects had completed the last passage, I told subjects to stop working, thanked them for their participation in the study, and dismissed them.

Design

This study employed a two-factor, repeated-measures design to test for differences across treatments on the four dependent measures: comprehension score, reading time, passage preference, and estimation of learning. Reading ability was the between-subjects factor and comprised two levels, good and poor readers. Treatment was the repeated-measures factor and comprised the four textual presentations. Each subject, who was either a good or a poor reader, read a different passage in each treatment condition. Treatment order was counterbalanced across subjects, and passages within a treatment were assigned randomly to subjects.

This design addresses a limitation in the earlier study (Reinking & Schreiner, 1985). In the design of that study, ability and treatment were completely crossed, and passages were read in a fixed order. We hypothesized that an order effect may have confounded the results. The present design controlled for order effects by counterbalancing the order of treatments across subjects and by using subjects as their own controls.

Results

Data were analyzed in four steps. First, a 4 (treatment) \times 2 (ability) repeated-measures analysis of variance (ANOVA) was used to test for differences between means on the comprehension test. In this analysis, ability was a between-subjects factor, and treatment was a within-subjects factor. This analysis permitted results of the present study to be compared with the main effects for treatment found in the earlier study (Reinking & Schreiner, 1985). Second, ANOVA procedures using three separate 4 (treatment) \times 2 (ability) designs were used to test for differences between means for reading time, passage preference, and estimation of learning. The purpose of this analysis was to examine whether these factors were affected by the treatments. If a statistically significant main effect for treatment was found, this difference was interpreted as an indication that some of the variation in comprehension scores might be attributable to that factor. When this condition obtained, a third analysis was conducted. Regression procedures were used to test for a relation between any factor so identified and comprehension scores. Finally, regression weights from the third analysis were used to adjust scores on the comprehension test by removing statistically the effects of that factor. These adjusted scores were analyzed using a 4 (treatment) \times 2 (ability) ANOVA, and the results were compared with those from the original ANOVA computed by using the unadjusted scores.

Comprehension test

Subjects responded to six multiple-choice comprehension items after reading each pas-

sage. Means and standard deviations for subjects' unadjusted scores on these items are shown by treatment condition and ability level in Table 1. A two-way (Treatment \times Reading Ability) ANOVA with repeated measures showed significant main effects for treatment, $F(3, 93) = 11.47$, $p < .001$, and for reading ability, $F(1, 31) = 7.86$, $p < .01$. There was no statistically significant interaction effect.

Because of the lack of interaction effect, pairwise comparisons of treatment means were made across ability levels. The Neuman-Keuls procedure was used for these analyses. These analyses revealed statistically significant differences between the select-options condition ($M = 3.34$) and the off-line ($M = 2.22$) and test-only ($M = 2.15$) conditions. The mean score in the all-options condition ($M = 3.55$) was also significantly different from the off-line and test-only conditions. The off-line and test-only conditions did not differ significantly in comprehension; nor did the select-options and all-options conditions.

These results indicate that the subjects achieved higher comprehension scores when the computer provided optional or mandatory assistance than when they read passages without this assistance. This finding occurred regardless of whether the passage without assistance was presented by the computer or on printed pages. Also, across all treatment conditions, good readers outperformed poor readers.

Table 1 Means and standard deviations for unadjusted scores on comprehension items

Ability	Treatment			
	Off-line	Test-only	Select-options	All-options
Good readers				
<i>M</i>	2.38	2.69	3.85	3.92
<i>SD</i>	1.26	1.11	1.14	0.95
Poor readers				
<i>M</i>	2.06	1.61	2.83	3.17
<i>SD</i>	1.11	1.14	1.76	1.47

Note. Maximum score = 6. Good readers: $n = 14$. Poor readers: $n = 19$.

Reading time

Reading time was defined as the time between initial presentation of a passage and a subject's decision to begin working on the questions that followed the passage. Subjects were free to reread and study the passage for as long as they wished between these events; thus, the reading time used in this analysis represents reading time plus any time that was devoted to studying the passage. In the select-options and the all-options conditions, subjects' use of the options for assistance was also included in this time.

Means and standard deviations for reading time by treatment and reading ability are given in Table 2. Means were compared using a two-way ANOVA (Treatment \times Ability) with repeated measures. The main effect for ability was not statistically significant. The main effect for treatment was statistically significant, $F(3, 93) = 35.18, p < .001$. There was no significant interaction effect. Pairwise comparisons of treatment means using the Neuman-Keuls procedure indicated that reading time was significantly longer for the select-options condition ($M = 2.89$) than for the off-line condition ($M = 1.78$) and the test-only condition ($M = 1.81$). In addition, reading time was significantly longer for the all-options condition ($M = 5.08$) than for the off-line ($M = 1.78$), test-only ($M = 1.81$), and select-options conditions ($M = 2.89$). No other pairwise contrast was statistically significant.

Table 2 Means and standard deviations for reading time (in minutes)

Ability	Treatment			
	Off-line	Test-only	Select-options	All-options
Good readers				
<i>M</i>	1.85	1.53	2.50	4.84
<i>SD</i>	0.87	0.72	1.09	2.32
Poor readers				
<i>M</i>	1.70	2.10	3.28	5.32
<i>SD</i>	0.56	2.14	2.50	2.42

Note. Maximum score = 6. Good readers: $n = 14$. Poor readers: $n = 19$.

These results indicate that subjects devoted more time to reading and studying passages when the computer made available options for assistance. Subjects also devoted more time to reading and study when the computer required them to view the options for assistance than when they were free to select options. The results also indicate that these differences were evident across both levels of reading ability; the difference in reading time between good and poor readers was not significant.

Passage preference

After they had finished reading and studying a passage, subjects responded to the following question: "How much did you like this passage?" They responded by selecting a number on a 5-point scale ranging from "didn't like at all" (1) to "liked very much" (5). Means and standard deviations for this measure by treatment and ability level are given in Table 3. Means were compared using a two-way ANOVA with repeated measures.¹ There was no statistically significant main effect for treatment or reading ability; nor was there a significant interaction effect. These results indicate that subjects did not vary in their preference for passages by treatment or ability level.

Estimation of learning

A second question to which subjects responded after reading the passage was "How much did you learn from this passage?" They

Table 3 Means and standard deviations for students' passage preference

Ability	Treatment			
	Off-line	Test-only	Select-options	All-options
Good readers				
<i>M</i>	3.79	3.50	3.79	3.36
<i>SD</i>	0.80	1.40	1.37	1.34
Poor readers				
<i>M</i>	4.05	3.58	3.63	3.68
<i>SD</i>	0.71	1.26	1.54	1.29

Note. Values based on a 5-point scale ranging from "didn't like at all" (1) to "liked very much" (5). Good readers: $n = 14$. Poor readers: $n = 19$.

responded by selecting a number on a 5-point scale ranging from "Didn't learn anything" (1) to "Learned very much" (5). Means and standard deviations for this measure are given by treatment and ability level in Table 4. Means were compared using a two-way ANOVA for repeated measures.¹ There was no statistically significant main effect for treatment or reading ability; nor was there a significant interaction effect. These results indicate that subjects did not vary in their estimates of their learning by treatment or ability level.

Regression analysis

The analysis for reading time resulted in a statistically significant main effect for treatment, and the direction of the observed differences paralleled statistically significant differences between treatments on comprehension scores. These results suggested that increases in reading time may have been related to increases in comprehension scores. Regression procedures were used to investigate this possibility. The analysis was similar to an analysis of covariance because comprehension scores were adjusted by removing statistically the effects of reading time. An *F* test was computed for the correlation between reading time and comprehension score and for a 4 (treatment) \times 2 (ability) repeated-measures ANOVA on comprehension scores adjusted for reading time. The ANOVA was calculated using the residuals of the test scores based on the difference between the observed score and the predicted score based on time.

The test for the regression of comprehension on reading time was not significant for treatment, $F(1, 28) = .067, p = .798$, or for ability, $F(1, 93) = 1.93, p = .168$.

Means and standard deviations for adjusted comprehension scores by treatment and ability level are given in Table 5. The main effect for treatment was statistically significant, $F(3, 93) = 4.70, p < .01$. The main effect for ability was not statistically significant; neither was the interaction effect. Pairwise comparisons of adjusted treatment means using the Neuman-Keuls procedure indicated statistically significant differences between the following

Table 4 Means and standard deviations for students' estimation of their learning

Ability	Treatment			
	Off-line	Test-only	Select-options	All-options
Good readers				
<i>M</i>	4.00	3.43	4.07	3.71
<i>SD</i>	0.78	1.34	1.14	1.33
Poor readers				
<i>M</i>	4.16	3.89	3.63	3.89
<i>SD</i>	0.90	1.10	1.46	1.24

Note. Values based on a 5-point scale ranging from "didn't learn anything" (1) to "learned very much" (5). Good readers: $n = 14$. Poor readers: $n = 19$.

Table 5 Means and standard deviations for comprehension scores adjusted for reading time

Ability	Treatment			
	Off-line	Test-only	Select-options	All-options
Good readers				
<i>M</i>	2.54	2.79	3.87	3.66
<i>SD</i>	1.20	1.11	1.14	1.07
Poor readers				
<i>M</i>	2.37	1.81	2.76	2.69
<i>SD</i>	1.05	1.23	1.68	1.33

Note. Good readers: $n = 14$. Poor readers: $n = 19$.

contrasts: The select-options treatment resulted in greater comprehension ($M = 3.32$) than the off-line ($M = 2.45$) and test-only conditions ($M = 2.30$); and the all-options condition resulted in greater comprehension ($M = 3.17$) than the off-line and test-only conditions.

These results indicate that reading time and comprehension scores were not related at a .05 level of significance. Furthermore, the pattern of differences between treatment means found in the post hoc analysis of comprehension scores that had been adjusted to control for time was identical to the pattern of differences found in the post hoc analysis of unadjusted scores.

Discussion

The results of the present investigation support previous findings that comprehension increases when a computer is used to expand readers' options for acquiring information from text or to control their processing of text. Subjects in the select-options and all-options conditions outperformed subjects in the off-line and test-only conditions on the comprehension questions after each passage. As was the case in several earlier studies, there was no statistically significant difference in comprehension between subjects who read passages displayed conventionally on printed pages (the off-line condition) and subjects who read passages displayed similarly by the computer (the test-only condition).

The present study also supports previous findings that readers devote more time to reading computer-mediated texts than to reading texts displayed on printed pages. In the present study, however, this was the case only when readers had options for assistance. The difference between subjects who read passages off-line and subjects who read passages without assistance on the computer was not statistically significant. Muter, Latremouille, Treurniet, and Beam (1982) found differences in reading time when comparing subjects who read conventional print and electronic displays under similar conditions, but the experimental text was narrative, and subjects read for 2 hours. There is also evidence that display factors, such as screen size, may have accounted for some of the differences in reading time between printed and electronically displayed texts (Haas & Hayes, 1985b). The results of the present study suggest that reading and study time may increase when options for assistance are included in computer-mediated texts. Reading time for short expository texts, however, appears to be unaffected by simply displaying the text on a computer screen.

There is no evidence in the present study that readers' passage preference or estimation of their own learning varies according to mode of presentation of the text or reading ability. Gam-

brell, Bradley, and McLaughlin (1985), on the other hand, found that intermediate-grade readers liked basal reader stories better when presented on a computer screen than in books, although this did not affect their comprehension. Further research that controls for factors such as type of text (narrative vs. expository), length of text, and subjects' experience with computers is needed to clarify these findings. Use of more sensitive measures of preference for text and estimation of learning may also be necessary. A type of ceiling effect due to a clustering of student responses at the upper end of the scales used in this study may have obscured effects related to these two factors.

The results of this study also suggest that increases in reading time alone do not account for increases in comprehension when the computer is used to provide readers with options for assistance. Although increases in reading time paralleled increases in comprehension, a statistically significant effect for treatment remained when comprehension scores were adjusted to control for the effect of reading time. In addition, the test for the regression of comprehension on reading time was not statistically significant. Thus, increases in comprehension under the conditions of this study are more likely to be due to deeper or more efficient cognitive processing than to prolonged exposure to the text.

This interpretation supports recent theoretical positions that define the differences between conventional and computer-mediated texts in terms of the computer's capability to influence cognitive processing more directly (see Daniel & Reinking, 1987; Duchastel, 1986; Reinking, 1987; Reinking & Schreiner, 1985). An important question raised by this finding, however, is the degree to which each of the options for assistance contributes to improvements in comprehension. Rickman (1985), for example, found improvements in comprehension of passages for which the computer provided only the definitions of difficult vocabulary. Another question raised by this finding is how computer assistance affects the time devoted to processing various aspects of text. For example, Kunz, Schott, and Hovekamp (1987) found that col-

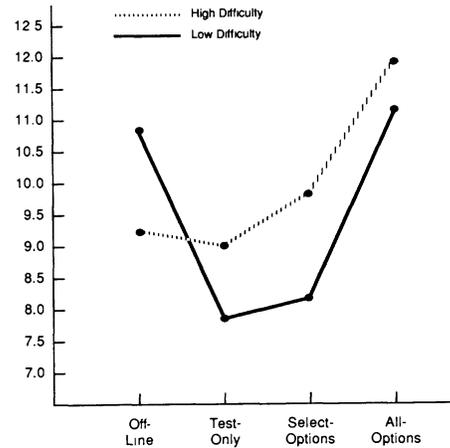
lege students reading either printed texts or computer-mediated texts that provided assistance did not vary significantly in their comprehension or overall reading time. However, those students reading the computer-mediated text spent significantly less time reading complex sentences and sentences more relevant to comprehending the text.

Because the four treatments in the present study varied little from those examined in the earlier study (Reinking & Schreiner, 1985), the results of the two studies can be compared. In the earlier study, comprehension was greater for subjects in the all-options condition than in the select-options and test-only conditions. The interpretation of the results was constrained, however, by an unexpected disordinal interaction between treatment and passage difficulty. This interaction is displayed in Figure 1. Subjects in the off-line condition scored higher on the low-difficulty passages as expected, but subjects in the remaining three conditions scored higher on high-difficulty passages. We offered several alternative interpretations of these findings, each of which will be discussed in light of the present study.

First, we speculated that the combined effects of subjects' inexperience with computer-mediated text and the fact that subjects read passages in a fixed order may have created the interaction between treatment and passage difficulty. All subjects read two low-difficulty passages before encountering one of the high-difficulty passages. Thus, comprehension scores for the low-difficulty passages in the three computer conditions may have been lower than in the off-line condition because subjects were not yet familiar or comfortable with using the computer.

These factors were less likely to affect performance in the present study. Subjects had considerable experience in working with the computer prior to the experiment and were given extended practice in using the experimental materials prior to data collection. In addition, subjects were their own controls in a repeated-measures design in which treatment order was counterbalanced and passages were assigned randomly to subjects within each treatment.

Figure 1
Treatment by passage difficulty interaction on comprehension scores from earlier study (Reinking & Schreiner, 1985)



[From "The effects of computer-mediated text on measures of reading comprehension and reading behavior" by D. Reinking and R. Schreiner, 1985, *Reading Research Quarterly*, 20, p. 545. Copyright 1985 by the International Reading Association.]

We also speculated in the earlier study that the difficulty of the experimental passages as measured by multiple-choice comprehension items may have been different from their assigned level of difficulty based on readability formulas. This discrepancy could be explained by limitations in using readability formulas to determine passage difficulty (Harris & Sipay, 1985) or by variation in the difficulty of the multiple-choice comprehension items completed after each passage.

In the present study, post hoc analyses of passage difficulty were carried out to investigate these possibilities. Comprehension scores on low- and high-difficulty passages in each cell of the 4 (treatment) \times 2 (ability) design were compared using a *t* test. None of these comparisons was statistically significant. This finding precludes a passage difficulty by treatment interaction and therefore supports our speculation that the interaction in the earlier experiment may have occurred because of methodological limitations. Comprehension scores for low-difficulty passages in the computer-based treatments may have been lowered by subjects'

limited experience with the computer. In addition, the lack of significant difference between scores on high- and low-difficulty passages in the present experiment suggests that the relative difference in difficulty between the two sets of passages was not as great as indicated by readability formulas.

We also suggested that the superiority of the all-options group in the earlier study may have been due to the computer's control of subjects' processing of the text. Subjects' comprehension in the select-options condition did not differ statistically from their comprehension in the conditions without options for assistance. When faced with the task of selecting assistance to enhance their own comprehension, perhaps intermediate readers do not or cannot make appropriate decisions and would benefit from computer control. Such an interpretation was consistent with research indicating that younger readers have less well-developed metacognitive skills (Baker & Brown, 1984).

However, the results of the present study raise questions about this interpretation. In the present study, subjects who read passages in the select-options condition obtained comprehension scores that were higher than when they read passages in the off-line and test-only conditions. Their scores in the select-options condition were also higher than in the all-options condition when those scores were adjusted for reading time, although this difference was not statistically significant. More research is needed to investigate how reader versus computer control is related to the comprehension of computer-mediated texts.

Existing research has not found consistent differences in reading comprehension when computers are used to display text in a manner similar to its presentation on printed pages. The results of the present study support this finding. However, the results support the conclusion that computers may enhance comprehension when they are used purposefully to effect more active processing of text. This conclusion is strengthened by the finding that variations in reading time, preference for text, and estimation of learning did not account for comprehension differences. Current research suggests, therefore, that the computer may be a potentially impor-

tant tool for aiding comprehension during independent reading. Continued research is needed to understand more fully the inherent impact of computer-mediated texts on reading comprehension, and to discover their potential uses.

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Footnote

¹Although there is some disagreement about the use of analysis of variance procedures to analyze ordinal data, it has been defended in situations like the present study in which assumptions underlying parametric statistics are not violated (see Blanchard & Carey, 1987).

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