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Graphic Aids in Electronic Texts

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ABSTRACT

The authors analyze the use of graphic aids in electronic texts by using four conceptual differences that distinguish printed and electronic texts. The four differences relate to the control of textual presentations, the interaction between readers and texts, the structure of texts, and the variety of symbolic elements that may be integrated with written prose. The authors propose that these four conceptual differences can act as a theoretical framework useful to researchers and instructional designers interested in the use of graphic aids in electronic texts. The authors contend that such a theoretical framework is needed because the current literature related to electronic texts has tended to focus on visual as opposed to more critical conceptual factors. They argue that the key to understanding the effects of graphic aids in electronic texts is found in considering the functional relations between graphical information, written prose, and reading strategies. Examples are provided to illustrate how each of the unique characteristics of electronic texts might affect these relations. The authors discuss the different perspectives of professionals interested primarily in literacy as opposed to those interested primarily in designing computer-based instructional materials, how these different perspectives might limit research and design, and how new understandings of electronic texts might bring the two perspectives closer together.

INTRODUCTION

Emerging theoretical positions and growing empirical evidence suggest that written texts presented electronically by a computer have unique characteristics when compared to conventional printed texts (see Reinking & Bridwell-Bowles, 1991). Furthermore, the critical differences between printed and electronic texts have been argued to be conceptual as opposed to visual (Reinking, 1992; see also Gillingham, 1988). That is, fundamental differences in the way printed and electronic texts can conceivably be written and read seem to have more direct, measurable effects on comprehension and learning than do variations in the visual aspects of displaying written prose on a computer screen. For example, the unique ways that textual information can be organized and accessed in electronic texts (e.g., hypertexts; see Jonassen, 1986; Bolter, 1991) represent a more critical difference than does a concern for reasonable variations in how many words should be displayed on a computer screen at one time. In this essay we extend the argument for considering conceptual over visual factors by addressing specifically how four conceptual differences may guide the use of and research about graphic aids in electronic texts.

We have chosen to use the term graphic aids because we are limiting our discussion to informational graphics such as pictures, illustrations, diagrams, charts, tables, maps and similar visual representations used in conjunction with written prose for the specific purpose of aiding understanding. Our use of the term graphic aids does not include graphical displays used for purposes less directly related to understanding such as gaining a learner's attention or increasing motivation to learn, although some graphic aids may also serve these functions. In addition, we believe the term graphic aids as it has been used in the literature (e.g., Reinking, Hayes, & McEneaney, 1988) focuses attention on the functional relations between graphical information, the written prose with which they are associated, and reading strategies that bring the two sources of information together (e.g., see Hegarty, Carpenter, & Just, 1991). We, as others (e.g., Crismore, 1989; Shallert, 1980; Tufte, 1983), argue that understanding graphic aids and their effect on learning lies at least as much in considering these functional relations as it does in considering visual elements of the graphical display alone.

Indeed, in printed and electronic texts alike, graphic aids, as we have defined them here, are never divorced entirely from verbal information. Although creating a graphic aid may involve conscious decisions about how best to arrange its visual elements to enhance learning, these decisions are rarely made in isolation from the verbal information to which they are related (Tufte, 1983). Thus, because conceptual differences have become theoretically and practically important, we

believe it is appropriate to consider how these differences might affect the relation between graphic aids and written prose in electronic texts.

When applied to electronic texts, however, the term graphic aids has one drawback. It may connote that graphical information plays a separate, ancillary role as is typical in printed texts. As we will discuss in a subsequent section, electronic texts tend to blur the distinction between graphic aids and written prose such that graphic aids may not appropriately be viewed as separate elements of textual structure.

We also have adopted a specific meaning for the term electronic text. The term text has a narrow and a broad meaning. The narrow meaning is "that part of a page or book which is the written or printed matter, in contrast to illustrations; words" (Harris & Hodges, 1981, p. 328). The broad meaning is in the sense of a textbook (Harris & Hodges, 1981) and this is closer to the meaning we wish to evoke by the term electronic texts. However, we do not mean to imply that electronic texts are like or should be like a printed textbook displayed on a computer screen. To the contrary, our analysis is based on identifying several unique characteristics of electronic texts that enable information to be presented in ways not feasible in conventional printed materials. However, electronic texts, as we use the term here, are equivalent to textbooks in that they can display written prose and graphical representations; and, electronic texts as we define them here are functionally equivalent to printed textbooks in that they are designed to help students learn. By our definition in this essay, virtually all instructional computer programs can be considered electronic texts, regardless of how such programs are classified (e.g., tutorials, drill-and-practice activities, simulations). Instructional computer programs can be considered electronic texts whenever they display written prose and graphical representations to increase student learning by supplementing or replacing conventional printed materials. When we wish to refer to the narrower meaning of the term text (i.e., words as opposed to graphical information), we will use the terms written prose or verbal information.

To address graphic aids in electronic texts, we first examine critically the relevant literature and identify limitations in current understandings of graphic aids in electronic texts. We then analyze graphic aids on the basis of a theoretical framework outlining four conceptual differences between printed and electronic texts. Our analysis is aimed at pointing out that there is a rich domain of ideas for research and development concerning graphic aids in electronic texts—a domain that can be explored by attending to the unique relations between written prose and graphic aids in electronic texts as opposed to the unique visual displays possible on a computer screen.

THE LITERATURE RELEVANT TO GRAPHIC AIDS IN ELECTRONIC TEXTS

There is an extensive literature devoted to the use of graphical representations in computer-based instructional materials. Relatively little of that literature is devoted to empirical research (cf. Alesandrini, 1987; Rieber, 1989a). What empirical research has been done is aimed primarily at investigating the effects of manipulating the visual presentation of graphical information separate from written prose. When this relatively small body of research is excluded, the remaining literature is devoted primarily to suggestions for displaying graphical information visually on computer screens. For example, several writers in publications aimed at instructional designers (e.g., Faiola & Deloois, 1988; Lucas, 1991; Merril, 1987) provide guidelines for displaying graphical information based on principles of visual design applied to computer screens, not on a consideration of how written prose and graphical information may be related differently in electronic texts. As is frequently acknowledged by these writers, there is little available empirical evidence to support the principles and guidelines they offer (cf., Alesandrini, 1987; Rieber, 1989a). Some empirical studies have examined the effects of using computer graphics to model complex processes, to facilitate problem solving, and to compensate for limitations in visual-spatial abilities (e.g., Kizer, 1987; Reed, 1985; Steinberg, Baskin, & Hofer, 1986; Steinberg, Baskin, & Matthews, 1985).

The previous studies provide empirical data linked to theoretical positions, their focus is on graphical representations alone, not on graphic aids used in conjunction with written prose to enhance learning. Therefore, much of the literature on computer graphics is of marginal relevance to the present discussion because here we examine how the unique characteristics of electronic texts suggest new ways of combining written text and graphical representations. We argue that understanding this new relationship within a well-defined theoretical framework should be useful for generating testable research hypotheses as well as for establishing guidelines applicable to the design of computer-based instructional materials.

A few studies have addressed the relative effects of graphic aids and written prose on reading and learning from electronic texts. For example, in a pair of related studies Alesandrini and Rigney (Alesandrini & Rigney, 1981; Rigney & Lutz [Alesandrini], 1976) compared learners who completed a computer assisted instruction (CAI) tutorial program in either an all-verbal or verbal-plus-graphics condition. In their first study the all-verbal condition contained a verbal elaboration of the basic content of the CAI program that was designed to be analogous to the graphical information presented in the verbal-plus-

graphics condition. Subjects in the verbal-plus-graphics condition scored higher on all of the dependent variables (knowledge, comprehension, application of content, and favorableness of attitudes toward the tutorial) indicating the superiority of that condition. However, in the second study, which added inserted questions to the all-verbal condition, subjects in the verbal-plus-graphics condition scored better on a pictorial but not on a verbal posttest. One conclusion that might be drawn by comparing these studies is that the effects of graphic aids in electronic texts are governed to some degree by the nature of the accompanying written prose. However, beyond this somewhat vague generalization there is little insight into what specific factors might have affected readers' learning.

Reid and Beveridge (1986) conducted an experiment in which the independent variables were mode of presentation (paper or computer), pictures (present or absent), difficulty of text (easy or difficult), and subjects' reading ability (four levels ranging from inferior to superior). The dependent measure was a multiple-choice test divided into three sections focusing respectively on information in the pictures, in the text, and in both the pictures and the text. The presentation of graphic aids in the computer condition was interactive in the sense that subjects had to request the graphic to be displayed after reading a portion of the text, although the authors do not fully describe this feature of the program. The results of six, two-way ANOVAs did not indicate any statistically significant effects for mode of presentation, although particular pictures interacted with reading ability. That is, specific pictures increased the performance of better readers while they decreased the performance of poorer readers. However, the study had several limitations. It did not investigate whether mode of presentation interacted with the other variables and subjects were assigned to treatment conditions on the basis of the school they attended. And, more to the point of the present argument, the study did not make a clear distinction between the use of graphic aids in the printed and computer-based versions. The study did include text difficulty as an independent variable, thus recognizing that there might be an interaction between variations in the written prose and in the type of graphics used. However, there was no apparent use of the computer's unique capabilities to create an electronic text distinctly different from a printed text.

Animation is a common component of instructional computer programs and some researchers have compared animated and static graphics accompanied by written prose in electronic texts. For example, Rieber and his colleagues (Rieber, 1989b,1990; Rieber, Boyce, & Assad, 1990; Rieber & Hannafin, 1988) have investigated the use of animation in presenting an introduction to Newtonian mechanics. They compared a written prose version of the content to versions in which the written

prose was accompanied by either static or animated graphics. Across these studies, animation had statistically significant effects on learning only under relatively constrained conditions. For example, among other conditions, the material had to be moderately difficult and had to be accompanied by supportive practice for animation to increase learning. The lack of robust effects in these studies supports the view taken here that simply manipulating visual effects (i.e., static vs. animated graphics) is not likely to produce notable increases in learning. On the other hand, thinking about differences between printed and electronic texts might suggest ways to affect reading strategies and learning by changing the relation between written prose and graphical information.

One line of research provides some evidence for this point of view. In a chapter discussing diagrams in scientific texts Hegarty, Carpenter, and Just (1991) report the results of several studies in which they compared the role of animated and static graphic aids in affecting readers' processing of texts discussing scientific concepts associated with movement. The studies closely parallel the Rieber, et al. studies in that they addressed the effects of static and animated graphics. However, unlike the Rieber et al. studies, they studied the relation between graphic aids and written prose in effecting changes in readers' reading and study strategies. Figure 1 shows one of their experimental texts with an accompanying graphic aid. Experimental texts were displayed either statically or in an animated version on a computer. By tracking eye movements during reading they found that all subjects spent more time on the graphic aid in the animated version. Additionally, they found that subjects with different levels of mechanical ability varied in how long they attended to the text or the graphic aid. As predicted, however, subjects with low mechanical ability performed better on a comprehension test when reading and studying an animated version. Based on this study alone, one might conclude that the capability of the computer to animate a graphical representation (a visual difference between printed and electronic texts) benefitted learning, presumably by compensating for readers' difficulty in generating an appropriate internal representation. However, in a follow-up experiment, low mechanical ability subjects seemed to benefit even more when the text provided guidance that was coordinated with animating relevant portions of the graphic aid. This finding clearly illustrates one of our major points. The capability of the computer to change the relation between graphic aids and written prose affected learning more perhaps because it took on some of the metacognitive functions that readers must employ to coordinate information derived from two different sources.

Hegarty, Carpenter, and Just's (1991) work is also informative because it illustrates research that investigates how graphic aids in

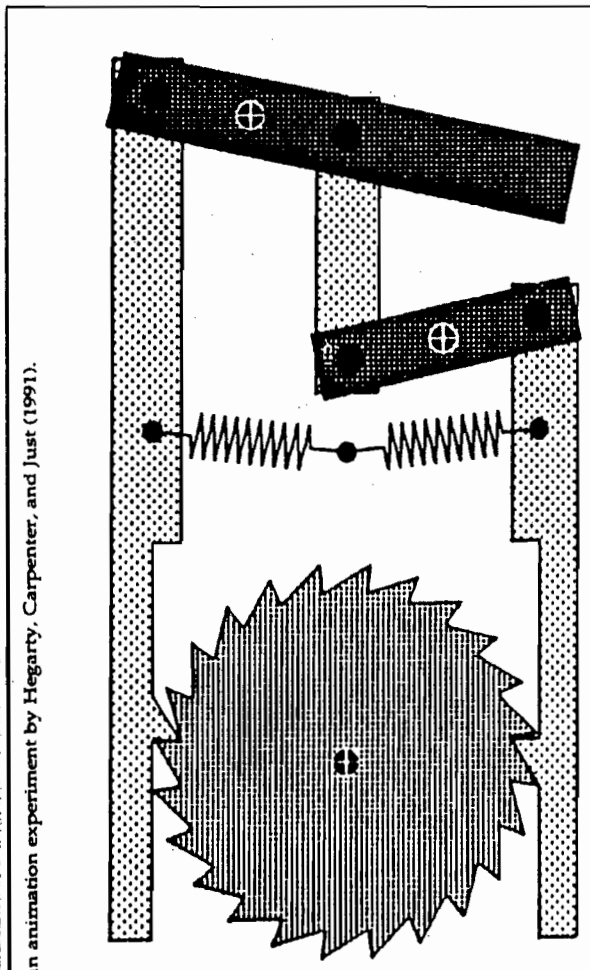

Figure 1. Graphic aid and written prose used in an animation experiment by Hegarty, Carpenter, and Just (1991).

[From "Diagrams in the comprehension of scientific texts" by M. Hegarty, P.A. Carpenter and M.A. Just, 1991, in R. Barr, M. L. Kamil, P. B. Mosenthal, and P. D. Pearson (Eds), *Handbook of Reading Research, Vol. 2*, p. 664. Copyright 1991 by Longman Publishing Company.]

electronic texts might affect readers' strategies. Because the computer can track readers' interactions with elements of electronic texts, it is a useful tool for studying cognitive processes during reading (Reinking, Alvermann, & Hynd, 1986). Other studies have employed computer-based methods to investigate how learners use graphics in learning new concepts (e.g., Berger, Jackson, & Edwards, 1988; Grayson & McDermott, 1988), including a few studies investigating how readers process tables and charts. For example, Guthrie (1988; Guthrie, Britton, & Barker, 1991) has used a computer to record subjects' interactions with an airline schedule presented on the computer screen in order to test a cognitive model of how readers locate information in documents such as tables, schedules, graphs, and notices. Kunz, Drewniak, and Schott (1989) used computer-mediated texts containing graphic aids to compare subjects' self-reports of their own learning strategies with and without a replay of their actions on the computer screen. They found that the self-reports supplemented by the computer-based replay were more highly correlated with subjects' performance on measures of how well the information had been learned. They also found differences in the use of organizational and representational pictures between subjects having high or low familiarity with the subject discussed in the experimental text. These examples show that studying readers' strategies for using graphic aids in electronic texts is facilitated by the computer's ability to present texts under controlled conditions and simultaneously to gather data that reflect readers' strategies. However, the purpose of these studies has been primarily to investigate readers' strategies in reading printed texts. The electronic texts were designed to create controlled conditions for gathering data, not for using the unique capabilities of the computer to enhance understanding.

A few studies have reported data involving the use of graphics in electronic texts, even though the primary focus of the research was not to investigate the effect of graphic aids. Reinking (1988; Reinking & Schreiner, 1985), for example, used some of the unique capabilities of the computer to provide readers with various types of assistance when they experienced comprehension difficulty while reading. One type of assistance involved viewing a graphical representation related to the topic of the text. Subjects free to select options for assistance selected this option most often. Although the data did not suggest any explanation for this finding, it is consistent with the findings from other studies suggesting that learners frequently have positive attitudes towards computer-based learning materials that include graphics (e.g., see Alesandrini, 1987). Whether such attitudes result in more attention to graphical information, perhaps at the expense of information in written prose is a question that remains unanswered.

In summary these studies lead us to the following conclusions:

1. The level of interest in and speculation about the use of graphical information in computer-based materials is not matched by the current level of empirical research that has been conducted in this area. There is not a coherent research base to guide decisions about using graphic aids in electronic texts or to guide further research in this area.
2. Only a few studies consider how graphical information, written prose, and reading strategies may be functionally related in reading electronic texts.
3. Although there is limited research upon which to draw conclusions, changing only visual aspects of graphic aids in electronic texts (e.g., animating static figures) may not have as robust effects on reading and learning as does using the unique characteristics of electronic texts to change the relations between graphic aids and texts (e.g., linking animated figures with written prose in ways not possible or feasible in printed texts).
4. Although the computer is a useful and convenient tool for investigating reading strategies, few studies have used this capability to study electronic texts that are uniquely different from printed texts.
5. Some studies have investigated electronic texts that use graphic aids in new ways, but the focus in these studies has not been specifically on the graphic aids.
6. Current knowledge about graphic aids in electronic texts is limited, despite the fact that electronic texts using graphic aids are becoming increasingly prevalent in a variety of instructional contexts. We argue that these limitations are due at least in part to a view of graphic aids in electronic texts as primarily visual elements separate from and unrelated to written prose or alternatively as visual extensions of the graphic aids used in printed texts. We believe that the current literature lacks an important perspective provided by an analysis of the differences distinguishing printed and electronic texts. To further these arguments, in the following section we analyze the use of graphic aids in terms of a theoretical framework focusing on the conceptual characteristics of electronic texts.

A Theoretical Framework for Considering Graphic Aids in Electronic Texts

In this section we apply an existing theoretical framework to the use of graphic aids in electronic texts. The framework is aimed at identifying how printed and electronic texts may differ conceptually in the way they are written and read as opposed to how their visual display differs on a printed page or a computer screen. The framework identifies the following four critical differences between electronic and printed texts:

1. **Control/Access:** Electronic texts can control readers' access to text during independent reading.
2. **Interaction:** Electronic texts permit readers and texts to interact in a literal as opposed to a metaphorical sense.
3. **Structure:** Electronic texts may be structured differently than printed texts.
4. **Symbolic representation:** Electronic texts make available a wide range of symbolic elements that can be integrated with prose.

Describing these four differences as a theoretical framework highlights the fact that it is intended mainly to define a perspective from which existing theories of reading and instructional design might be applied to graphic aids in electronic texts. For example, Paivio's (1986) theoretical perspective that attributes comprehension to a dual coding process involving linguistic and visual information is clearly relevant to displaying graphical information in electronic texts, especially given the expanded range of visual effects available in that medium. However, the additive effects of verbal and visual representations postulated in that theory can not be accurately applied to electronic texts unless the relation between verbal and visual information in such texts is understood. The framework serves to make this relation more explicit. Thus, we believe the framework is useful for generating testable hypotheses that take into account existing perspectives on graphic aids in printed texts as well as the unique capabilities of electronic texts.

Specifically our intent in using the framework is a) to encourage a conceptualization of graphic aids in electronic texts that focuses on relations between text and graphics instead of visual displays, b) to illustrate how differences highlighted by the framework might be considered in the design of computer-based materials employing graphic aids, and c) to provide a coherent base for interpreting existing research as well as for generating new hypotheses.

ELECTRONIC TEXTS CAN CONTROL READERS' ACCESS TO TEXT DURING INDEPENDENT READING

A major difference between printed and electronic texts is that a computer permits control over the portions of a text a reader can access during reading. The unit of text over which control is exercised can be quite small such as individual letters and words, or quite large such as an entire chapter in a conventional book, but a natural unit is the text displayed on a single screen. The degree of control can also be varied such that a reader at some point can be completely restricted from viewing a particular portion of a text, partially restricted based on certain limiting conditions, or completely unrestricted.

This capability might be employed in a wide range of contexts and applications. For example, unlike a printed text, an electronic text can be presented in such a way that readers must attend to a portion of a text under certain conditions (e.g., mandatory review after missing an inserted question; see Tobias, 1987). Or, unrestricted access can be enhanced by powerful search functions such as using key words to find specific information in texts. Computers also enable the contingencies for accessing portions of texts to be varied for different readers reading the same text. For example, a reader who spends 30 seconds reading a screen can be permitted to proceed to the next screen, while one who "reads" for 3 seconds may be temporarily prevented from accessing the next screen.

The fact that electronic texts are displayed as if through a window represented by the computer screen is the characteristic that creates a variety of options for limiting readers' access to portions of a text. Printed texts, on the other hand, almost always enable a reader to have unrestricted access to a text in its entirety often without readily available opportunities for elaboration or clarification, which places the primary burden on a reader to decide what portion of the text merits attention at any particular moment during independent reading. The notion of independent reading is itself a reflection of the necessary contingencies of reading printed texts but not necessarily of electronic texts. Theoretical perspectives and empirical research related to this difference between printed and electronic texts can be found in the literature: Bolter, 1991; Daniel & Reinking, 1987; Landow, 1993; Reinking, 1987, 1988. 1992; Tobias, 1987, 1988; Wilkinson, 1983.

From the standpoint of designing electronic texts this difference raises a new concern, unknown to the writers and designers of printed texts: They must decide when to display a portion of a text (a decision related to understanding how electronic texts differ conceptually from printed texts) as well as where to display it (a decision related primarily to visual differences). Put another way, decisions about displaying

printed texts are basically two dimensional, while decisions pertaining to the display of electronic texts are three dimensional, with time being the third dimension (see Daniel & Reinking, 1987). Likewise, a new set of research questions emerge when considering how electronic texts can control readers' access to text. For example, an obvious issue is the effects of manipulating the degree to which the computer or the reader controls access to texts under various conditions. Another issue raised by this capability is under what conditions such control is ethical (Reinking, in press).

The capability to limit readers' access to portions of electronic texts creates unique opportunities for purposefully changing the relation between graphic aids and the texts they accompany. An example familiar to many classroom teachers illustrates how a relatively straightforward use of this capability might have profound implications for learning. A teacher assigning students to read independently a particularly difficult chapter in a conventional printed text may strongly encourage students to note several particularly helpful graphic aids while they are reading. Under such circumstances it would not be unusual for many students to disregard the teacher's advice, perceiving careful study of the graphic aids to be too time consuming. Students may be more intent on finishing their reading of the written prose than on carefully studying the graphic aids, which they may consider to be secondary sources of information or even irrelevant textual decorations that conveniently shorten reading assignments.

Students who do follow the teacher's recommendation may be inefficient or unproductive in their processing of the graphic aids. For example, textbooks often do not direct readers' attention to graphic aids by referring to them at appropriate points in the text (Friedman & Tinzman, 1985). Indeed, adding such cuing has been shown to increase attention to and learning from graphic aids among poor readers who presumably need such guidance (see Reinking, Hayes, & McEneaney, 1988).

On the other hand, if independent reading assignments were presented as electronic text, all students could be placed in a situation where they must attend to the graphic aids in the text and to do so at opportune times relative to other components of the text. That is, the reading would not be independent in the same sense as reading a printed text. Readers, for example, might be prevented from accessing a subsequent portion of a text until they had responded correctly to questions about a graphic aid displayed at a point in the text when it was considered vital for understanding. Or, students not responding correctly to a question, might be branched back to a graphic aid for mandatory review. In short, the fact that electronic texts can control readers access to text during independent reading enables electronic

texts to be constructed in ways that make graphic aids much more difficult to avoid, thus integrating them into texts in ways not possible in printed texts. Put more positively, readers who would benefit from attending to a graphic aid at a particular time during reading can more readily be helped in electronic texts.

A variety of new research questions emerge from this conceptual difference between printed and electronic texts. For example, how might such capabilities affect comprehension of, learning from, and attention to graphic aids. Similarly, under what conditions might it be desirable to have readers or the computer control when graphic aids are accessible?

ELECTRONIC TEXTS PERMIT READERS AND TEXTS TO INTERACT

Another critical difference between electronic texts and printed texts is that electronic texts can effect an interaction between a reader and a text. The interaction that is possible when reading electronic texts is a literal interaction, not the metaphorical interaction that is often used to describe the nature of reading printed texts. Describing the reading of a printed text as an interaction between the reader and the text is metaphorical in the sense that the printed text can not respond to individual readers during reading. Printed texts are essentially static, inert stimuli challenging a reader to make sense of them. Reading printed texts is interactive only in the sense that elements of the text (e.g., the linguistic information encoded in print) and the characteristics of a particular reader (e.g., her/his knowledge of the world) must both be considered in accounting for what is understood during reading. Describing the reading of printed texts as an interactive process highlights the active role of readers in generating meaning from the printed page; it does not suggest that reading involves the individualized give-and-take that characterizes a dialogue or a collaboration between two individuals. Readers must activate relevant background knowledge, select appropriate strategies for increasing their own understanding, and so forth, but printed texts by themselves can not provide differential input and guidance to individual readers having or not having success in carrying out the processes necessary for successful reading.

Electronic texts, on the other hand, can be interactive in a literal sense. That is, using the capabilities of a computer, the text can be presented in such a way that it is responsive to a particular reader's needs during reading. The possibilities for adapting electronic texts to readers' needs during reading are limited only by the requirement that some condition or aspect of a reader's performance must be convertible to an electronic

signal. This requirement is not restrictive in that many aspects of a reader's processing of a text can be monitored electronically. Options include volitional choices that a reader might make by pressing keys, clicking with a mouse, or using voice commands as is possible in the latest Macintosh computers; but, other options might include unconscious actions and physical states such as monitoring the number of regressive eye movements or galvanic skin response to indicate confusion and anxiety. Most of the existing theoretical perspectives and empirical research focus on the former type of options (e.g., Blohm, 1982, 1987; Daniel & Reinking, 1987; Duchastel, 1988; MacGregor, 1988a, 1988b; Reinking, 1987, 1988; Reinking & Schreiner, 1985; Tobias, 1987).

Like written prose in electronic texts, graphic aids may be presented interactively when displayed by a computer. For example, the difficulty level of a graphic aid or the depth of information it provides could be varied either at the request of the reader or based on an analysis of a reader's characteristics or performance. Or, as is currently possible with several utility programs designed to create graphs, a bar graph may easily be converted to either a line graph or a pie chart during reading. In addition, a reader may wish to observe the effect of manipulating various data displayed in a graph. A reader may wish to access additional information clarifying a portion of the graphic aid or to request an explanation of the graphic aid's relation to a particular portion of the text.

Upon encountering the text and graphic aid shown in Figure 1, a reader might request that the machine be shown from a different angle or that a distracting portion of the machine be removed from view while it is animated. Likewise, a computer set up to monitor a reader's eye movements (as was done in the experiment from which this example was taken) could determine that a reader was focusing attention on an unimportant portion of the machine and thus suggest a shift in focus. Another illustration of how graphic aids might be used interactively is a portion of the Interactive Reading and Instruction System (IRIS) developed by WICAT Systems (see Schnitz, Maynes, & Revel, 1983). A portion of that integrated learning system asks readers questions pertaining to a graphic aid displayed on the computer screen. However, not only must students respond to the question, they must also click on a portion of the graphic aid that provides the information necessary for answering the question. Incorrect responses can be remediated by the computer.

These examples represent only a few possibilities for effecting a literal interaction between readers and the graphic aids used in electronic texts. The effect of making graphic aids interactive in electronic texts is unknown. One might reasonably hypothesize that at least some forms of interactive graphic aids would enhance learning over the non-

interactive presentations in printed texts. Perhaps more importantly, one might hypothesize that animation in service of developing interactive graphic aids might be more likely to affect readers' attention and understanding than it would if used in a fashion paralleling the use of graphic aids in printed texts. Nonetheless, the key variables that might guide the use of interactive graphic aids in electronic texts await further theoretical development and research.

ELECTRONIC TEXTS MAY BE STRUCTURED DIFFERENTLY THAN PRINTED TEXTS

More than any of the other differences between printed and electronic texts, the important theoretical and practical implications of differences in structure can not be adequately addressed within the scope of this essay (see Bolter, 1991; Duchastel 1986; Landow, 1993 for extended discussions about the structure of electronic texts). However, hypertext is an increasingly familiar example that illustrates clearly how electronic texts can alter fundamentally the way textual information is structured (see Jonassen, 1986). Given the technology of print, the most common and natural textual structure is a linear presentation of information organized hierarchically and is designed to be read sequentially. By contrast, computer technology supports alternative structures such as hypertexts, usually consisting of interrelated chunks of written prose (and sometimes graphics) accessed through non-linear, associational networks and designed to be read in many possible orders.

The unique structural characteristics of hypertexts are intuitively obvious, even if their implications for writing, reading, and learning are not. Not as readily noticed is that graphic aids may play a different role in the structure of electronic texts than they do in printed texts. In most printed texts, graphic aids are of necessity treated as adjunct information, separate from the written prose; that is, as separate structural elements of the text (see Tufte, 1983). There is, as Bolter (1991) states, a strict "separation of the verbal and pictorial writing spaces" (p. 75). However, in electronic texts, graphic aids and the written prose must literally share the same writing space, drawing them closer together as equal elements in a meaningful whole. The structural distinction between written prose and graphical information becomes blurred and both are drawn together into a unified semantic whole (see Bolter, 1991). Also, in electronic texts written prose is increasingly becoming more like a picture (e.g., graphic interfaces that portray texts as if they are stacked one upon another or the increasing use of font changes to signal meaning) and pictures are becoming more like prose (e.g., icons that create an ideographic writing on computer screens).

If graphical information can not clearly be separated from written prose in electronic texts, the definition of a graphic aid given at the

outset of this article may not be entirely accurate for electronic texts. The term graphic aid suggests that the graphical information is serving a separate, supportive role in helping a reader understand textual information. However, graphical information in electronic texts may not necessarily play a secondary role. Instead, in electronic texts such as hypertexts, a graphical representation may be the starting point for a reading followed by related written prose serving as support for the graphic. In such a case the bulk of the written prose becomes the aid to comprehension serving more like captions under graphical representations in printed texts.

The language associated with printed texts reflects its structure and the dominance of written prose. For example, the *body* of a printed text is usually considered to be written prose, while related graphical information usually falls into the category of *adjunct* material. However, in electronic texts there need not be separate structural components analogous to the main body of written prose, graphic representations that serve an adjunct role, and captions or other specialized written prose designed to explain the graphical representations. Figure 2 is a schematic representation that contrasts alternative structural relations between written prose and graphical information in printed and electronic texts.

Using Figure 1 again, it is possible to illustrate how graphical information may become a structural component more fully integrated with written prose in an electronic text. As it appears here as a figure on a printed page it is in a form that might have been excerpted from a conventional science text discussing the parts of simple machines, such as levers and gears. In such a context, its purpose might be to provide an example of the concepts being discussed and perhaps to provide visual scaffolding for recalling and integrating the concepts discussed in the written prose comprising the main body of the text. As such, the figure and its caption are separate structural components that supplement and amplify the main body of the text. Because they are separate from the text, the reader must decide when to attend to them: before, during, or after reading the main text. If attended to during reading, they are at least a digression, if not an interruption; if before reading, they may be viewed as a preview; if after reading, a review.

Compare this situation to a not uncommon scenario in which a version of Figure 1 could be included as part of some computer-based instructional materials. The figure might be displayed initially as a consequence of a reader selecting an option to see an example of a simple machine from a menu in which several other choices were available. Thus, within the structure of an electronic text the figure is one of several informational nodes that might be accessed during reading, each of which might contain written prose, graphical information, or both. Furthermore, such a structure can be recursive

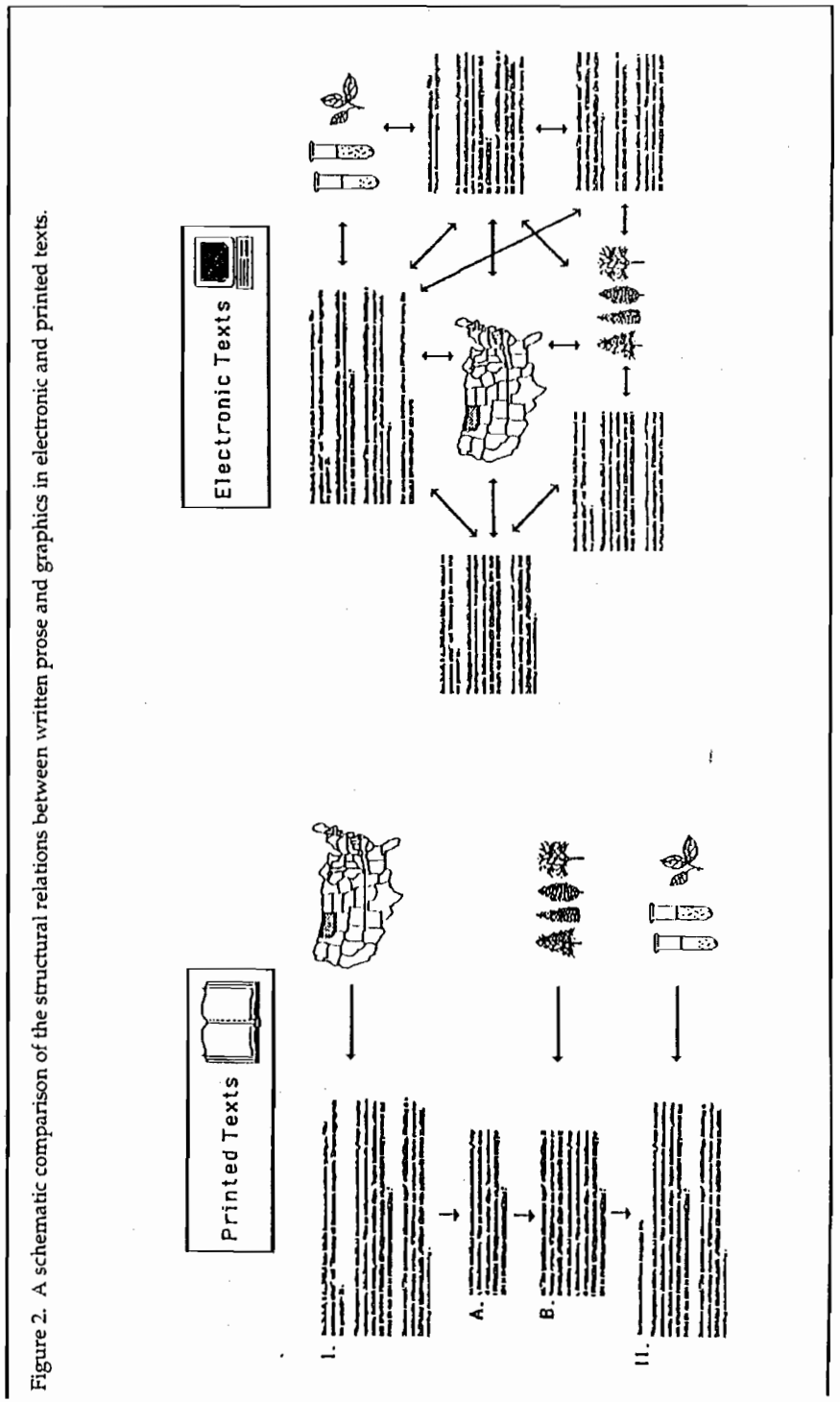

Figure 2. A schematic comparison of the structural relations between written prose and graphics in electronic and printed texts.

containing multiple layers of information. For example, a reader could point to or click on a part of the machine in Figure 1 to find out more about the operation of that part, either specifically in the machine shown or generally in all machines.

Interestingly, graphic representations have begun to play another informational role related to the structure of electronic texts. They have been used to assist readers to navigate through the maze-like organizational structures that are characteristic of many hypertexts. Figure 3 shows a screen from a hypermedia application on the constitutional convention developed by Peters (1988). Numbers have been added to identify various areas of the screen. Near the number 5 is shown a map of the text's structure highlighting inter-connected textual nodes and the paths that readers may choose between them. It also shows which nodes have been accessed previously and which node is currently displayed. The number 6 identifies a simulated doorway to a related node through which the reader can pass by clicking on the door, an action which is accompanied in this example by the sound of a squeaky door opening and closing. The magnifying glasses by the number 12 represent choices a reader might make to pursue a topic in varying degrees of depth. The screen represented in this figure also illustrates, therefore, the multiple functions that graphical information may serve in electronic texts.

ELECTRONIC TEXTS MAKE AVAILABLE A WIDE RANGE OF SYMBOLIC ELEMENTS THAT CAN BE INTEGRATED WITH PROSE

Electronic and printed texts are clearly different in one respect: Computers enable a variety of audio effects and visual images to be fully integrated into the writing and reading of electronic texts. Printed texts can be combined with other technologies that create sound and motion (e.g., motion pictures, tape recorders, and more recently novelty children books that have audio devices placed with their bindings). However, computer technology combines these capabilities into a single device that enhances significantly the flexibility and integration possible in blending audio effects, moving images, and written prose. Thus, electronic texts can appeal more richly to the senses of sight and sound. This potential can be clearly seen in hypermedia applications that combine several audio and video technologies into an integrated, interactive presentation managed by a computer. For example, from the screen shown in Figure 3 a reader could hear a portion of one of Benjamin Franklin's speeches or see a video showing actors portraying his role at the constitutional convention.

The capability to integrate a variety of audio and video effects with

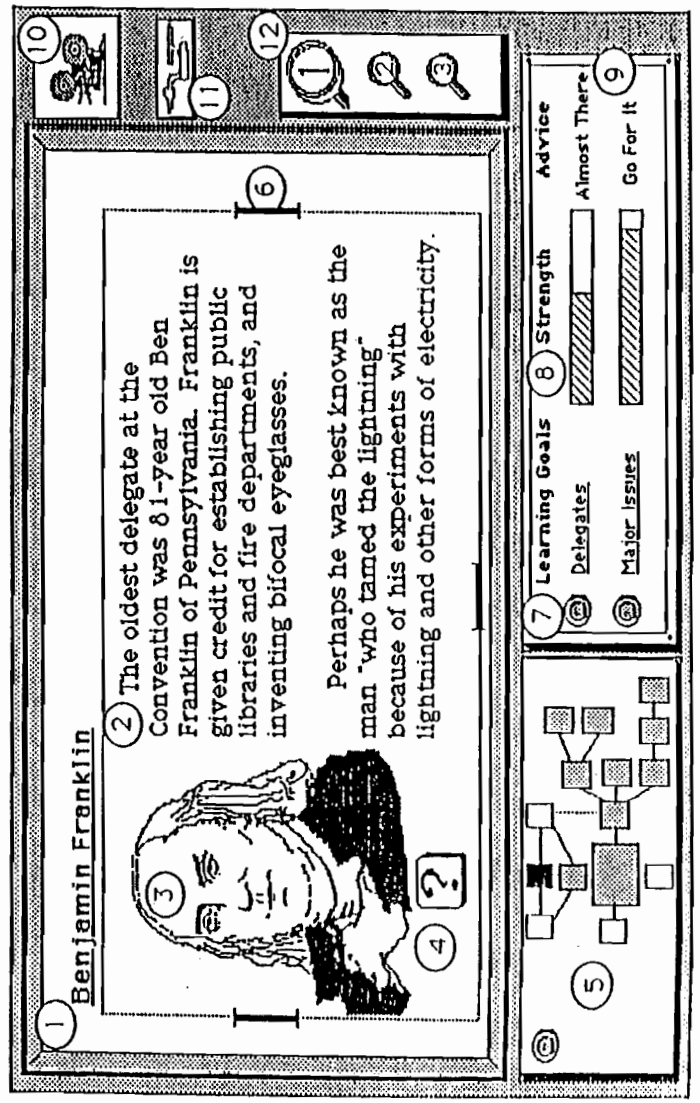

Figure 3. Screen from a hypermedia program used in an experiment by Peters (1988).

written prose in interactive computer programs means that electronic texts can communicate information using a wider range of symbolic elements than are available in printed texts. This difference is important because determining the symbolic elements available for conveying information is the first step in distinguishing instructional media and ultimately each medium's potential for influencing cognitive processes and learning (Salomon, 1979). On this basis, Reinking (1987) has argued that electronic and printed texts are separate instructional media.

One consequence of having more symbolic elements available in electronic texts is that decisions about displaying graphical information and written prose become more complex. A writer of a printed text faces decisions such as determining when a graphic aid may be useful, whether it should be a simple line drawing or a more detailed sketch, where it should be displayed relative to the text or other graphical information, what portions of the graphic aid merit highlighting, and how such highlighting might be done with color to convey meaning. Researchers are interested in studying the effects of these decisions on readers' cognitive processing and learning under various conditions. In addition to all of these decisions, the writer of an electronic text might consider questions such as: Should a portion of the graphic aid be animated and when should that occur relative to the display of related text? Should a video segment be slow motion or stop action? Would written prose or verbal narration be more appropriate to accompany the video? Should readers of differing abilities be given different graphical representations at this point in the text? Should an audio signal be used when readers' states or actions indicate that they are attending to an inappropriate portion of the video display? The greater number of decisions faced in designing electronic texts reflects the wider range of symbolic elements that can be used to convey meaning electronically, which in turn increases exponentially the number of research and design questions that might be asked about graphic aids in electronic texts.

The expanded array of visual and audio effects made possible by computer-based technologies also expands the ways that graphic aids can be used in association with verbal information. For example, in a conventional printed text it is difficult to imagine how one might use a graphic aid to assist a reader to understand an unfamiliar word such as *jovial*. However, in an electronic text a video segment from a drama could be used to show a character in a jovial mood. Animation, a more common visual effect used in computer-based instructional programs, can also effect new relations between graphic aids and written prose. For example, using a computer, the machine in Figure 1 could be animated to one position whereupon a textual explanation for the movement to that point would appear on the screen below the diagram. As the machine is animated to its next position a new segment of

explanatory text replaces the first, and so on until the machine has moved through an entire cycle. Thus, using animation and the ability to coordinate the textual display with movement of the diagram makes use of new symbolic elements changing the relation between the graphic aid and the written prose. In this case, the meaning conveyed by the graphic aid and the written prose are more closely juxtaposed so that they become intertwined as a semantic unit as opposed to related yet independent components as they usually must be in printed texts.

Just as the availability of a wider range of symbolic elements adds complexity to practical decisions about the use of graphic aids in the design of electronic texts, research questions and theoretical issues also become more complex. Considering only the computer's ability to animate graphic aids suggests a number of interesting new research questions and hypotheses. The current research in this area is sparse and the existing research is not frequently found in rigorously peer-reviewed publications (see Rieber, 1989a). However, the findings from Hegarty, Carpenter, and Just (1991) discussed in a previous section suggest some promising areas for study. For example, why did readers low in mechanical/spatial ability require more guidance from the text even when the machine in Figure 1 was animated to compensate for their lack of ability? Also, how exactly did they make use of the graphic aid and the verbal text, and how might electronic texts be used to encourage more efficient learning strategies?

A wider range of symbolic elements also enhances and reinforces the three differences previously discussed in the framework, adding further to the practical and theoretical complexity of electronic texts. For example, using live action video as a symbolic element to help define an unfamiliar word (**symbolic representation**) could lead to further digressions from the text in which the word was used (**structure**) that might be made mandatory (**control/access**) for a reader whose performance indicated the word was inhibiting comprehension (**interaction**). Thus, all of the differences identified in the framework may be intertwined in designing electronic texts and in researching their effects on learning.

SUMMARY AND DISCUSSION

In this essay we extended the argument that electronic texts have greater potential to affect learning when researchers and instructional designers focus on what have been called conceptual differences between electronic and printed texts as opposed to visual differences alone. Four conceptual differences between printed and electronic texts outlined in an earlier review (Reinking, 1992) were applied specifically to an analysis of graphic aids in electronic texts. In that review, research

evidence was cited to support the argument that conceptual differences between printed and electronic texts have a more direct, measurable effect on learning than do visual differences. The present review of the research literature related to graphical information in electronic texts produces no such direct evidence. The wide-spread interest in the use of graphics in computer-based instructional materials has not produced abundant research. Much of the literature focuses on an intuitive analysis of the visual factors that might be considered when displaying graphical representations on a computer screen. A few empirical studies have compared the use of graphic aids in printed and electronic texts, especially the use of static vs. animated graphics. The findings in the majority of these studies have been equivocal or statistically non-significant. We could locate only one series of studies (Hegarty, Carpenter, & Just, 1991) that addressed specifically how using the unique capabilities of electronic texts to change the relation between graphics and written prose could affect learners' strategies and learning.

Based on our analysis we argue that graphic aids in electronic texts might be better understood if researchers and instructional designers would view them within a theoretical framework such as the one used here rather than relying on intuitive awarenesses of the differences in how graphical information can be displayed visually on pages or computer screens. Despite limited empirical evidence, our analysis leads us to the conclusion that the unique characteristics of electronic texts amplify the importance of examining the relation between written prose and graphic aids. Electronic texts change the nature of writing and reading by expanding the possibilities for presenting written prose and graphical information. There are simply more ways to combine written prose and graphic aids in electronic texts and this inevitably complicates the issues relevant to researchers and instructional designers.

There may be some resistance to the perspective that we have outlined in this article and that resistance may vary depending upon one's professional or disciplinary stance. For example, those interested primarily in conventional literacy associated with printed texts may feel uncomfortable with the notion that electronic texts blur the distinction between written prose and graphical representations. Professionals interested in conventional literacy have much invested in viewing written prose as the predominate focus of literacy with graphical information being a secondary, and perhaps even as a relatively inferior way of communicating information to learners. Put simply, reading teachers and researchers tend to define their professional interests in terms of words, not pictures. Those interested primarily in instructional design, on the other hand, have more interest in seeking out a variety of representational modes for communicating information to learners.

Written prose is likely to be viewed as only one mode of communication, and perhaps as a relatively mundane one. Thus, instructional designers may have a tendency to focus on graphical representations without a concurrent concern for their relation to written prose. Indeed, the capability to use audio and visual effects has tended to become the *sine quo non* of computer-based instructional materials because such effects obviously distinguish the computer as a technologically intriguing instructional medium (see Rieber, 1989). Thus, to those interested in instructional design, especially design that involves computers, written prose may be secondary to graphical information. The resistance common to both perspectives may be exacerbated by the fact that written prose and graphical information must vie for the limited space available on individual computer screens.

One way to reconcile these opposing perspectives, which both tend to limit research and design, is to conceptualize all computer-based instructional materials as electronic texts possessing the four unique characteristics highlighted in the theoretical framework. From the perspective of those who think more in terms of books, conceptualizing an electronic text as a computer program may lead to an acceptance of the notion that in electronic texts written prose need not predominate over graphical representations. From the perspective of those who think in terms of innovative instructional technologies, conceptualizing computer programs as electronic texts may lead to a more creative use of written prose in computer-based instructional materials.

Electronic texts challenge conventional notions about reading, writing, and learning from instructional materials. And, as our analysis suggests, they challenge conventional notions about graphic aids. This challenge can only be addressed by developing new perspectives that transcend words, pictures, and the various technologies used to present them. Comparisons of printed and electronic texts reveal the inadequacies of one-sided viewpoints originating with either written prose or with graphics. Relying on the conventional wisdom from either viewpoint alone would seem to be less productive than a unified approach to considering graphic aids in electronic texts. The present analysis is intended to extend a growing literature aimed at developing deeper theoretical understandings of electronic texts and how they might be designed to increase learning (cf., Bolter, 1991; Landow, 1993; Lanham, 1989; Duchastel, 1988; Reinking, 1987). Equipped with more powerful and parsimonious theoretical perspectives, researchers and designers interested in electronic texts can more readily identify fruitful areas to focus their efforts.

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Engaging the New Basal Readers

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ABSTRACT

This article describes ratings and ranking by both researchers and children of the new and old basal text series and then describes categories of students' responses to the texts. Using the perspective of engagement, the authors found that the 1993 basal reading series received higher ratings than the1986/87 series on scales measuring holistic qualities, content, language, and design. When kindergarten, first, and second graders ranked twenty of the basal stories, their rankings agreed with the researchers' in seven of the ten pairings. Categories of students' responses validated the researchers' categories of content, language, and design and also extended into familiarity, personal experience, and realism. The findings identify some engaging qualities of text and extend previous research which was often limited to readability.

For decades basal readers have dominated instructional practices. Resistant to innovative ideas (Chall, 1983; Venezky, 1987; Shannon, 1989), basal systems have been a strong force in sustaining the status-quo by offering teachers materials that encourage them to do what traditional teachers have done in the past. Criticism of earlier basal readers centered around their use of controlled vocabulary and emphasis upon isolated skills (Goodman, 1986). Basal readers have been characterized as containing insipid stories lacking in conflict, character development, or authentic situations; using contrived language; having low interest; and being rewritten and excerpted, substituting decodeable words for original language (Goodman, Shannon, Freeman, & Murphy, 1988; Shannon, 1987). In short, these texts have not been engaging to many young readers, especially those