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# LEARNING FROM HYPERTEXT: RESEARCH ISSUES AND FINDINGS

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## 23.1 INTRODUCTION TO THE RESEARCH ISSUES

The question of how we learn from hypertext is more complicated than that of how we learn from traditional text. Although all the same elements of character decoding, word recognition, sentence comprehension, and so forth remain the same, a number of features unique to hypertext produce added complexity. It is these features that drive the research of hypertext in education and have shaped our discussion in this chapter.

The most basic feature of hypertext, of course, is its *nonlinear structure*. How nonlinear structure alters learners' mental representations or ability to use their new knowledge has been an active area of research. This feature gives way to a number of factors related to learning. Primary among these is a *flexibility of information access*. Whereas traditional text allows the author to assume what information has already been encountered and present new information accordingly, information within a hypertext may be retrieved in a sequence specified by each user. In other words, there is a greater degree of *learner control* when engaged in hypertext-assisted learning (HAL). The shift in control of access from author to learner places a greater cognitive burden on the learner. Specifically, the learner must now monitor to a greater extent whether he or she understands what has been read, determine whether information must be sought to close information gaps, and decide where to look for that information in the text. In short, there are greater *metacognitive demands* on the reader during HAL.

While the vast majority of research on hypertext is not specifically relevant to learning, investigation into its educational utility began to heat up in the 1980s, and many research reports and articles have been published since then. Chen and Rada (1996) conducted a metanalytic study of learning from hypertext. Of 13 studies they found comparing learning outcomes for subjects using hypertext versus nonhypertext systems, 8 revealed an advantage of hypertext. Although the combined effect size was small to medium ($r = .12$), it was highly significant ($p < .01$). In addition, they report that the effect sizes and significance levels among studies comparing learning from hypertext and linear text were heterogeneous. They interpret this result as an indication that factors such as system design, system content, and experimental design influence educational effectiveness, and a number of empirical studies have pointed to the influence of such factors on learning outcomes.

In addition to system variables, user traits such as goals, motivation, and prior knowledge are also factors in HAL. Moreover, these learner variables interact with hypertext characteristics to influence learning outcomes. We have attempted here to sort through the data to identify the variables that affect HAL most strongly and the mechanisms through which this occurs. Wherever it is appropriate, we have also tried to explain how user and system variables interact. Because of such interactions, the field is largely looking toward adaptive technology to tailor systems for the user, so we have also included a section on adaptive hypertext systems. We conclude with a discussion of problems surrounding research on HAL. First, though, we begin with a brief discussion of theories that may explain the cognitive processes underlying HAL, as these theories serve to anchor much of our discussion.

## 23.2 THEORETICAL VIEWS OF LEARNING FROM HYPERTEXT

Although there are no well-developed models of hypertext-based learning per se, a number of theories of reading and learning may explain the cognitive underpinnings of the process. The two models that have had the greatest impact on research and our understanding of the process are the construction-integration model (CIM; Kintsch, 1988) and cognitive flexibility theory (CFT; Spiro, Coulson, Feltovitch, & Anderson, 1988; Spiro, Feltovitch, Jacobson, & Coulson, 1992). These theories and their relationship to hypertext-based learning are presented here.

### 23.2.1 Construction Integration

The CIM of text processing (Kintsch, 1988) suggests a three-stage process of text comprehension. The first is character or word decoding, which is invariant across media. The second is the construction of a *textbase*. This is a mental model of the factual information presented directly in the text. The process of textbase construction is also thought to be invariant across media. The third stage in the process is the creation of the *situation model*. It is this stage that is highly relevant to our understanding of learning from hypertext. A situation model is constructed when prior knowledge is integrated with new information from a text (the textbase). According to the CIM, the integration of prior knowledge with new information is necessary to achieve a deep understanding of new material. In other words, if no situation model is formed, no meaningful learning has been achieved.

For a situation model to be developed, then, active learning is necessary. The promotion of active learning is the essence of hypertext. As Landow (1992) has noted, the act of choosing which links to follow requires that the user take an active approach. He quotes Jonassen and Grabinger (1990), who urge that "hypermedia users *must* be mentally active while interacting with the information" (cited in Landow, 1992, p. 121). Indeed, a good deal of work has shown that active use on the part of learners results in advantages of hypertext, often beyond that seen in traditional text. However, although hypertext encourages active engagement with the material, it does not require it. The fact is that hypertext may be used passively. Some of the earliest studies of hypertext identified passivity as a cause for potential educational ineffectiveness (Meyrowitz, 1986). We discuss these points in some depth later in this chapter.

As a model of learning, the CIM has had a substantial influence on the way in which researchers think about learning in general, including HAL. It is common to find references to the construction of textbases and situation models in authors' discussions of HAL. In fact, these concepts are woven so deeply into many people's understanding of HAL that they are often referred to in research articles, even when no explicit reference is made to the CIM itself. This way of thinking about mental representations has become many hypertext researchers' standard framework for understanding HAL.

### 23.2.2 Cognitive Flexibility

Spiro and his colleagues have proposed CFT, a constructivist theory of learning from various media (Spiro et al., 1988, 1992). Like the CIM, CFT proposes the application of prior knowledge to go beyond the information given. To account for advanced learning, however, it also stipulates that the mental representations invoked for this purpose are constructed anew, rather than retrieved as static units from memory. This model of learning is based on the supposition that real-world cases are each unique and multifaceted, thus requiring the learner to consider a variety of dimensions at once. This being the case, the prior knowledge necessary to understand new knowledge cannot be brought out from intact memories of other single cases or experiences. Rather, stored knowledge derived from aspects of a variety of prior experiences must be combined and applied to the new situation. As Spiro et al. (1988) explain, "The *re*construction of knowledge requires that it first be *de*constructed—flexibility in applying knowledge depends both on schemata (theories) and cases first being disassembled so that they may later be adaptively reassembled" (p. 186). The implication of this model is that advanced learning takes place not only as a consequence of active learning and prior knowledge use, but also as a consequence of constructing knowledge anew for each novel problem.

This perspective of learning is relevant to hypertext-based learning because hypertext offers the possibility of coming at a topic from various perspectives. Because a learner can access a single document from multiple other sites, he or she will come to that document with multiple perspectives, depending on the point of origin or learning goal. In this way, CFT predicts that the mental representations resulting from repeated, ill-structured hypertext use will be multifaceted, and one's ability to use that knowledge should theoretically be more flexible. A number of studies have supported this perspective for advanced learners (Jacobson & Spiro, 1995; Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987). This evidence is discussed with relevance to the importance of system structure in a later section.

In sum, the CIM and CFT each take different approaches to the task of explaining the cognitive processes underlying HAL, but both offer enlightenment. The CIM offers a detailed description of how stable mental representations are created during learning. There is a great deal of support for the CIM in the literature and it successfully predicts some of the conditions under which HAL will succeed or fail. The CIM is informative to hypertext research because it offers an explanation of the relevance of user behavior. Specifically, it explains the research that points to user behaviors such as link choice, navigation patterns, and metacognitive practice as mediators of learning. CFT offers an explanation of meaningful learning on the part of advanced learners. It successfully explains why the exploration of identical texts can result in more flexible, transferable knowledge from a hypertext than a traditional text. It adds to our understanding of HAL because it offers a unique explanation of how mental representations are constructed, reconstructed, and altered by exposure to dynamic information structures. Each of these frameworks for understanding HAL centers on a number of learner variables. The importance of these variables to HAL is discussed throughout the remainder of this chapter.

## 23.3 COGNITIVE FACTORS ASSOCIATED WITH READING AND LEARNING FROM HYPERTEXT

### 23.3.1 Basic Reading Processes

Decades of reading research can provide valuable insights to ground our understanding of how people read and learn in hypertext learning environments. Although there are differences between reading hypertext and reading traditional text, researchers have noted similarities in the basic cognitive processes associated with reading in either context. For example, Wenger and Payne (1996) examined whether several measures of cognitive processing that have been used to assess recall and comprehension when reading traditional text (i.e., working memory span, speed of accessing word knowledge in memory, reading rate) would also hold when reading hypertext. Twenty-two university students read three hierarchically structured hypertexts and completed a battery of reading proficiency assessments. They concluded that ". . . the relationships between the information processing measures and the hypertext reading measures replicate those documented between these information processing measures and performance with normal printed (linear) text" (p. 58). This provides support for the notion that the basic reading processes that guide the design of printed text can also be applied to the design of hypertext.

As mentioned under Introduction to the Research Issues, there are also clear differences between reading traditional text and reading hypertext, because the hypertext environment provides a whole new set of issues to be addressed. Alexander, Kulikowich, and Jetton (1994) showed how subject-matter knowledge contributed to readers developing a unique self-guided text when reading hypertext. That is, readers' past experiences and prior knowledge led them to make choices about the sequence for reading information in the hypertext in ways that are not possible when reading printed text. Further, when reading hypertext, the readers' focus can be at a more global level of processing, as opposed to the microprocessing orientation typically adopted when reading printed text. When reading hypertext, readers often focus on navigating the complex system rather than deriving meaning at the word, sentence, or paragraph level (Trumbull, Gay, & Mazur, 1992).

Other differences relate to the physical attributes associated with presenting hypertext on a computer screen. The limited size of the computer screen often necessitates the use of scrolling and the presentation of text in frames (Walz, 2001). Both of these characteristics of hypertext place an increased load on the working memory. Eye movement research has shown that during reading, the eyes move forward and backward to allow the reader to reflect on what was read, predict what is coming, and confirm meaning in the text (Nuttall, 1996; Swaffar, Arens, & Byrnes, 1991). Left-to-right scrolling features in some hypertext makes that natural reading eye movement pattern difficult, as previously read text keeps scrolling off the screen. Breaking text into frames also inhibits the reading process in that what is read in one frame must be remembered when moving to new frames if the information across multiple frames is to be integrated. Other distractions that are often found in hypertext environments include unusual color schemes; reverse contrast (light letters on a dark background); multiple fonts, type sizes, and styles; and the use of drop-down boxes that may cover portions of the text (Walz, 2001). These features tend to interrupt the normal automatic reading processes of readers and thereby change the basic reading process. However, text structures must be examined in the context of their interactions with learner variables to understand the complexity of HAL.

### 23.3.2 Metacognition and the Role of the Reader

Despite claims that hypertext frees the reader to create his or her own individualized text, Smith (1996) points out that there is nothing inherent in the hypertext that is "democratic or antihierarchical." Hierarchy is apparent in the maps, outlines, and menus that serve as navigation aids in the hypertext. Although the sequence of accessing information in a hypertext is not imposed, the author determines the structure and content of information and the linkages among information nodes. The reader makes choices about how to proceed, creating a linear path through the text by following the links the author has established. Actual reading of words and sentences is essentially a sequential process that is the same as reading printed text.

What differs from reading printed text is the requirement that the reader make choices about how to proceed through the text, ostensibly increasing reader interest and engaging the reader in deeper processing of the information (Patterson, 2000). According to Patterson, a fundamental shift in the reading process relates to hypertext readers having to create their own path through the text. Actively engaged readers tend to feel a greater sense of control over what they read and how they read it. Results of their choices are instantaneous and readers become part of the meaning construction as they "write" an individualized text that may differ from what the author intended. Printed text tends to formalize the role of the author, while hypertext challenges our assumptions about the roles of the author and the reader. Thus, many view educational uses of hypertext as emancipatory and empowering because it forces readers to participate actively in creating meaning from the text.

Changing the reader's role in this way places additional cognitive requirements on the reader. As in traditional reading of printed text, the learner must engage basic lower-level processes (such as letter recognition and decoding words) and higher-level processes (such as relating new information to prior knowledge). Reading hypertext requires additional metacognitive functioning like choosing what to read and deciding on the sequence for reading information. Further, less proficient computer users must use cognitive resources to operate the computer (working the mouse, pressing keys, activating on-screen buttons, etc.; Niederhauser, Reynolds, Salmen, & Skolmoski, 2000). Compounded by factors such as reading ability, subject-matter knowledge, and the cognitive load required to read and navigate, hypertext may actually *interfere* with the reader's ability to make meaning from the text (Niederhauser et al., 2000; Shapiro, 1999).

However, a number of investigations have shown that increased metacognitive activity when reading hypertext can contribute positively to HAL outcomes. For instance, Shapiro (1998a) showed that students who used a principled approach to hypertext navigation performed better on an essay posttest of conceptual understanding than their less thoughtful counterparts. In that study, a relatively ill-structured system was used to encourage thoughtful navigation. Those who were given a highly structured system were less principled in their approach, using ease of access as a major criterion for link choice. In this case, students who were forced to be more metacognitive when navigating the less structured system learned more.

In some very recent reports, investigators have attempted to encourage metacognitive skills more directly. Azevedo and colleagues (Azevedo, Guthrie, Wang, & Mulhern, 2002; Azevedo, Seibert, Guthrie, Cromley, Wang, & Tron, 2002) engaged learners with a hypertext about the human circulatory system. Subjects were either paired with a human tutor who was trained in Winne's (1995, 2001) self-regulated learning (SRL) techniques, trained on the techniques themselves, asked simply to complete a self-generated goal, or given a series of factual questions to answer. In the coregulation condition, the tutor encouraged metacognitive strategies by providing a variety of prompts. Specifically, she encouraged self-questioning, content evaluation, judgments of learning, planning, goal setting, prior knowledge activation, and other activities. In the strategy instruction condition, subjects were trained to do the same thing as the tutor but to do so as independent learners. The other two conditions provided no metacognitive prompts, tutors, or training. Analyses of posttests revealed that the sophistication of learners' mental models shifted significantly more when provided with tutors or metacognitive training than when simply given learning goals and no training. Both the tutor group and the strategy instruction group demonstrated the greatest use of effective learning strategies and the least incidence of ineffective strategies. Subjects in the simple goal conditions showed great variability in their self-regulation. This investigation shows that, given traditional learning goals with little guidance about how to work through and think about the system, users are less able to meet the challenges inherent in HAL and do not meet their full potential. Giving learners a short introduction to SRL techniques, however, can be almost as effective as providing a personal tutor.

Other investigators have experimented with using prompts or questions designed to encourage metacognition without training or tutors. Kauffman (2002) presented subjects with a hypertext designed to teach about educational measurement. Half the subjects were assigned to work with a system that presented automated self-monitoring prompts in the form of questions. The prompts appeared each time a user moved from one node to another. If students were unable to answer the question correctly, they were encouraged to go back and review the page they had just read. The other half of the subjects were able to click freely on link buttons and move to a new page without answering any questions about their understanding. Both groups performed comparably on the declarative knowledge test. Students in the metacognitive prompt condition, however, outperformed their counterparts on a posttest that assessed their ability to apply what they learned to real-world problems (a measure of situation model learning). Interestingly, the groups did not differ in their awareness of metacognition. Providing automated self-regulation prompts was an effective means of encouraging deep learning, even if subjects were unaware of how the prompts altered their thinking about their own learning. It should also be noted that, because of the small size of this hypertext, there were few link buttons and subjects received only three or four prompts during the learning period. That clear improvement in learning was observed after such a mild intervention speaks to its promise.

In sum, the nature of hypertext renders HAL a more cognitively demanding mode of learning. As such, the use of metacognitive strategies is all the more important in this context. A number of studies have shown, however, that even minimal user training or automated prompts may be used successfully to promote metacognitive strategies and augment learning outcomes.

### 23.3.3 Conceptual Structure

Much of the interest in using hypertext to promote learning is grounded in the notion that hypertext information structures may reflect the semantic structures of human memory (Bush, 1945; Jonassen, 1988, 1991; Jonassen & Wang, 1993; Tergan, 1997b). Researchers have asserted that developing a hypertext that provides access to an expert's semantic structures could improve the learning and comprehension of nonexperts who read it. The assumption is that ". . . the network-like representation of subject matter in a hypertext as well as the kind of links between information units which support associative browsing correspond to the structure of human knowledge and basic principles of the functioning of the human mind (Bush, 1945; Jonassen, 1990). Because of the suggested match, it is assumed that in learning situations information represented in hypertext may be easily assimilated by the learners' minds" (Tergan, 1997b, pp. 258–259). Thus, researchers have attempted to determine whether nonexpert users will assimilate expert conceptual structures modeled in a hypertext.

Jonassen and Wang (1993) developed a series of studies to examine whether university students' learning of the structural nature of hypertext content was enhanced by a "graphical browser" based on an expert's semantic map. The structure of the graphical browser resembled a concept map, with the concepts arranged in a weblike structure. Lines on the map indicated connections among the concepts, and descriptive phrases superimposed over the lines described the connections between the concepts. The hypertext was quite large, containing

240 informational screens and 1167 links. Seventy-five major concepts were represented in the concept nodes. Assessment measures addressed relationship proximity judgments, semantic relationships, and analogies. All were designed to assess students' structural knowledge of the content presented in the hypertext. Students read versions of the text that provided structural cues about the topic (either the graphical browser or a pop-up window explaining the connection represented by the link that was just accessed). Results showed little evidence that learners internalized the expert's semantic structures after being exposed to the structural cues in the hypertext-user interface. It should be noted that when a task was introduced that required students to construct a semantic network about the topic, their ability to represent relationships among the concepts was affected. (The importance of task variables in HAL is addressed later in the chapter.) Nonetheless, the direct measures in this study did not reveal a strong effect of system structure on learners' conceptual structures.

McDonald and Stevenson (1999) used indirect measures to examine the effects of structural cues on cognitive structures. They explored differences in learning when students used what the authors referred to as a "conceptual map" versus a "spatial map." As with Jonassen and Wang's graphical browser, the conceptual map provided a representation of the key concepts in the text and specified the relations among them. The spatial map presented a hierarchical representation of the hypertext nodes and links showing what information was available and where it could be found. In the spatial map condition the structure of the text was represented but there was no attempt to show connections among the concepts.

In their study, university students read a 4500–word hypertext (45 nodes) on human learning that used highlighted keywords to link between nodes. Assessments included a 40–question test. Twenty items tested factual knowledge and 20 items were synthesis-type questions that required a deeper understanding of the text. Students received access to a spatial map, received access to a conceptual map, or were in a control group that did not get access to any map. Results indicated that the spatial map facilitated navigation but that students in the conceptual map condition performed better on learning measures on a 1-week-delayed posttest. Thus, use of the conceptual map available in this hypertext appeared to help students gain more durable and useful knowledge.

Why the discrepancy between these results and those of Jonassen and Wang (1993)? Jonassen and Wang tried to measure semantic representations directly. They tried to demonstrate a direct relationship between expertlike structures modeled on the hypertext and the cognitive internal structures of the learners. McDonald and Stevenson inferred the nature of learners' cognitive structures based on student responses to higher-level thinking questions. Their assumption was that if users could answer synthesis-type questions, they had internalized the expertlike structures. In addition, inconsistencies may have been related to the fact that McDonald and Stevenson used a much smaller, less complex text.

There is little evidence, then, that simply working with a hypertext system designed to represent an expert's conceptual understanding of a topic can lead to a direct transfer of expertlike mental representations to the reader. Developing and changing learners' conceptualizations has long been a challenge for educational researchers (Dole & Sinatra, 1998; Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1992). It seems clear that some degree of cognitive engagement is required if readers are to benefit fully from HAL. As McDonald and Stevens' (1999) work demonstrates, though, traditional assessments of learning (such as short-answer and essay tests) are clearly affected by system structure. The next section explores in detail how system structure effects HAL.

## 23.4 THE EFFECT OF SYSTEM STRUCTURE ON LEARNING

As the previous section showed, system structure can be communicated to users through a variety of means, including the organization of links on pages, maps, overviews, and indexes. In their metanalysis of studies on learning from hypertext, Chen and Rada (1996) searched for evidence of a learning advantage from one of these tools over another. They found no linear trend in the relationships among learning effectiveness and indexes, tables of contents, or graphical maps. They conclude that the "organizational structure of information dominates the extent that users' performance was affected and that individual components of hypertext or nonhypertext systems, such as indices, tables of contents, and graphical maps, may have a relatively weaker influence" (p. 145). Given this evidence, the present section discusses learning outcome based on the system structure in general, rather than the particular means through which the structure is communicated.

### 23.4.1 A Seemingly Contradictory Literature

As Chen and Rada (1996) have noted, the majority of studies have shown that system structure effects learning outcome, yet a number of studies have shown no such effect (Dee-Lucas and Larkin, 1995; Foltz, 1996; Shapiro, 1998a, 1999). This lack of effect may be due to any number of variables, including the way in which learning is assessed, users' prior knowledge, learning tasks and/or goals, navigation patterns, and actual interest in the domain. Indeed, one problem with research on HAL is that there are no standards for tests of learning outcome, user variables, or system design. (See Problems with HAL Research for more on that topic.) As such, a lack of results may often be attributable to a lack of distinction between systems or a failure to account for interacting variables. Even among studies that do demonstrate learners' sensitivity to a system's global structure, conclusions about what a "good" structure is differ greatly.

Some studies have shown advantages to using a highly organized system structure such as a hierarchy. Simpson and McKnight (1990) suggest that a well-structured system can augment learning. They presented subjects with a 2500–word hypertext on houseplants. Subjects were shown indexes listing the system content that were structured either hierarchically or alphabetically. In other words, only one system organized the information according to conceptual relationships. The differences between groups' learning outcomes were marked. The hierarchical group outperformed the alphabetical group on a posttest of content and was better able to reconstruct the organization of content on a mapping posttest.

Does this mean that highly organized, hierarchical structures are always superior? Research on learning from traditional text would suggest so. A large body of literature on the relevance to hierarchical structures to learning has shown that such well-defined structures are important to information acquisition (Bower, Clark, Lesgold, & Winzenz, 1969; Eylon & Reif, 1984; Kintsch & Keenan, 1974) and expert performance and problem solving (Chase & Simon, 1973; Chi & Koeske, 1983; De Groot, 1965; Friendly, 1977; Hughes & Michton, 1977; Johnson, 1967). This work largely influenced the design of hypertext systems from the beginning. The hypertext literature makes clear, however, that no single structure, including hierarchies, is appropriate for all learners, learning goals, or domains of study. In fact, some studies have shown no benefit of a hierarchical system structure over other nonlinear hypertexts (Dee-Lucas & Larkin, 1995; Melara, 1996). Dee-Lucas and Larkin (1995), for instance, gave subjects either a generalized or a specific learning goal while working with a hypertext on electricity. Some of the subjects received the information in a linear format, whereas others used one of two hypertext systems. One of these was hierarchical and the other was an index. Subjects were later asked to summarize what they had read. Analyses of the summaries revealed no differences between the two hypertext groups. Further, neither hypertext group outperformed the linear group when the goal was specific.

Beyond showing no advantage of hierarchies, some studies have actually found advantages of working with ill-structured hypertexts. Shapiro (1998a) presented subjects with identical systems that presented the links either within a clear, hierarchical structure or as a collection of links and nodes with no particular underlying structure. A posttest revealed that subjects in the unstructured group wrote essays that were of significantly higher quality. Their essays were also judged to reflect a significantly greater understanding of the material than did those written by the well-structured group.

To make matters even more complicated, still other studies have demonstrated the pitfalls of an ill-structured system design. Gordon, Gustavel, Moore, and Hankey (1988) were able to show that students who read a linear presentation of material actually came away with greater comprehension of the main ideas presented in the material than those who had worked with a hypertext system. In response to posttest questions about the experience of learning from these systems, those in the hypertext condition reported a feeling of disorientation; they were not sure what to expect on a document after clicking a button. Presumably, the resulting feeling of disorientation prevented subjects from creating a coherent mental representation that would allow them to store information with greater effectiveness. This study is part of a larger literature that demonstrates how a poor structure can mitigate learning by disorienting learners (Dias, Gomes, & Correia, 1999; Edwards & Hardman, 1989; Hammond, 1991).

This idea was studied in some depth by Britt, Rouet, and Perfetti (1996), who manipulated the transparency of their system's underlying structure. They presented subjects with systems designed to teach about history that presented the information either in a linear format or in a hierarchy. Each of those conditions either was scrambled or thematically organized the nodes. When the underlying structure of the material was made clear to subjects through thematic organization, subjects recalled the same amount of information on a free-recall posttest, regardless of whether they studied with a hypertext or a digitized, linear text. When the organizing information was removed and subjects were given only a "scrambled" overview of the system documents, the linear subjects actually did better than the hierarchical subjects on the recall test.

As shown here, the literature can appear to be downright contradictory but some common themes have emerged. As we see in the remainder of this section, the effectiveness of "good' structures like hierarchies tends to hinge on interactions among learners' prior knowledge, learners' goals, and the activity (or metacognitive) level of the learners' approach. In the following sections we explain two general conclusions drawn from the literature and explain the ways in which these variables interact to influence learning.

### 23.4.2 When a Well-Defined Structure Is Best

Learners with low prior knowledge benefit from well-formed structures like hierarchies during HAL. Several studies converge on this general conclusion. A recent study by Potelle and Rouet (2002) clearly illustrates the effect. Subjects identified as having low knowledge of social psychology were asked to use a hypertext to learn about the topic. They were assigned to use systems that presented the information as either a hierarchy, a seemingly unprincipled network, or an alphabetically structured list of topics. Subjects were given 20 min to learn about the topic and were then given posttests designed to assess the level of textbase and situation model knowledge they had gained. The results were unambiguous. On measures of textbase learning, multiple choice, and simple recall, subjects in the network condition were outperformed by those in the hierarchy or list conditions. On the posttest questions designed to assess subjects' situation models, however, subjects in the hierarchical condition outperformed those in both of the other groups.

These results strongly suggest that subjects were confused by the seemingly random (at least from their perspectives) network structure and learning was mitigated. This was so even for factual information present on individual documents (as tested by the textbase questions). When subjects were oriented by the other system structures, they were able to acquire this type of knowledge from the system. Simple orientation was not enough, however, to aid subjects in attaining a coherent, meaningful understanding of the information as a whole. Instead, subjects gained that type of knowledge best when they were shown the hierarchy. Only the hierarchical system was able to keep subjects oriented enough to create a textbase while also providing conceptual relationships that promoted deeper learning (the construction of a situation model).

System structure need not be hierarchical to benefit novices. The important characteristic for low-knowledge learners is that the conceptual relationship between documents be made clear. This was demonstrated by Shapiro (1999). In that study, subject identified as nonexperts in biology were assigned to work with either a hierarchy, an arrangement of thematic clusters, an unstructured collection of interconnected documents, or a linear (electronic) book. All system conditions presented the same documents about animal biology.

A cued-association posttest showed that subjects in all three hypertext conditions were able to recall the conceptually related topics, which were presented through system links. Subjects assigned to the electronic book condition differed significantly in this regard from those in the linked conditions. (The possibility of a repetition effect through simply seeing the link button names was ruled out with a separate control condition.) Learning across conditions was shown to be shallow, however, as all groups performed poorly on a problem-solving posttest. A closer look at the data, however, revealed that problem-solving performance was related to an interaction between the user interface and the navigation pattern. Specifically, the clustered condition presented short phrases adjacent to each link button that provided some detail about the relationship between the current document and the one represented by the link. The data revealed a significant correlation between the actual use of these buttons and performance on corresponding inferential items. Simply put, subjects were more likely to get a problem-solving question correct when they actually used the link that joined the documents relevant to the question.

In this case, not even the hierarchical structure aided subjects in creating a meaningful understanding of the material. However, the use of more explicit pointers to conceptual relationships was related to an increase in problem-solving ability. The important point about this study is that there is nothing "magical" about hierarchies for novices. Rather, any device that will explicate the conceptual relationships between topics can aid low-knowledge learners.

The importance of a clear, conceptually based system structure as it relates to meeting specific learning goals was also demonstrated by Shapiro (1998b). Specifically, she was able to show that the ability of low-prior knowledge learners to meet their goals may be mediated by a structure's compatibility with the learning goal. In the study, subjects were all pretested for knowledge of animal family resemblances and interspecies relationships within ecosystems. Subjects were included only if they had good knowledge of animal families but low knowledge of ecosystems. They were then asked to learn about a world of fictitious animals with the aid of a hypermedia program that provided an advance organizer structured around either animal families or ecosystems. They were also assigned the goal of learning about either animal families or ecosystems, with these factors fully crossed. All groups performed equivalently on posttest items that probed knowledge of animal families. These results were attributed to subjects' prior knowledge of that domain.

The posttest of ecosystem knowledge revealed how both prior knowledge and learning goals influence the effectiveness of system structure. Those who did not see the ecosystems organizer performed poorly on the ecosystems posttest items, even when they were in that goal condition. The ecosystem organizer, however, aided learners in meeting an ecosystems learning goal about which they had little or no prior knowledge. The effect was strong enough to produce incidental learning effects, as those assigned to learn about animal families also learned about ecosystems when exposed to the ecosystem organizer. In fact, subjects in the ecosystems organizer group who were *not* assigned to the ecosystems learning goal actually learned more about that topic than those in the animal families organizer condition who *were* told to learn about ecosystems. Thus, for learners with low prior knowledge of ecosystems, subjects learned about ecosystems only when they saw that structure. This result speaks to the great potential of a well-defined, goal-appropriate structure for initial learning by novices.

While most of the research examining HAL has been conducted with adult readers, work with children has been largely consistent with that with adults. Shin, Schallert, and Savenye (1994) examined the relationship between prior knowledge and learner control in learning by 110 second-grade students. A simple hypertext on food groups was presented in a free-access condition that allowed students to access every possible topic in the lesson in any order through a button-driven network structure. The same text was also presented in a limited-access form that had a hierarchical structure allowing the students to choose only topics that were related to the topic just presented. Both texts were also divided into an advisement condition, in which the program made suggestions to the reader on how to proceed, and a no-advisement condition. Students completed paper-and-pencil pre- and posttests to assess their learning of the content. According to the authors, ". . . High prior knowledge students seemed able to function equally well in both conditions whereas low prior knowledge students seemed to learn more from the limited-access condition than from the free access condition" (p. 43).

There have been some notable exceptions in this area of the literature. Among these is a study by Hofman and van Oostendorp (1999). Forty university students read a hierarchically structured hypertext on basic physical and biological science concepts. Half of the students had access to a graphical conceptual map that included information nodes and cause-and-effect relations between them. The remaining students read the same text, with a topic list in place of the conceptual map. Students then responded to 32 multiple-choice questions that addressed text-based recall questions and inference questions that required linking concepts from two or more screens and drawing on prior knowledge. Both types of questions addressed detailed, or micro-level, and general, or macro-level, content. Results indicated that students with low prior knowledge who had access to the conceptual map had lower scores on the inference questions than did low-prior knowledge students who did not have access to the map. The authors suggested that the conceptual map might have hindered the understanding of less knowledgeable readers because it drew students' attention away from the content of the text and focused them on macro structures. Low-prior knowledge students may have been overwhelmed by the complexity of the information system as revealed in the conceptual map.

In sum, well-structured hypertexts may offer low-knowledge learners an introduction to the ways in which topics relate to one another and an easy-to-follow introduction to a domain.

This is especially so when the structure is compatible with the learning goal. Well-defined structures also allow novices to stay oriented while exploring the information. However, some evidence has been found that contradicts this conclusion, and as Spiro et al. (1987) note, there is danger in oversimplifying a topic for learners. Providing rigid structures, especially for ill-structured domains (such as history and psychology), can impose arbitrary delineations that may impede progress as a learner advances in knowledge. For this reason, ill-structured hypertexts also offer advantages.

### 23.4.3 When Ill-Structured Systems Are Best

Both the CIM and CFT predict that ill-structured systems will benefit more advanced learners. From the perspective of CFT, ill-structured, multiply linked systems provide the learner with the opportunity to approach ideas from multiple perspectives, laying the groundwork for creating flexible knowledge that can be applied to new situations. The CIM also predicts gains from ill-structured systems because they promote the application of prior knowledge by encouraging the user to seek global coherence. In an article comparing and discussing three educational hypertext systems, Anderson-Inman and Tenny (1989) note that "one of the most important factors influencing whether or not studying will actually lead to knowledge acquisition is the degree to which students become actively involved in trying to make sense out of the material" (p. 27). They go on to explain how system structure can encourage this type of approach in a discussion of "exploratory" hypertexts. These are hypertexts that allow users to interact with and explore the system in ways that meet their particular goals or purposes at the moment. In other words, such systems do not impose a restricting structure on the information, allowing users to explore various aspects of relationships between ideas. Indeed, Anderson-Inman and Tenny note that exploratory hypertexts encourage learners to build their own organizational schema for the information. Since the publication of that article, empirical studies have been able to show that exploratory hypertexts can have such an effect on learning. Specifically, it has been shown that there is a relationship among system structure, active strategies, and learning.

As mentioned earlier, Shapiro (1998a) compared hierarchical and unstructured systems in a study of American history learning. Subjects in that study performed better on several measures when presented with the unstructured system. Among the measures of learning was an essay that was scored on four dimensions: (1) How well integrated was the information in the essay? (2) How clear was the author's argument? (3) How deeply does the author understand the topic about which he or she is writing? and (4) How was the overall quality of the essay? On each of these dimensions, subjects in the unstructured condition significantly outperformed those in the hierarchical condition. Further, navigation patterns differed between the system condition groups. Subjects in the hierarchical group were able to navigate more passively because the highly structured nature of the system kept them oriented in the information space. As a consequence, they used ease of access as a major criterion for link choice. Those in the unstructured system condition, however, were more principled in their movements through the information.

Taken together, the essay and navigation results suggest that the less structured system promoted more active processing and a deeper level of learning. How can these results be reconciled with Simpson and McKnight (1990) or the large literature showing the superiority of hierarchical information structures in traditional text? At least part of the answer lies in the importance of active learning as an interacting variable. Subjects who take advantage of the opportunity to work actively tend to show improved learning. Indeed, in a study of traditional text-based learning, Mannes and Kintsch (1987) note that refraining from "providing readers with a suitable schema and thereby forcing them to create their own. . . might make learning from texts more efficient" (p. 93). However, providing students with ill-structured hypertexts does not guarantee that active learning will occur, as not all students will thoughtfully engage with the hypertext content.

Another important point to consider when evaluating the educational value of any hypertext is the type of learning assessed. The significant difference in learning between groups in Simpson and McKnight's study was on a test of factual content (the textbase), while Shapiro (1999) examined students' answers to essay questions (the situation model). Rote learning is often aided by easily accessed structures that make fact retrieval simple. Deeper learning is aided by systems that promote a bit of "intellectual wrestling."

Jacobson and Spiro (1995) provide an excellent example of this point. In their study subjects were asked to read a number of documents about the impact of technology on society. Subjects in all conditions had been introduced to several "themes" concerning how technology influences a society. They were then randomly assigned to work with differing hypertext systems to meet a learning goal. Those in the control condition were told to explore the hypertext to identify a single theme running through the documents. Those in the experimental condition were told to identify multiple themes running through a series of "minicases." As such, they were put in a position to see multiple connections between documents, each signifying a different type of relationship. The material, then, appeared less orderly for the experimental subjects. After working with the systems for four sessions, the control group actually gained more factual knowledge than the experimental group. On the problem-solving posttest, though, the experimental group significantly outperformed the control group. Jacobson and Spiro were also able to show that those who had pretested as active, engaged learners performed better in the experimental condition than their less active counterparts in the same condition. Compared with other high-action learners, subjects performed better in the experimental than in the control condition.

The work reviewed in this section illustrates the benefits of ill-structured hypertexts for meaningful, advanced learning on the part of active, engaged learners. A cautionary note is warranted, however. Giving too little information about structure may also be detrimental. A great number of studies have examined the pitfalls of getting disoriented or "lost in hyperspace." Also, too little guidance can paralyze learners with an overwhelming cognitive load. A balance must be struck, allowing learners to reap benefits from systems that offer skill-appropriate guidance yet do not "spoon-feed" the information.

### 23.4.4 Conclusions

The research on organizing tools and system structure indicates that well-defined structures (such as hierarchies) are helpful if the learning goal is to achieve simple, factual knowledge (a textbase). Such structures can also be helpful (and perhaps even necessary) for beginning students. In keeping with prior research in text-based learning, however, promoting active learning is also an important consideration. By providing a structure that is highly organized or simple to follow, learners may become passive. The challenge for designers is to challenge beginning learners sufficiently while not overburdening them to the point where learning is mitigated.

Ill-structured systems are often beneficial for deep learning, especially for advanced learners. Providing less obvious organizational structures has the effect of challenging the learner to seek coherence within the system. The overall effect is to promote active strategies and improve learning. We do not claim, however, that ill-structured systems are always best for advanced learners, as learners do not always apply their prior knowledge. A passive learner will garner little from any hypertext system, beyond some facts stated explicitly in the text. The work reviewed in this section suggests that system structure and learning strategy interact to enhance advanced learning.

## 23.5 LEARNER VARIABLES

### 23.5.1 Individual Knowledge and Engagement

As discussed previously, readers come to a hypertext with differing levels of *prior knowledge,* and this variable has received considerable attention in the context of HAL. Specifically, research has yielded fairly consistent findings concerning different levels of control (Balajthy, 1990; Dillon & Gabbard, 1998; Gall & Hannafin, 1994; Large, 1996; Tergan, 1997c). That is, low-prior knowledge readers tend to benefit from more structured program-controlled hypertexts, whereas high-prior knowledge readers tend to make good use of more learner-controlled systems. Gall and Hannafin (1994) state, "Individuals with extensive prior knowledge are better able to invoke schema-driven selections, wherein knowledge needs are accurately identified *a priori* and selections made accordingly. Those with limited prior knowledge, on the other hand, are unable to establish information needs in advance, making their selections less schema-driven."

Another important individual difference that has received attention in the literature is the effect that learning style, or *cognitive style,* has on learning from hypertext under different treatment conditions. As our explanation of the interaction between active learning strategies and system structure showed, individual differences in learning style are often important to the learning outcomes. This is so largely because they interact with other factors such as system structure.

Some researchers believe that there may be a relationship between types of navigational strategies in hypertext and whether the learner is field dependent or field independent. Field-independent learners tend to be more active learners and use internal organizing structures more efficiently while learning. Thus, it would seem that degrees of structure in hypertext will be related to the learning outcomes for field-dependent or -independent learners.

Lin and Davidson-Shivers (1996) examined the effects of linking structure type and field dependence and independence on recall of verbal information from a hypertext. One hundred thirty-nine university students read one of five hypertext-based instructional programs on Chinese politics. Treatments included linking structures with varying degrees of structure from linear to random. Field dependence or independence was determined by the Group Embedded Figures Test and learning was assessed through a 30–item fact-based multiple-choice test on the content provided in the lesson. According to the authors, subjects who were more field independent had higher scores on the recall measure regardless of treatment group. That is, the authors did not find a significant interaction between linking structure type and field dependence or independence.

These measures were text-based. Thus, it is notsurprising that no effect was observed, as the posttest did not assess the kind of knowledge that would be augmented by hypertext or active strategies (see Landow, 1992). However, Dillon and Gabbard (1998) have noted the frequency of such negative results and concluded that "the cognitive style distinction of field dependence/independence remains popular, but, as in most applications to new technology designs, it has failed to demonstrate much in the way of predictive or explanatory power and perhaps should be replaced with style dimensions that show greater potential for predicting behavior and performance" (p. 344). Although their sample size was small (only four studies), Chen and Rada (1996) also reported no general effect of active versus passive learning strategies in their metanalysis of HAL. As noted earlier, however, a great deal of research converges on the fact that passive engagement with a hypertext will mitigate learning outcomes when working with an unstructured hypertext. It may be that learning strategy affects learning outcomes primarily when it interacts with other factors (such as system structure). Additionally, success in meeting simplistic goals such as fact retrieval is not generally affected by learning style.

### 23.5.2 Reading Patterns

Researchers have attempted to identify patterns of reader navigation as they read hypertext. In an early study of navigation patterns, researchers watched subjects read hypertext and identified six distinct strategies: skimming, checking, reading, responding, studying, and reviewing (Horney & Anderson-Inman, 1994). Another effort, by Castelli, Colazzo, and Molinari (1998), examined the relationships among a battery of psychological factors and a series of navigation indexes. Based on their examinations the authors identified seven categories of hypertext users and related the kinds of cognitive characteristics associated with the various patterns. However, such studies simply addressed what readers did, not the relationship between reading patterns and learning.

Other investigations have examined how individual navigation patterns relate to learning (Lawless & Brown, 1997; Lawless & Kulikowich, 1996). For example, Lawless and Kulikowich (1996) examined navigation patterns of 41 university students who read a 150–frame hypertext on learning theories. Their purpose was to identify how students navigated and how their strategies related to learning outcomes. They identified three profiles that characterized readers' navigation of hypertext. Some students acted as knowledge seekers, systematically working through the text to extract information. Others worked as feature explorers, trying out the "bell and whistle" features to see what they did, whereas others were apathetic users who examined the hypertext at a superficial level and quit after accessing just a few screens. They found that learner interest and domain knowledge had a significant influence on readers' navigational strategies. There was also some indication that knowledge seekers tended to learn more from the text than did feature explorers.

Other research has attempted to determine underlying cognitive characteristics that are reflected in the navigation strategies employed. Balcytiene (1999) used a highly structured 19-node hypertext on Gothic art recognition. Inserted "guiding questions" were designed to focus the readers' attention. Fifteen Finnish university students read the hypertext and completed a pretest, a posttest, and an interview. The pretest and posttest involved recognizing whether artifacts were Gothic and providing a rationale for their opinions.

The authors identified two underlying characteristics for these readers. "Self-regulated readers" tended to extract systematically all of the information in the text. They were more independent and exploratory in their reading patterns. In contrast, "cue-dependent readers" focused on finding the answers to the guiding questions. They were highly task oriented, looking for the "right answer" rather than learning general concepts. The pattern of findings was interesting. Self-regulated readers went from an average of 62.5% correct on the pretest to 98% correct on the posttest, while the cue-dependent group's average scores actually declined slightly, from 91.5% to 87.5% correct. Consistent with work reported previously in this chapter, this highly structured hypertext appeared to be more beneficial to low-prior knowledge readers. Although their results were nonsignificant (probably due to the small sample size or strangely high pretest scores of the cue-dependent group), further research into the self-regulated/cue-dependent distinction may be warranted.

Hypertext navigation is not, however, always a systematic and purposeful process. An extensive area of hypertext navigation research centers on examining the effects of reader disorientation, or becoming "lost in hyperspace" on learning. According to Dede (1988; cited in Jonassen, 1988), "The richness of non-linear representation carries a risk of potential intellectual indigestion, loss of goal directedness, and cognitive entropy." Disorientation appears to stem from two factors (Dias, et al., 1999; McDonald & Stevenson, 1999). First is the complexity of the HAL task. Readers must allocate cognitive resources to navigate the text, read and understand the content, and actively integrate the new information with prior knowledge. Second is what Woods (1984; cited in McDonald & Stevenson, 1999) calls the "keyhole phenomenon." The scope of document content and the overall linking structure are not apparent when one is viewing an individual screen, causing readers to have problems locating their position in the document relative to the text as a whole.

A considerable body of research has attempted to address the keyhole phenomenon. Much of this work examines the effects of different types of user interfaces on user disorientation (e.g., Dias et al., 1999; Schroeder & Grabowski, 1995; Stanton, Taylor, & Tweedie, 1992). Unfortunately, this research has been concerned predominantly with the identification of system structures to promote ease of navigation rather than the effects of such structures on learning.

Niederhauser et al. (2000) addressed the other disorientation issue, cognitive resource allocation, by providing options to allow readers to choose their method for accessing text information and to change that method as they read. The researchers developed a hypertext describing behaviorist and constructivist learning theories that could be read in a linear fashion, moving sequentially down each branch of the hierarchy for each topic, or hypertextually, by linking between related concepts on the two topics. Reading the 83–screen hypertext was part of a regular class assignment for 39 university students who participated in the study. Students were tested on the content as part of the class. Examination of navigation patterns showed that some students adopted a purely linear approach, systematically moving through each frame for one theory, then moving through the second theory in the same manner. Other students read a screen on one theory, then used a link to compare that information with the other theory, and proceeded through the text using this compare and contrast strategy. Results indicated that students who read the text in a linear fashion had higher scores on a multiple-choice test of factual content and an essay that required students to compare and contrast the major themes in the hypertext. Increased cognitive load was hypothesized as the reason students who used the linking features did not perform as well on the posttests.

In sum, the need to navigate through a hypertext is a defining feature that differentiates reading and learning in a hypertext environment from reading and learning with traditional printed text. Initial navigation strategies may be adopted due to interest, motivation, and intrinsic or extrinsic goals of the reader. Several authors (Niederhauser et al., 2000; Shapiro, 1999; Tergan, 1997c; Yang, 1997) have discussed issues of cognitive load when engaging in HAL. (See Paas & van Merrienboer [1994], Sweller [1988], and Sweller, van Merrienboer, and Paas [1998] for more about the problem of cognitive load during instruction.) When the cognitive load associated with navigating through the text interferes with the reader's ability to make sense of the content, the reader may adopt compensatory strategies to simplify the learning task. Thus, navigation strategies may influence what the reader learns from the text and may be influenced by the conceptual difficulty associated with the content and the learning task.

### 23.5.3 Learning Goals

Goal-directed learning appears to have a powerful influence on HAL (Jonassen & Wang, 1993). According to Dee-Lucas and Larkin (1999), "Readers develop an internal representation of the text's propositional content and global organization, which forms their textbase. They also construct a more inclusive representation of the text topic incorporating related prior knowledge for the subject matter, which is their situation model. The nature of the representations developed by the reader reflects the requirements of the study goal ..." (p. 283). Thus having a purpose for reading gives the learner a focus that encourages the incorporation of new information into existing knowledge structures in specific ways.

Curry et al. (1999) conducted a study to examine the effect of providing a specific learning objective to guide the reading of a hypertext. Fifty university students read a 60-frame hypertext on Lyme disease. Half of the students were given a specific task to guide their learning. They were given a scenario about a man with physical symptoms and a probable diagnosis and told to use the hypertext to determine the accuracy of the information in the scenario. The other half of the subjects were told to read the text carefully, as they would be asked a series of questions at the end. Although there were no differences found on recall measures, the concept maps that students drew did show differences. Students with a specific goal constructed more relational maps, which the authors felt demonstrated a more sophisticated internal representation of the content.

Not all specific learning goals promote deep, meaningful learning, however. In a study discussed earlier, Azevedo et al. (2002) gave some subjects a goal of answering specific questions about the human circulatory system, whereas other subjects were able to generate their own goal. Some subjects in the question-answering groups showed an increased sophistication of their mental models of circulation, but many actually showed a decrease in sophistication. None of the subjects in the learner-generated condition showed a decrease in their mental models' quality, whereas almost all showed an increase. Moreover, those in the self-generated goal condition demonstrated more effective use of metacognitive strategies.

Subjects in Curry and his colleagues' study (1999) benefited from a specific goal because it capitalized on the features offered by hypertext. The specific goal of fact-finding assigned by Azevedo et al. was not so compatible with HAL. Early in the history of hypertext in educational settings, Landow (1992) wrote about the importance of matching learning goals to the uniqueness of the technology. He points out that hypertext and printed text have different advantages and that hypertext assignments should be written that complement it. Goals like fact retrieval squander the richness of hypertext because fact-finding is not aided by multiple links. A number of studies, including that reported by Azevedo et al. (2002), exemplify this point.

What sort of learning goals do hypertext environments enhance? Landow suggests that assignments should be written to allow learners to capitalize on the connectivity. He implores educators to be explicit with learners about the goals of the course, and about the role of hypertext in meeting those goals, and to provide assignments with that in mind. In describing his own approach, Landow (1992) writes,

> ... Since I employ a corpus of linked documents to accustom students to discovering or constructing contexts for individual blocks of text or data, my assignments require multiple answers to the same question or multiple parts to the same answer. If one wishes to accustom students to the fact that complex phenomena involve complex causation, one must arrange assignments in such a way as to make students summon different kinds of information to explain the phenomena they encounter. Since my courses have increasingly taken advantage of Intermedia's capacity to promote collaborative learning my assignments, from the beginning of the course, require students to comment upon materials and links they find, to suggest new ones, and to add materials. (p. 134)

Note how Landow's approach reflects the philosophy that grounds CFT. Indeed, Spiro, Jacobson, and colleagues have long advocated the kind of approach described by Landow (Jacobson & Spiro, 1995; Spiro & Jengh, 1990; Spiro et al., 1988).

Some work has also been reported examining the compatibility between learning goals and characteristics of hypertext structure. In a series of studies with university students, Dee-Lucas and Larkin (1995) examined the effect of segmenting hypertext into different-sized units to examine students' goal-directed searching under these conditions. Sixty-four students with limited prior knowledge of physics participated in the study. Two hypertexts on buoyant force were created. One had 22 units organized in three levels of detail, and the second had only 9 units, with each unit reading as a continuous text. Students read one version of the hypertext under two conditions, once with an information-seeking task and a second time with a problem-solving task. Readers with the more segmented hypertext tended to focus on goal-related content, resulting in detailed memory for goal units but narrower overall recall. Readers with the less-segmented hypertext tended to explore unrelated units and recalled a broader range of content. However, when the larger size of the less-segmented text blocks made information location more difficult, fewer readers completed the goal.

The authors concluded that narrow, well-defined goals that require the reader to locate and/or interrelate specific content may be more efficiently achieved with hypertext that is broken down into smaller units. Conversely, learning goals that require the reader to integrate related prior knowledge (problem solving, inferential reasoning, etc.) may benefit from reading a less-segmented hypertext. Hypertext that contains larger text blocks may promote text exploration and development of a more complex mental model. Thus, a less-segmented hypertext may be appropriate for learning goals that require readers to internalize a wide range of text content or a more thoroughly developed conceptual model of the content.

In sum, the literature shows with a fair degree of consistency that learning with hypertext is greatly enhanced when the learning goal is specific, although a clear goal is not always enough to augment learning outcomes. Tasks that do not capitalize on hypertext's unique connectivity, such as fact seeking, may be enhanced by the use of a highly segmented and indexed hypertext but can promote poor learning strategies and superficial learning. However, in most cases hypertext is designed to encourage students to seek relationships between ideas, consider multiple aspects of an issue, or otherwise promote conceptual understanding. Developers, teachers, and users who attend to these goals are most likely to reap advantages from hypertext.

## 23.6 ADAPTIVE EDUCATIONAL HYPERTEXT

The lion's share of work in adaptive hypertext surrounds techniques in *user modeling*. This refers to any of a number of methods used to gather information about users' knowledge, skills, motivation, or background. Such data may be gained from written surveys, test scores, hypertext navigation patterns, and so forth. Characteristics of users are then used to alter any number of system features. The most common feature adapted in hypertext systems is the links. Specifically, links can be enabled or disabled for given users, or they may be annotated. Typical types of annotations will tell users whether a document has already been viewed or if they have sufficient experience or knowledge to view a document's content. (See Brusilovsky [2001] for an extensive review of current adaptive technologies). For example, Interbook (Brusilovsky & Eklund, 1998) and ELM-ART II (Weber & Specht, 1997) both place a green ball next to links leading to documents that a learner has sufficient prior knowledge to understand. A red ball indicates that the content will be difficult because the user lacks sufficient prior knowledge. In this way, the "stoplight" indicators serve to suggest best navigation choices for each user.

Another component that may be adapted is the actual document content. Some of the best work in this area has been applied to informal learning environments, such as virtual museums (Dale et al. 1998; Milosavljevic, Dale, Green, Paris, & Williams, 1998). These systems create a user model based on which virtual exhibits a user has already visited. That information is used as an indicator of prior knowledge. The text for each exhibit is generated from a database, rather than a static text. As such, each document is tailored for each user. A visitor to an exhibit of Etruscan military helmets, for example, might read something about metal smelting during that era. If he or she had already visited a site on Etruscan jewelry, however, the system would leave out that information, because he or she would already have read it at the jewelry exhibit. The generated text is remarkably natural sounding.

Decades of work on human cognition and learning, as well as much of the hypertext work reviewed in this chapter, strongly suggest that tailoring information in these ways should benefit the learner. Whereas such technological innovation is under vigorous pursuit by engineers and computer scientists, very few empirical studies on the educational effectiveness of these technologies have been reported. A small number of studies have looked at navigation issues (e.g., Brusilovsky & Pesin, 1998), but the data do not say much about actual learning. The majority of studies that do address learning overtly are plagued by methodological problems.

One study by Weber and Specht (1997) looked at the effect of annotating nodes on student motivation, which is a predictor of learning. This was measured by how far into the material students got before quitting. They found that for novices, the annotated links had no effect on motivation. For intermediate learners, however, those who were exposed to annotated links completed much more of the lesson. While the difference was nonsignificant, the small number of participants (no more than 11 per condition) makes the study less than conclusive.

Brusilovsky and Eklund (1998) tested the same type of adaptation. This study used a larger number of subjects and also attempted to assess actual learning, rather than motivation to learn. Their initial analyses found that the annotated group did not perform better than a group working with a nonannotated system. Additional analyses showed that many of the students did not take the advice offered by the annotations, however. If the advice is not followed, it should not be expected that the annotations will have an effect. Further analysis revealed that the degree of compliance with the suggestions offered by the annotations was significantly correlated with posttest performance ($r = .67$).

In summary, we know of no studies that have investigated the educational effectiveness of adapting actual document content. The few studies reported on adaptive hypertext have concentrated on adapting links. While hardly conclusive, these studies suggest that further investigation into the educational effectiveness of adaptive systems is warranted. It is important to identify the characteristics that are most effectively used in user modeling, as well as the system characteristics that are most important to adapt. Both of these topics offer promise as fruitful areas of investigation.

## 23.7 PROBLEMS WITH HAL RESEARCH

As is probably clear to the reader, HAL is a complex and challenging process for educators and psychologists to address. Efforts to examine it over the past decade have met with limited success. In this section, we highlight some of the primary concerns surrounding HAL research.

### 23.7.1 Theoretical Issues

Tergan (1997b) has challenged several of the common theoretical assumptions underlying HAL, some of which have been explored in this chapter. The "plausibility hypothesis" holds that linked networklike subject matter representation in hypertext should be assimilatable because it matches the structure of human knowledge and the workings of the mind. The research exploring conceptual structure, which we discussed in an earlier section of this chapter, indicates that exposing students to systems structured after experts' domain knowledge is not effective in promoting expert conceptual structure. Another common misconception is that self-regulation and constructivist learning principles will be enhanced due to the active, exploratory, and metacognitive aspects of reading hypertext. Studies reviewed here also concur that hypertext use alone does not necessarily promote active learning.

Beyond these common theoretical misconceptions is the lack of a coherent theoretical framework supporting research efforts. Indeed, this is a central problem in HAL research (Gall & Hannifin, 1994; Tergan, 1997b). We have chosen to ground our review in CFT and the CIM. Others, if they addressed theoretical foundations at all, have drawn on a variety of related orientations such as schema theory (e.g., Jonassen, 1988, 1993), dual coding, and cue summation theory (e.g., Burton, Moore, & Holmes, 1995) to situate HAL. Thus, "the efforts are typically isolated in terms of their focus and foundations, obscuring their broader implications" (Gall & Hannafin, 1994).

Tergan (1997b) proposes that no current theories have the power to explain HAL because they are too rigid and broad in scope. He advocates a less reductionist and more complex and all-encompassing framework for the study of HAL. He suggests that any successful theory of learning from this media will have to encompass the many facets of technology-based instruction including learner variables, instructional methods, attributes of the learning material, the media used, and situational constraints (such as authenticity of the learning situation). Although it may be true that a more complex and inclusive set of theories is needed to capture the complexity of HAL, we must keep in mind the fact that hypertext research is in its infancy. Some degree of reductionism and variable isolation may be necessary at this stage to understand better some of the basic underpinnings of HAL. Conducting profitable hypertext research from a holistic perspective will be difficult until this is accomplished.

### 23.7.2 Methodological Issues

Comparing and reviewing hypertext research is difficult because of a marked lack of coherence in the field. According to Gall and Hannafin (1994), we need ". . . a unified, coherent framework for studying hypertext . . . " (p. 207). For example, we do not share a common language. In this review we focus on Hypertext, which includes systems that are *primarily* text based but may include graphics. Others have presented hypertext as a purely textual component of hypermedia (Burton et al., 1995; Dillon & Gabbard, 1998; MacGregor, 1999), and others still view hypertext as synonymous with multimedia and hypermedia and use the terms interchangeably (Altun, 2000; Large, 1996; Unz & Hesse, 1999). This creates two problems when trying to understand the hypertext literature.

First, in this chapter we have made the case that understanding HAL should be grounded in research about learning from traditional text—that basic low-level reading processes are present regardless of the presentation medium. This allowed us to bring in a wealth of knowledge from the field of reading research and focus our attention on the set of variables unique to reading hypertext. However, the text-based reading research foundation is clearly compromised when extensive graphics and audio and video components are included in the hypertext. When these additional features are included in an experimental hypertext, the effects of learning from graphics (pictures, charts, graphs, etc.), audio, and video must be factored into the analysis. This problem is compounded in that experimental research on learning in these areas does not have the extensive history that has developed in the reading research field.

Second, there is a problem with comparing research studies when our lexicon about the field is so lacking in precision. As already mentioned, hypertext researchers do not even agree on a common definition for the most basic term—hypertext. Further, researchers may use different terms to describe similar constructs (e.g., concept map, spatial map, and semantic map; nonlinear, unstructured, and ill-structured hypertexts; and web-like and "graph of information nodes") or the same terms to describe different constructs (a conceptually easy text in one study may be equivalent to a conceptually difficult text in another). How, then, can we be confident in our claims about HAL when participants in the discussion have different meanings when using and encountering terminology in the literature? To move hypertext research forward we need a shared lexicon for the field. Gall and Hannafin (1994) proposed a framework for the study of hypertext in which they attempt to define a common language for the description and discussion of hypertext-based research. While this may be only a beginning, and not *the* definitive glossary of terms, it is certainly a step in the right direction.

In addition to the conceptual and language issues addressed above, experimental variables tend to interact and confound in the complex HAL environment. Learners with different individual characteristics (prior knowledge, field dependence or independence, activity level, goal for reading, spatial ability, etc.) are examined using different hypertext systems (level of structure, type of navigational structure, level of support, level of segmentation, etc.) and different text content (ill-structured versus well-structured domain, conceptual difficulty level, expository or narrative nature of text, etc.). This point reflects the complexity issue discussed earlier and points out the need for systematically designed programmatic research.

Finally, methodological flaws in much of the research have been widely reported in the literature. Dillon and Gabbard (1998) cite failure to control comparative variables, limited pretesting, inappropriate use of statistical tests, and a tendency to claim support for hypotheses when the data do not support them as serious concerns regarding the validity and reliability of conclusions drawn from the research base. In an extensive critique of the hypertext literature, Tergan (1997a) outlines a series of methodological problems that hamstring HAL research. In addition to confounded results due to the lack of empirical control of differential characteristics and contingencies of learners (as discussed above), he identifies lack of specificity in reporting methodology and limitations in learning criteria as major issues.

As an example of reporting specificity, Tergan points to the fact that many studies do not indicate the size of the experimental hypertext—despite the fact that there appear to be clear differences in content structure, navigability, and, therefore, learning based on the size of the text. In his critique of the limited spectrum of learning criteria, he points out that many of the measures used to examine HAL reflect traditional measures of reading—recall of factual information from the textbase and general comprehension. However, adherents claim that hypertext promotes deeper-level learning that is not addressed through these measures. Thus, "the potential of hypertext/hypermedia learning environments designed for supporting advanced learning to cope with a variety of different tasks and learning situations as well as learning criteria has not yet been explored in much detail" (Tergan, 1997a, p. 225).

## 23.8 GENERAL CONCLUSIONS

Despite the hype and excitement surrounding hypertext as an educational tool, there is really very little published research on the technology that is related directly to education and learning. Of the literature that does explore educational applications, there is little in the way of quality, empirical studies. As we have tried to show here, however, a number of things have been learned about HAL over the years.

Perhaps the most basic finding is that hypertext is not the panacea so many people hoped for at the time that it became widely available. Turning students loose on a hypertext will not guarantee robust learning. Indeed, doing so can actually mitigate learning outcomes in some circumstances, especially if students are novices and offered no training, guidance, or carefully planned goals. In the right circumstances, though, hypertext can enhance learning. It does so by presenting environments that offer greater opportunities for students to engage in the type of cognitive activities recognized by theorists as encouraging learning: active, metacognitive processing aimed at integrating knowledge and boosting understanding. In short, while hypertext does not offer any shortcuts for learners, it offers rich environments in which to explore, ponder, and integrate information.

Related to this point, it is clear that the effectiveness of HAL is directly related to the learning goal. Hypertext cannot help cram facts into students' heads any more effectively than most texts. It is most effective for helping students to integrate concepts, engage in problem-solving activities, and develop multifaceted mental representations and understanding. Goals and systems designed to promote such activities are most useful and productive. For this reason, learning outcome measures that explore factual knowledge alone often reveal little effect of hypertext use. Measures of deep understanding, problem-solving ability, and transfer (situation model measures) are those most likely to highlight the effectiveness of a hypertext.

Another important consideration is that, with few exceptions, there is little evidence that any single variable produces a replicable main effect on learning outcomes across diverse learners. As this review has made clear, almost every hypertext variable explored with reference to learning shows an effect primarily as an interacting variable. System structure, learning goals, prior knowledge, and learning strategies all interact. Exploration of any one of these factors without consideration of the others has tended to produce little in the way of informative results.

Finally, if future research in this area is to generate a well-grounded understanding of the processes underlying HAL, some standards for terminology and methodology will need to be developed. Only after this is done can an encompassing theory, grounded in research, emerge from the kaleidoscope of perspectives currently employed by researchers.

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