Mental Models and Hypermedia User Interface Design

By Michael D. Corry

The conceptual or mental model a user forms of a hypermedia computer system is crucial to the effective and efficient use of the system. It is important that this model accurately reflects the actual hypermedia system design. The user interface of the system plays an important role in the development of this model. This article is a survey of the research into user interface design and its impact on the development of hypermedia users' mental models. Various design issues, including the functionality of the system, system purpose, differences in user background, and usability, are discussed.

This article emphasizes the significance of the user interface design to the development of an accurate mental or conceptual model by the users of a hypermedia computer system. It begins with a review of the role of mental/conceptual models and their importance to hypermedia users. Also discussed are the role of the user interface in hypermedia systems and specific design issues that impact the user interface and mental model.

MENTAL/CONCEPTUAL MODELS

The conceptual or mental model users form of a computer system is very important as they use the system. A mental model is the means whereby humans are able to generate descriptions of system purpose and form, as well as how the system functions, and predictions of future system interfaces and functionality.

Norman (1986) explains that a user can manipulate a system easily if the “user model” (the mental model of the system held by the user) is closely aligned with the “design model” (the mental model of the system held by the designer) as seen through the “system image” (the physical structure which has been built including documentation and instructions). He explains that,

Mental models seem a pervasive property of humans. I believe that people form internal, mental models of themselves and of the things and people with whom they interact. These models provide predictive and explanatory power for understanding the interaction. Mental models evolve naturally through interaction with the world and with the particular system under consideration. These models are highly affected by the nature of the interaction, coupled with the person's prior knowledge and understanding. The models are neither complete nor accurate, but nonetheless they function to guide much human behavior. (p. 46)

Many researchers in the field of cognitive psychology agree that mental models exist and are needed by humans to perform tasks (Gagne & Glaser, 1987; Johnson-Laird, 1983; Norman, 1983). Driscoll (1994) describes mental models research as attempting to "explicitly lay out human understanding within specific subject matter domains" (p. 152). She goes on to explain that mental models are formed when people interact with the environment, other people, or the artifacts of technology. As they interact, they develop interpretive representations that affect their performance.

All learners—young and old, novice and expert—are affected by the mental models they develop. For example, one of the explanations of differences between experts and novices is that experts have a better conceptual understanding or have developed a better mental model than novices (Gagne, Yekovich, & Yekovich, 1993). Another everyday example is that people must have spatial mental models of their home in order to navigate through them successfully in the dark (Johnson-Laird, 1988). The implications of mental model research for instruction are important to understand. Norman (1982) explains:

As a designer, it is our duty to develop systems and instructional materials that aid users to develop more coherent, usable mental models. As teachers, it is our duty to develop conceptual models that will aid the learner to develop adequate and appropriate mental models. (p. 14)

A good mental model is easy to learn, drawing upon information that is highly familiar to learners, and functional in that it corresponds to important aspects of the target system it is designed to clarify (Driscoll, 1994). For user interface designers, the real problem is to design a system so that, first, it follows a consistent coherent conceptualization—a design model—and, second, so that the user can develop a mental model of that system—a user model—consistent with the design model” (Norman, 1986).

USER INTERFACE DESIGN

The user interface in human-computer interaction can be thought of as the medium through which the user and the information come together (Li, 1991). Norman (1986) explains that the interface can be thought of as having two sides: the system side and the human side. The system side
of the interface can be changed through proper design. The human side of the interface can be changed through training and experience.

Wright (1989) explains that “general aspects of good practice in screen design and dialogue construction will apply to hypertexts just as surely as they apply to other instances of human computer interaction” (p. 169). However, she argues that “hypertexts do raise additional issues relating to ways in which readers can be helped to move within the information resource and to exploit novel information handling techniques (e.g., creating their own personal links within the material)” (p. 169). Dillon (1989) explains that interface design has become more important over the last decade and that “it is generally understood that despite functionality, a system will often stand or fall on the strength of its user interface” (p. 186).

In addition to being the part of the system that the user sees, the user interface can also provide users with the tools they can use to manipulate the computer program. In a discussion of hypertext user interfaces, Marchionini and Shneiderman (1988) state that,

An interface enables users to perform their tasks by providing selection mechanisms, feedback mechanisms, and input/output devices. In a book, the default sequence is top-down due to the linear nature of the text. The interactive and flexible characteristics of hypertext require users to make more choices (selections) in searching for information. Furthermore, each selection requires appropriate and understandable feedback to maintain a fruitful interaction. Since the organization of the information in hypertext is not linear, mechanisms for selections and feedback are critical to good design. (p. 78)

Zhu (1996) concurs, explaining that the search for metaphors in hypermedia interface design has been less successful than in other computer applications because it is conceptually different from traditional media. She explains that the non-linear structure of hypermedia is unfamiliar to people and can be complex. Hypermedia becomes more complex if the interface tools provided to the user are also complex in nature. As advice to designers of user interfaces for hypermedia systems, Dillon (1989) states,

First and foremost, know the users. Who are they, what skills and abilities will they have and most importantly, what tasks are they going to perform with the system? It may seem obvious, but there is little point in designing a powerful, adaptable interface for users who will never interact with it for longer than a few minutes to extract simple information. Similarly, but less obvious, there is no point placing all one’s emphasis on ease of learning if, after becoming proficient the user finds the system incapable of satisfying his/her information needs. (p. 192)

He continues by stating that “a usable system that lets a user perform some of their tasks is better than an unusable one that theoretically does everything they want but in practice they can’t operate” (p. 193).

Wright (1989) explains that it is important to know the user before designing an interface, but she cautions against blindly following lists of principles or design guidelines that come from human factors readings. She states that the type of advice hypertext designers need is “very unlikely to be in the form of recipes to do this and do that” (p. 180). Instead she suggests providing hypertext interface designers with advice “based on task functionality, where the cognitive constituents of learning tasks are fully articulated” (p. 183).

Designers can use this advice much like a road map. It will help hypertext designers appreciate the range of ways any required functionality can be instantiated, and it will point out that dangerous territory is being entered when that functionality is instantiated in particular ways” (Wright, 1989, p. 183).

Zhu (1996) discusses two common hypermedia interface design strategies: browsers and typed links. Browsers help the user form a visual map of the information in a computer system. Conklin (1987) describes several different types of browsers as part of the Tektronix Neptune hypertext system. “A graph browser provides a pictorial view of a subgraph of nodes and links; a document browser supports the browsing of hierarchical structures of nodes and links; and a node browser accesses an individual nodes in a hyper-document” (p. 29).

The visual map developed by users can assist them in working with a hypertext system, helping them get the “big picture” of the system. This allows users to better understand how the system can be used to meet their individual needs. It is also beneficial in navigating through a hypertext system.

Typed links also attempt to provide the user with information that will help them more efficiently and effectively use a hypertext system. Zhu (1996) states,

Typed links give user[s] an indication of what lies at the destination, providing additional processing power over hypertext networks. For example, in Storyspace the designer or the user can create links of their own and specify the name of those links to help users understand relations between links. (p. 19)

In a study comparing typed link design strategies, Welsh (1994) allowed some users access to a hypermedia system where the link indicators were hidden so that the users had to manually filter links. Other users were provided a hypermedia system where the link indicators were available in a common visual appearance. The results of his study indicated that learners who could visually filter link indicators accessed fewer annotations and spent a greater proportional amount of time reading annotations than those who could not during both the comprehension and information locating tasks (Welsh).

A third common design strategy for hypertext systems can be seen in the Intermec System. It is described as the consistent user interface for creating and retrieving documents (Cunningham, Duffy, & Knuth, 1993). Yankovich, Haan, Meyrowitz, and Drucker (1988) describe this as the style paradigm. “Styles are sets of properties or characteristics that govern the appearance of data within a document. Users can define or modify a style by editing a form called a style sheet (sometimes referred to as a property sheet)” (p. 82).

A style sheet can specify information such as formats for
paragraphs, indented quotes, lists, and titles. There can also be guidelines for graphics such as line width, pen style, and fill style. The purpose of this type of strategy is to “enable users to learn new applications quickly and predict the behavior of features they have never used before” (Yankelovich et al., 1988, p. 82).

Finally, Shneiderman (1992) provides eight golden rules which can be used when designing user interfaces. They are (a) strive for consistency, (b) enable frequent users to use shortcuts, (c) offer informative feedback, (d) design dialogs to yield closure, (e) offer simple error handling, (f) permit easy reversal of actions, (g) support internal locus of control, and (h) reduce short-term memory load.

General and Information Design

Jonassen and Grabinger (1989) explain that designing hypermedia is not like designing other computer systems for instruction. Hypermedia is structured, developed, and interacted with differently than other computer systems. Therefore, they provide three different approaches to structuring and developing hypermedia systems. They are deductively developed hypermedia, inductively developed hypermedia, and instructional systems development.

A deductively developed hypermedia system is a top-down design approach which begins with a well-prescribed content structure or expert's knowledge structure. It is assumed that learning is a process of replicating the content or expert's knowledge structure. Therefore, the hypermedia system is designed in accordance with this structure in mind.

An inductively developed hypermedia system follows a bottom-up design approach. It is based on observation of users of an unstructured hypermedia system. Users are observed to determine how they assimilate, access, and use information in the unstructured system. Hypermedia systems are then designed and structured to support the verified user patterns.

An instructional systems development approach is a systematic process for designing and developing instructional hypermedia systems. This process typically includes needs assessment, task analysis, test item construction, selection of instructional strategies, and selection of the delivery system (Jonassen & Grabinger, 1989).

Zhu (1996) explains that one of the most important issues to be considered in hypermedia design is the structure of the information. She refers to research by Conklin (1987) who compares the structure of traditional text paragraphs to hypertext nodes. Traditional text paragraph boundaries have a relatively minor impact on the flow of the reading. However, the structure of the hypertext node of information has a much more profound impact. Conklin states “a hypertext node, unlike a textual paragraph, tends to be a strict unit which does not blend seamlessly with its neighbors” (p. 36).

Walley (1989) concurs that one of the most important issues in hypertext design is the structure of the information. He states:

An important issue concerning the role of hypertext in learning is the fragmenting effect of the medium, the “nuggets of knowledge” problem. This is not just a matter of screen size but stems from the basic, and conceptually simple, pointer structures underlying hypertext systems. Whatever the screen size, the author has to make semantic decisions about the size of information nodes; the amount to be displayed at any one time. This has both pedagogic and epistemological consequences. (p. 62)

In discussing the structure of information in hypertext systems, Jonassen and Grabinger (1989) propose that the structure of information be dictated by how the hypertext will be used. Different applications require different information structures. They provide five approaches to structuring information which can be used.

1. Semantic structures reflect the knowledge structure of the author or an expert.
2. Conceptualized structures include predetermined content relationships such as taxonomies.
3. Task-related structures are those that resemble or facilitate the completion of a task. Primary tasks include retrieving information, such as in information retrieval systems, and learning from instructional systems.
4. Knowledge-related structures are those that are based upon the knowledge structures of the expert or the learner.
5. Problem-related structures simulate problems or decision making (p. 12).

It should be noted that this list of approaches is by no means exhaustive, although it contains several common approaches. However, to be sure that the structure of information will be dictated by how the hypertext will be used, it is necessary to ask several questions regarding the information. For example, “How can we identify and represent the knowledge structure necessary to achieve the purpose for which the hypermedia is designed?”, “What type of structures are most appropriate for what types of tasks?”, and “What methods are available for developing a task-related or conceptual structure?” (Jonassen & Grabinger, 1989, p. 12).

The Impact of System Purpose on Design

The purpose or objective of a hypermedia system has a direct impact on the design of the system. Marchionini and Shneiderman (1988) discuss the differences between systems used to find facts and systems used to browse for knowledge. They state “users’ information retrieval depends on the cognitive representation (mental model) of a system’s features, which is largely determined by the conceptual model designers provide through the human-computer interface” (p. 70).

Zhu (1996) concurs when she explains that different hypermedia systems have different focuses or purposes. Like Marchionini and Shneiderman, she describes two types of systems. The first system encourages users to wander through clouds of information gathering knowledge along the way. This type of system could be a database of information which can be freely explored by the user. An example of this would be the World Wide Web.

The second system Zhu describes is directly tied to problem solving and specific learning tasks. She explains that this type of hypermedia system takes the form of electronic learning documents. An example of this would be the Encuentros system previously described.
In a discussion of the uses of hypertext in education, Duffy and Knuth (1989) outline four types of hypertext systems based on their purpose or use. The first purpose is to "explore a large database." They further describe this purpose as giving "the learner access to more information and to help the learner, through link traversal, acquire the important relations and the structure in that body of information" (p. 201).

The second type of system is to "access elaborations on core information." This is described as allowing "the student to select elaborations on that core body of information as necessary for comprehension" (p. 201).

The third purpose of a hypertext system is "operating on a database." This type of system "provides the opportunity for making tools available on an 'as needed' basis that can be used to manipulate the information in the database" (p. 201).

The fourth system purpose is "building a database"; users are allowed to author or add information to the system. For example, users may "be able to add nodes of information to an existing database" (p. 201).

After describing the different uses of hypertext systems, Duffy and Knuth (1989) continue by explaining that there are specific pedagogical assumptions and learner activities that accompany the different systems based on their purpose or use. These assumptions have a direct impact on the design of the system.

In another example of how the purpose of the hypermedia system impacts the design, Zhu (1996) describes distinctions between reading for comprehension and reading to locate information. Different cognitive processes are involved for each. She states that "skills used to accomplish these two tasks and devices needed for tasks' completion can be different" (p. 28).

One of the articles Zhu references is the research of Guthrie and Kirsch (1987). In an examination of adults' reading comprehension and their ability to locate information in text, they hypothesize that,

Locating information such as facts, names, or numbers in text is a reading task requiring comprehension that is distinct from text recall in two aspects. First, cognitive processes that control reading comprehension and locating information are expected to be different; second, the frequency of engagement in comprehension and locating are expected to be independent. (p. 220)

The results of their research reveal that "locating information is a generalized cognitive process that may be applied to prose in articles, information in manuals, and components in schematics; however, it was psychometrically distinct from prose comprehension" (Guthrie & Kirsch, 1987, p. 220). This again supports the notion that the design of a hypertext system can have a direct impact on how successful users are at accomplishing their goals or fulfilling the purpose for which they are using the system.

The Impact of Differences in User Background on Design

Differences in the background, experiences, and prior knowledge of users of a hypertext system can have an effect on their use and learning in the system. An important challenge in the design of hypertext systems intended for general use is making them accessible to a variety of users and groups from differing demographics (Leventhal, Teasley, Instone, & Farhat, 1994).

In a survey of benchmark studies, Nielsen (1990) explains that "individual differences have the largest impact on the performance when using hypertext systems" (p. 162). Marchionini and Shneiderman (1988) agree when they state,

Each user is unique, possessing mental representations for task domains. A generic knowledge base of information-seeking experiences includes mental models for various search strategies, dynamic mental models for search systems, and a control mechanism for relating these internal representations to one another and to external entities. Of particular interest for designers is how users develop mental models for new systems and how they apply these mental models when using systems. (p. 73)

There has been little experimental research done to provide design guidelines on how to match the system to different users. In a study of age-related differences in the use of hypertext, Leventhal, Teasley, Instone, and Farhat (1994) found that adults were superior to children in speed and accuracy, but there were no qualitative differences in navigation patterns or perceptions of the system. They did find, however, that some children used unexpected, but nonetheless effective, information searching strategies. In addition, they found that once the level of experience with the system increased, users ceased to use the system hierarchy to find information. Instead, they used more direct paths to get to the desired information.

In a related study, Shin, Schallert, and Savenye (1994) examined learner control, advisement, and prior knowledge on young students in a hypertext environment. In their study they varied access to the system. Some students used Limited access in the form of a hierarchical structure. Other students were allowed free access to the system where they could enter and exit the system at any point. They found that learners with different levels of prior knowledge required different kinds of instructional approaches. For example, "low prior knowledge students achieved higher scores under the limited-access condition than under the free-access condition" and "finished their lesson more quickly under the limited-access condition" (p. 45). Additionally, they found that "if prior knowledge is high, a free-access condition, representing a network structure, can be as effective as a limited-access condition" (p. 45).

In a discussion of learning with hypermedia, Hammond (1993) explains that consideration of individual differences is very important but something of a luxury in most hypermedia systems. In addition, he states,

Different individuals will adopt different learning styles for the same materials, and a single individual may change learning styles from one occasion to another. Such differences are highly informative of the underlying processes of learning and their variability, and have some practical consequences for the provision of optimal learning for a range of individual styles. (p. 63)
System Usability

Central to user interface design issues are issues of usability. The usability of a system is sometimes referred to as its "user-friendliness" or "usefulness." However, it has evolved over time to encompass more than just user-friendliness. Nielsen (1989) explains that in order for a hypermedia system to be useful it must be (a) easy to learn, (b) efficient to use, (c) easy to remember, (d) relatively error free, and (e) pleasant to use.

Dumas and Redish (1993) believe that usability "means that people who use the product can do so quickly and easily to accomplish their own tasks" (p. 4). They also explain that their definition of usability is based on four points: (a) usability means focusing on users, (b) people use products to be productive, (c) users are busy people trying to accomplish tasks, and (d) users decide when a product is easy to use (p. 4).

As can be seen, Dumas and Redish's definition of usability focuses on the user of a system. When this focus on users is incorporated into the design of systems, it is sometimes called "user-centered design." Norman (1988) defines user-centered design as "a philosophy based on the needs and interests of the user, with an emphasis on making products usable and understandable" (p. 188).

Marchionini and Shneiderman (1988) present a user-centered framework for evaluating hypermedia systems. The framework is applied to design issues when developing hypermedia systems. This framework was used during the design and development of the HyperText system and the Grolier's Electronic Encyclopedia system. Designers of hypermedia systems who use the user-centered framework must "attend to the physical system, the conceptual model the system presents (the user interface), and the mental model the user is expected to develop for the system" (Marchionini & Shneiderman, 1988, p. 78).

Nielsen (1989) explains that the usability of a system is one piece of information that ultimately ties into system acceptability. If the usability of a system is low, then the likelihood of it being acceptable to those who use it is equally low. Total system acceptability is based on social acceptability and practical acceptability (which includes usability).

CONCLUSION

The conceptual or mental model a user forms of a hypermedia computer system is crucial to the effective and efficient use of the system. The user interface of the system plays an important role in the development of this model. Hypermedia designers should keep in mind the importance of keeping the user's mental model, the designer's mental model, and the user interface closely aligned (Norman, 1986). They should also remember that a good mental model is easy to learn, drawing upon information that is highly familiar to learners (Driscoll, 1994). And that despite functionality, a hypermedia system will be successful based on its user interface (Dillon, 1989). Key areas of focus for hypermedia designers should include the system purpose, differences in user background, and usability.

References


