University of Oklahoma
Graduate College

Use and Effectiveness of Navigational Aids in Hypertext

A THESIS
SUBMITTED TO THE GRADUATE FACULTY
in partial fulfillment of the requirements for the
degree of
MASTER OF EDUCATION

BY
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Norman, Oklahoma
1993

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Acknowledgements

I would like to express my gratitude to my committee members, Drs. John Behrens, Ray Miller, Mary Boyce and Barbara Greene. Thank you Dr. Greene for giving me an opportunity to explore HyperCard. Also, I am grateful to Dr. Boyce for her technical assistance on HyperCard and Dr. Miller for his suggestions on motivational issues.

I especially wish to express my thanks to Dr. Behrens for his help on idea generation and refinement, proofreading, statistical analyses and even financial support. It is noteworthy that Dr Behrens has been helping me in deepening my insight in statistics and widening my horizon on philosophy of science.

Moreover, I would like to extend my appreciation to Robert Schull, SAS consultant at the University Computing Services. Mr. Schull is my mentor of SAS programming. Without his debugging, the data analysis of this project would be much more difficult.

Sincere appreciation is expressed to Apple Computer Inc. and SAS Institute. Without their fine technologies this project would not be possible.

May honors go to my mother culture, which empowers me to overcome adversaries. More importantly, my deepest gratitude goes to my parents for their unconditional love. My parents are the living examples of the Confucian work ethic, which is the source of my spiritual inspirations.

Last but not least, I am thankful to Dr. Susan Mendoza and Minister Ann Chen, who have been giving me encouragement and spiritual support throughout the last two years.

Contents

ABSTRACT

The goal of this study is to investigate use and effectiveness of navigational aids in a hypertext system. In addition, this study explained the effectiveness of training concerning strategies for using navigational tools. It was hypothesized that the frequency of use of navigational tools would be significantly different between strategy trained and untrained groups, and that performance would be positively correlated with the frequency of using navigational tools and the objective. Strategy training and use of objective did not lead to a significant difference in learning measured by pretest-posttest difference, but use of navigational tools was found to be a good predictor to performance. Moreover, users perceived pop-up as the most useful hypertext feature while map was perceived as the least helpful. Last, perception of usefulness of navigational aids was positively correlated with use of those tools. Based on these findings, it is recommended that a strategy training should not only inform the users about strategies, but also persuade users that those tools are helpful and motivate users to try them out. These results suggest that for novice users, easy access to information (e.g. pop-ups) may be more important than random access capabilities provided by other aids.

CHAPTER I RATIONALE

Developments in computer software and hardware have grown faster than the study of human-computer interfaces. Hypertext in education is one example. This technology has been available for almost half a century, and many hypertext packages have been developed. However, the characteristics of hypertext that make it effective are not well understood because very few empirical studies of hypertext have been conducted. In this paper, hypertext is defined as a linked information system for random access, which is guided by navigational aids. Random access is a double edged sword. It can lead to greater learning or greater confusion, depending on how navigational aids are used.

The purpose of this paper is to investigate how training concerning different navigational features affects feature use, and how feature use is related to learning in a hypertext environment. This chapter presents a definition of hypertext, a rationale for the investigation and states the hypotheses investigated. Results and Discussion are presented in Chapter 3 and 4, respectively. A comprehensive review of the literature is presented in Appendix A (see Page 65).

Properties of Hypertext

Hypertext/hypermedia evolved from the ideas of Bush (1945), who attempted to develop a random access retrieval system for microfilm. Following Bush's idea, Nelson (1967) coined the term "hypertext" while developing a hypertext system named "Xanadu." His bold plan has been to incorporate all world literature online into a giant database. Based on the principle that hypertext enhances human problem solving ability, Douglas Engelbart (1968) developed a hypertext system named NLS, which introduced several news aspects of user interface such as a mouse and multiple windows on the screen. Atkinson's HyperCard blends hypertext and hypermedia together, and this software is capable of different linking functions within the HyperCard packages and across different platforms such as computer, CD-ROM, stereo sound device and laserdisc player.

At the 1987 Hypertext Conference, Halasz (cited in Nielsen, 1988) predicted that in the future hypertext would become a standard interface style for computer systems, rather than just being a feature of a particular product. He highlighted three major hypertext research issues: (a) How to optimize search and query, (b) how to link basic nodes to form an explicit information structure, (c) how to use cues and implications to form a virtual structure. These concerns emphasize the need for collaboration between the methods of accessing of information and the organization of that information in a hypertext system. The properties of random access and implicit structure in hypertext subsume three design principles. First, random access requires interactivity. Second, search activity must be goal-oriented, and third, goal-directed searching demands a strong and meaningful association of information. Each of the principles are reviewed below.

Interactive Learning

Hypertext is typically developed on the assumption that learners are active and adaptive. Meaningful interactivity during learning can lead to a high degree of engagement. Some CAI developers seem to believe that having a user press a key or click the mouse to go to the next page is the total extent of interaction required. Hypertext designers should make the hypermedia product interactive in meaningful ways such as demanding learners to make decisions, or solve challenging problems.

Meaningfulness is important since most cognitive theorists view humans not as passive respondents to external stimuli, but rather as active choosers of what is perceived and responded to. Anderson (1990) asserted that human cognition and behavior is rational and adaptive to the environment. Rationality is defined as an orientation towards goals. If one has the knowledge that a certain action will lead to a goal, then one will choose that action. Therefore, learning is an active, constructive and goal-oriented process that is dependent on the mental activities of the learner.

The emphasis on interaction in hypertext is, in part, based on empirical studies supporting the notion that interactivity can increase learner motivation and promote the development of higher cognitive skills. Brown and Ferrara (1985) found that interactive learning led children to believe that they were collaborating in a problem solving process. In their study, even when adults provided such explicit clues that the answer was virtually given to the children, interactivity led the children to maintain faith in their own part in the learning solution. They seemed to feel they have worked toward a solution that they eventually discovered for themselves.

Other studies have also demonstrated the worth of interactive learning in a hypermedia environment. Riskin (1990) used an interactive multimedia system that allowed instant access to film, sound, television, images, and text in a college-level social science class. There were no constraints on the selection of the available media, or the ordering, structuring, and use of mass media materials. Riskin suggested that students were engaged in the subject matter and motivated to participate in the teaching/learning process. It was suggested that such interactivity promotes non-linear, creative thinking among students, yet allows an objective structure to grow out of a subjective mass of seemingly non-related materials. It was concluded that what the students have accomplished is a means of achieving a bridge that spans the gap between the knowledge of one's own creative reason and knowledge of the objective world of social phenomena.

Learning Objectives

There is a risk in interactive learning when there are few specific goals to drive information access decisions. If a user is allowed to make all decisions and it is completely up to the learner to "discover" the knowledge, the lack of direction may cause disorientation.

With regard to the degree of user's freedom, Barker (1989) differentiates among three types of computer-aided instruction (CAI): informatory CAI emphasizing computer control, exploratory CAI focusing on learner control, and instructional CAI stressing adaptive control. In the first type of CAI, the computer delivers the lesson to students in a fixed format. In the second type, the learner has the freedom to browse anywhere in the program while the last format tailors different paths to users with different mastery levels and learning styles.

Studies of learner control in traditional CAI programs found that students who have little prior knowledge about the subject are likely to perform poorly under learner control or discovery learning (Higginbotham-Wheat, 1988; Snow, 1979; Steinberg, 1989). Marchionini (1988) warned that learner control can be confusing because it increases decision-making load. A rich learning environment like hypertext can easily become an environment of "hyperchaos." More importantly, Locatis (1989) found that students experiencing learner control had a more negative attitude towards the CAI lesson.

Taking the above findings into consideration, a hypertext program should offer learning objectives in order to avoid users' disorientation. A key to meaningful browsing is a focus on learning objectives. Several hypertext researchers (Connell & Wellborn, 1991; McKnight, Dillon & Richardson, 1991) suggested that interactive learning and browsing must work hand in hand with explicit learning goals. Some researchers (Dreher & Guthrie, 1990; Guthrie & Mosenthal, 1987) also found that information extraction will be more efficient if readers allocate more of their search time to an initial stage of selected relevant categories of information for pursuing their goals, rather than focusing on later stages of information look up.

Association of Information

In addition to explicit learning objectives, a representation of knowledge structure, which states the relationships between individual datum, is essential for a meaningful learning environment. In other words, a hypertext system that can lead to a strong association of information would avoid disorientation, enhance recalling and comprehension of knowledge.

Anderson (1990) argued that it is important to have a interconnected mental schema for learning. According to Anderson, there are two types of memory, namely, short term memory/working memory, and long term memory. Short term memory is so limited that it can hold only a small amount of in-coming information or a small set of information from the long term memory. Information is represented in long term memory as a network of associations among concepts. A coherent subset of this network may be represented as a "schema." Information is retrieved by spreading activation from concepts in working memory through the network structure. The activation of various concepts in the network is determined by the strength of activation in the nodes. In this view, learning is not a piecemeal process. New information is assimilated into the schema if the information can "kick-start" activation in the schema. Unrelated or ill-structured information disappears in the short term memory.

While spreading activation is a continual unconscious process, the activation may lead to conscious associations or the desire to acquire information regarding incomplete concepts. When this occurs easy access to related information may aid the schema building process. High short term memory load required for extensive search of information in books or computers could inhibit such a process. Accordingly, the random access capabilities of hypertext may help the schema building process.

A similar notion could be found at the beginning of this century when psychologist O. Selz suggested that human problem solving is the process of filling in the gaps of partially completed information (cited in Lucas & Gaag, 1992). A concept must be explained in terms of many other concepts. If the student has one or several missing required components, the new concept would not be understood. Although a textbook has tables of contents and indexes for reviewing, students have to flip pages back and forth to locate the information that they need. In order to help the students interconnect the nodes to form a mental schema of the knowledge structure, immediate access to related information is desirable.

Navigational tools

Immediate access to information in hypertext is accomplished by navigational tools. However, navigation in hypertext is not a well-studied psychological phenomenon (McKnight et al, 1991). In the present investigation, four searching features which are thought to facilitate interactive learning are examined. All navigational functions are supposed to work hand in hand with the explicit learning objectives in order to form a meaningful association of knowledge. The navigation aids are the "find," "index," "map" and "pop-up-text" features. The buttons which invoke these aids, are shown in Figure 1 (page 139). The "find" button is represented by a picture of a hand picking up a card. The "index" is represented by an icon of arrows to four directions on top of a stack of cards. The "map" button is a grid icon, which symbolizes co-ordinates. The map and index buttons also include the text "map" and "index" below the icons. Pop-up text segments are illustrated by boldface type within the text.

Find

"Find" is a button on every card that enables a user to search for words typed into a dialog box. It is the most free form of hypertext function to be studied. The advantage of "find" is that a user can key in any word that he/she wants. The value of this type of hypertext is supported by the work of Horney (1992), who noted that hypertext users in his study overwhelming preferred making up their own patterns rather than follow explicit navigational techniques. However, because unconstrained use of "find" can lead to getting lost among cards, the present study included a "go back where I was" button to help the user avoid getting lost.

Index

"Index" is a button that can lead a user to an index card with all major key words listed alphabetically (see Figure 2, page 140). If a user clicks on a particular keyword, the card illustrating that concept is shown immediately. The "index" button also appears on every card.

The advantage of "index" is that users can concentrate on individual concepts rather than an the overall hierarchy. Horn (1989) argued readers tend to remember the information in the higher levels of a hierarchial map. Thus an index is considered a cue for leading the reader into details while map is a tool for presenting an overview.

However, by using non-hierarchial form of the index, it does not mean that index users learn only scattered concepts without an overall structure of knowledge. According to Downs and Stea (1977), humans tend to perceive the world with hierarchial categories even though the distinctions in the physical world could not be seen easily. Horn (1989) asserted that readers build within their minds representations that often have a hierarchical structure whether or not the structure is present in the text. Furthermore, Edwards and Hardman (1989) argued that in most cases hypertext users imagined a hierarchical form and they considered using the index as merely a method of traversing their perceived hierarchy. The above arguments assume that a user has a vague overall structure of knowledge in advance and knows what he/she wants to look in the index.

Map

On every card there is a "map" button for a user to leap into a hierarchial map illustrating the relationship of concepts. In contrast to non-structured "find" and perceived-structured "index," "map" has an explicit structure (see Figure 3, page 141).

One of the arguments for using a concept map is that in the hypertext system, a hierarchical structure, or a tree diagram, encourages a top-down approach of learning, i.e. the learner can overview the general information first and then can go into details later (Garzotto, Paolini, Schwabe, & Bernstein, 1991). The hierarchical map is believed to help readers build a coherent mental model of the materials since it suggests that all ideas relate to a central theme (Landow, 1989; Garzotto et al, 1991).

Besides organizing the information, a hierarchial map can provide learners with the information regarding their readiness to learn further information. Proper sequencing depends upon the learner's prerequisite knowledge. Learning a concept too early in an instructional sequence may leave the student confused about the goals and context of the new information. Learning a concept too late in an instructional sequence may require revision of previously learned conceptions. By providing a concept map the learner may see where a topic fits into the overall organization of the instructional web (Sharples, 1991; Love et al., 1991).

Pop-up text

Unlike "find","index", or "map","pop-up text" pre-determines what the reader will read. There are "hot spots" in several cards. When a user clicks on the hot spots, either a hidden text field in the same card will reveal itself or another sequence of cards will pop up for elaborating on previous information.

"Pop-up text" is the most rigid hypertext format since the link is predefined by the designer. In other words, the author must pre-determine the importance of various concepts, and to anticipate the user's expectations and difficulties.

Some researchers such as Mayes, Kibby and Anderson (1990) are opposed to the imposition of the designer's knowledge structure on the user. In contrast, Ogdin and Davison (1990) and Love et al. (1991) insisted that instructors' intention, expertise and experience should be used while building structured links. Moreover, Doland (1989) counteracted the criticism of academicians as "gatekeeper of knowledge" by the following argument:

Books are not neutral, why should hypertext be? A well designed hypertext/hypermedia document will be very powerful and persuasive indeed; there is little possibility of achieving hermeneutical neutrality. Hypertext is basically an interpretative act; that is to say, it possesses its own meaning and impresses its own meaning upon texts. (p.9)

In summary, the four hypertext features could be differentiated in terms of the strength of structure and the degree of user freedom. The "find" button does not contain any pre-determined knowledge structure. The user has absolute freedom to browse around the stack. The "Index" allows the user to construct or modify his/her perceived knowledge structure by following a list of glossary items. The user has less freedom in using "index" than in using "find." By using the "Map," the learner is exposed to a set of explicit relationships of concepts. His/her freedom in using the "map" is less than that in "index." Last, the "Pop-up text" gives user virtually no freedom for exploration. This hierarchy is illustrated by Table 1 (see Page 117).

Research on these hypertext features have led to inconsistent results concerning their efficiency and effectiveness. Although some studies showed that a hierarchical map led to better performance than other navigational aids (Billingsley, 1982; Simpson and McKnight 1990; Stanton and Stammers; 1990), Allinson and Hammond (1989) found that increasing familiarity with the topic results was matched with a shift from preference for system control (i.e. guided tour), to shared control (i.e. maps and indices) and then to user control (i.e. hypertext links).

Goals

This study is a partial replication and extension of the work by Allinson and Hammond. It is similar to their study in that use of navigational aids was evaluated. It differs from their study in the navigational aids use, and more importantly, users were given navigational aid use strategy training i.e. users were told under what circumstance should a navigational aid be used (Appendix B, Page 88). The study of Allinson and Hammond indicated a relationship between use of navigational tools and familiarity with the topic. Instead of letting students discover this strategy, in this study the techniques were taught to the treatment group. Further, the work by Freher and Guthrie (1990) and Guthrie and Mosenthal (1987) showed the importance of goal setting and category classification. Thus, this experiment used learning objectives as a guideline for locating information (see Appendix C, Page 101). The goals of this study are as follows:

(a) To compare the use of navigational aids by strategy informed and uninformed users. In the control group, the users were instructed about the features of different navigational aids. In the treatment group, students were told not only the availability of the navigational tools, but optimal strategies for applying them. It is hypothesized that the frequency of use of various navigational aids would be significantly different between two groups, as would their post-test performance.

(b) To assess the relation between use of navigational aid and performance measured by an objective test. It is hypothesized that the performance would be positively correlated with the frequency of using navigational tools.

(c) To assess the relation between use of objectives and performance. The hypothesis is that reviewing objectives, which is considered a strategy for effective searching, would improve performance.

Null Hypothesis

The following null hypotheses were used to test the hypotheses stated above:

(a) There is no relationships between strategy training and the frequency of use of navigational aids or performance when the effect of use of objective is partialed out.

(b) There is no relationships between overall frequency of navigational aid use and posttest performance, provided that the variables "strategy training" and "use of objective" are controlled.

(c) There is no relationships between frequency of use of objectives and posttest performance when the effect of use of navigational aids and strategy training are partialed out.

Data Analysis

Confirmatory Data Analysis

To examine the preceding hypotheses concurrently, multiple regression models were used. Cohen (1968) and Hardy (1993) proposed that any combination of categorical and continuous variables can be analyzed within a multiple regression model framework simply through the dummy coding of the categorical variables. In this study, the presence or absence of strategy training was coded as "1" or "0." Because only main effects such as strategy training, navigational aids and objectives were hypothesized, the following model was adopted:

$$\mathbf{Y} = \upsilon + \beta_1 \mathbf{X_1} + \beta_2 \mathbf{X_2} + \beta_3 \mathbf{X_3} + \varepsilon$$

and:

$\mathbf{X_1}$ = Frequency of using navigational aids
$\mathbf{X_2}$ = Presence or absence of strategy training
$\mathbf{X_3}$ = Frequency of viewing objectives

In a multiple regression model, a test of b is equivalent to a test of r. If x and y are related, then y varies with x and the slope is non-zero. Otherwise, all ρ s and β s are zero as the following:

$$\beta_1 = \beta_2 = \beta_3 = \mathbf{0} \ \ \textbf{cong} \sim \rho_1 = \rho_2 = \rho_3 = \mathbf{0}$$

Besides regression models, one-tailed t-tests, randomization tests and repeated measures were run to examine the difference between the trained and non-trained groups in terms of performance and use of navigational aids. A t-test requires several assumptions and the power of a t-test decreases tremendously in case of one-tailed test (Hays, 1988). In addition, a t-test would return only the approximation of a p value. In contrast, a randomization test is distribution-free and empirical-oriented. A randomization test is carried out simply by switching subjects across the two groups and generate a distribution of statistics based upon as many as permutations (combinations of actually observed scores) possible. Thus, one can determine in the most extreme case the exact, not approximate, probability of obtaining the statistic (Maxwell & Delaney, 1991). Repeated measures were used because unlike t-tests that introduce higher error variance, repeated measures remove the variability among subjects due to individual difference (Stevens, 1986).

Exploratory Data Analysis

In reality, it is rare that one outcome is caused by individual factors. Therefore, interaction effects should be paid attention to in order to obtain the best estimation (Aiken and West, 1991). Navigational aids by themselves may not be effective in facilitating learning without the help of learning objectives and the training of searching strategy. In addition to the hypothesized main effects, possible interactions were examined while there is no strong theory to formulate hypothesis of interaction effects. This examination may suggest additional areas of investigation for future work. This was tested by using the full regression model is as follows:

$$\mathbf{Y} = \beta_0 + \beta_1 \mathbf{X_1} + \beta_2 \mathbf{X_2} + \beta_3 \mathbf{X_3} + \beta_4 \mathbf{X_1} \mathbf{X_2} + \beta_5 \mathbf{X_1} \mathbf{X_3} + \beta_6 \mathbf{X_2} \mathbf{X_3} + \beta_7 \mathbf{X_1} \mathbf{X_2} \mathbf{X_3} + \varepsilon$$

with:

$\mathbf{X_1X_2}$ = Interaction between use of navigational aids and strategy training

$\mathbf{X_1X_3}$ = Interaction between use of navigational aids and learning objectives

$\mathbf{X_2X_3}$ = Interaction between strategy training and learning objectives

$\mathbf{X_1X_2X_3}$ = Interaction between navigational aids, strategy training and objectives

In addition to interaction effects, the relationship between the perception of helpfulness of navigational aids and use of them, as well as issues raised in the evaluation questionnaire, were also explored.

CHAPTER II METHOD

Subjects

The target population for this study is learners who are beginners in college-level statistics. The available population is students of the College of Education at the University of Oklahoma. Power analysis was used to determine the sample size required for a correlation coefficient between using hypertext features and test scores of .4 with power of .7. According to Cohen (1977), the proper sample size should be approximately 28 in each group, given that the alpha level is .05. Therefore, subjects were 59 students who took an undergraduate-level course in the College of Education. In order to make the result generalizable, the subjects should have a variety of backgrounds such as different age groups, genders, social classes and races. However, other types of lurking variables should be controlled. Therefore, the subjects were expected to have little or no prior knowledge of statistics.

Although group assignment was randomized and the difference between pretest and posttest scores are used as the outcome variable to adjust pre-existing divergence of subject ability, it is desirable to examine the profile of the subjects.

Originally there were sixty-eight participants for this project. Later nine subjects were excluded from the study. Among those nine people, two used "map" and "index" far above the average (see Figure 4, Page 142), and seven of them never used computers, who are unusual among college students. Although an effective CAI should be user-friendly to people who never used computers, the focus of this study is not "intuitive computing" or how to reduce anxiety of computer operation. Basic computer skills were assumed as prerequisite for participation in this study. Therefore these subjects were removed from the analysis. After these outliers were taken away, the profile of subjects was as follows: Although in both control and experimental groups there were more females than males (see Table 2, Page 118), a Chi-square test indicated that there is no significant difference in the ratio of genders across groups: X2(1, N = 58) = 1.484; p = .223.

The average age of control group is 24 with a standard deviation of 4.23 while the mean age of the treatment group is 25 with a standard deviation of 6.13. A t-test shows that there is no significant difference between the average age of two groups: t(1, 53.4) = -.7498; p = .4567.

In the control group, 23 subjects (88.24%) never took any statistics courses (Question 4), while 28 (90.32%) subjects in the experimental group. With regard to exposure to statistics within other courses (Question 5), 11 (40.74%) subjects in the control group answered "no," as did 16 members (51.61%) of the treatment group (see Table 3, Page 119).

In addition, the majority of both control and treatment groups were unfamiliar with the topic of central tendency (see Table 4, Page 120).

Pertaining to the familiarity with the hardware and software (Question 7, 8, 9), the majority of the subjects declared being unfamiliar with HyperCard though many subjects in both groups claimed to be familiar with the operation of a Macintosh computer. Chi-square tests were run to detect if there is any unexpected imbalance across groups. Again, no significant differences were found between the two groups in regard to the proficiency of handling computer (see Table 5A-5C, Page 121-123).

In light of these analyses, it was concluded that neither prior knowledge of statistics nor gender or computer skill differences would function as confounds in this study.

Content and Materials

Students used a program called "Hyper-Statistics" (Yu, 1993) adapted from Toothaker's (1986) text "Introductory Statistics for Behavioral Sciences." The lesson covers measures of central tendency such as the mean, mode and median. Concepts of various distributions are also included such as the normal distribution, skewed distributions, uni-modal distributions, bimodal distributions, and multi-modal distributions.

Because a pilot study found that subjects became impatient after reading a single chapter, only one chapter was used for this study. Since other chapters must require prior knowledge, central tendency is the appropriate starting point for novices.

Before reading the chapter, users in both groups worked through a tutor stack. In the treatment group learners were exposed to a detailed strategy training (Appendix B, p.88) and were encouraged to practice with the navigational tools. The study was developed in reaction to the work by Allison and Hammond (1989). These authors found that learners use navigational aids differentially according to their knowledge level of the subject. In order to reduce suspicion in the control group and avoid resentful demoralization (Cook and Campbell, 1979), the control group became a placebo treatment group. Although users in this group also read a tutor stack, the stack was only a list of navigational tools with one sentence description for each tool.

In the beginning of "Hyper-Statistics" the program presents the learning objectives. Moreover, on every subsequent card there is a button for the user to view the objectives if desired. Although the user can use any navigational tools at any time, he or she is advised to return the card viewed after relevant information is found.Instruments

There are three evaluation tools for this study. The first one is a built-in tracing program inside "Hyper-Statistics." The program records the frequency of clicking the searching buttons of each HyperCard user.

The second evaluation tool is a 40 multiple-choice-item test, which is presented in Appendix D (see Page 105). There are 20 questions in both pretest and posttest. The content of the two tests are exactly the same. In addition, the posttest includes ten dummy questions in order to make the subjects think the posttest is different from the pretest. Order of post-test questions was randomized. The difference between the two tests was used as the criterion variable.

The test contains more conceptual questions than computational questions because the former are considered to match the objectives and content more closely. This notion is derived from the observation by Gourgey (1987), who observed that some students on CAI appeared to be guessing by typing random answers into the computer while being asked a computational question. Therefore he asserted that it is important to teach concepts rather than just making students memorize formulas.

A pilot study showed that the Cronbach Coefficient Alpha of the original test was .55. Because low reliability means inconsistent responses within subjects, possible explanation of the low reliability is that the items are too difficult and therefore the students guessed the answers randomly. With this in mind those items which have negative correlation coefficient with the overall score were rewritten with reference to standardized statistics testing procedures. The difficulty of each item of the revised test is relatively even (see Table 6A, Page 124). Except Question 33 in the post-test (M = .1525) there is no very difficult item in either pre-test or post-test. On average subjects gained improvement in all but three items. The mean, standard deviation, and alpha of each item are listed in Figure 6B-6E (see Page 125-128). Surprisingly, the Cronbach Coefficient Alpha of both pretest and posttest was low: .22 and .48, respectively.

The third instrument is an evaluation form consisting of 27 items, which is presented in Appendix E (see Page 114). The major objective of the evaluation questionnaire is to obtain the feedback of using navigational aids, which is measured both qualitatively and quantitatively. Therefore, in the evaluation form some questions are open-ended and some are Likert-scaled.

Procedure

A series of experiments were conducted in a computer lab which have 10 Macintosh IIVXs. Five to ten subjects were allowed to come to the lab at one time. The group numbers were marked on the answer sheets next to the computers. The subjects were assigned to a group while choosing a seat. After the experimenter read through the instruction sheet, the subjects began the task. They were told that there was no time limit and to feel free to learn as much as they could.

In order to prevent subjects from getting pre-impression or pre-judgment of the study, those subjects who came first were instructed not to tell anything about the experiment to other participants after finishing the task. Question 26 in the evaluation was used to double check the confidentiality of the study. No one reported being informed about the details of the experiment prior to beginning their participation.

In order to motivate them to try their best in the tutorial, they were told that those who got 90 percent correct answers in the posttest would receive five dollars. No participants reached this criterion.

CHAPTER III RESULTS

Assumptions of Multiple Regression

Several assumptions for the data should be met in order to apply a multiple regression model to the analysis. Wonnacott and Winacott (1981) argued that if the assumptions of linearity, normality and independence are upheld, additional assumptions such as fixed values of Xs are not problematic. Therefore, testing of assumptions focused on these issues as well as the degree of heteroscedasticity and multi-collinearity.

Homoscedasticity

When the variance of the error terms appears constant over a range of predictors, the data are considered homoscedasticity. If this condition is not satisfied, the data are said to be heteroscedastic. The assumption of homogenous variance of residuals will be highly affected by outliers because of large residuals. On some occasions like this study, a scatterplot matrix of dependent variable against independent variables is not sufficient in spotting outliers. Outliers might be hidden after any form of manipulation such as substraction and summation. The dependent variable "pretest to posttest improvement" was measured by posttest scores subtracting from pretest scores, and the independent variable "use of navigational tools" is the summation of use of find, index, map and pop-up. Thus, a scatterplot matrix of pretest, posttest, find, index, map, pop-up and objective were used (Figure 4). The matrix indicated that one subject used the "map" feature 40 times and another used the "index" feature 36 times. They were outliers regardless of which variable index or map was plotted against. Therefore, the subsequent computation was done without these outliers.

While several test statistics are available for measuring homoscedasticity (e.g. Levane test, Hartley's F test, Cochran's test, Bartlett-Box test and Scheffe test), such tests are considered redundant by some modern statisticians such as Box (1953). Therefore in this study none of the above tests were used.

Linearity

Fox (1991) suggested that although it is useful to plot y against each x for the examination of linearity, these plots are inadequate because they only tell the partial relationship between y and each x, controlling for the other xs. It is desirable to use residual plots against each y. In this study, both types of plots were used to examine patterns between the explanatory variables and the criterion variable (see Figure 5A-5F, Figure 6A-6C, Page 143-151).

In spite of the vague pattern occurring in these plots, original data were still retained instead of applying data transformation. Fox (1991) stated that when discrete data are plotted, it is difficult to interpret the pattern. Continuous values spread through the value spectrum. For instance, within the range of 1 to 3, we may obtain 1.2, 1.21, 1.22, 1.23, 2.1, 2.12, 2.21, 3, 3.1, 3.5 etc... In contrast, discrete values such as count of use of navigational aids and objectives lead to the result that many subjects fell into the same short-ranged values: 1, 2, 3. In this case, data transformation such as logarithm, exponentiation, and reciprocal cannot help much to linearize the data.

Independence of Residuals

Residuals plots were used to detect whether the error terms were independent (see Figure 6). The plots indicated there is no systematic pattern among the errors.

Normality

Both normal probability plot and Shapiro-Wilk test were adopted to examine the distribution of residuals. In a normal probability plot, the normal distribution is represented by a straight line angled at 45 degrees. The standard residuals are compared against the diagonal line to show the departure. Although the plot in Figure 7 (see Page 152) showed that there was not serious departure, Hair, Anderson, Tatham and Black (1992) suggested that in a small sample size it is safer to use both normal probability plot and test statistics to ensure the normality.

There are two test statistics for detecting the presence of non-normality, namely, Shapiro-Wilk and Kolmogorov. If the sample size is less than 2000, the former should be used (Shapiro & Wilk, 1965). For this sample, the Shapiro-Wilk test statistic is .986441 and the p-value is .9073, which is far greater than .05. It was concluded that the data met the assumption of normality.

Multicollinearity

Multicollinearity will cause the variances to be high. These inflated variances are quite detrimental to the use of regression for hypothesis testing because some variables add very little or even no new and independent information to the model (Belsley, Kuh & Welsch, 1980). Although Schroeder, Sjoquist and Stephen (1986) asserted that there is no statistical test that can determine whether or not multicollinearity really is a problem, there are still several ways for detecting multicollinearity such as a matrix of bivariate correlation and the regression of each independent variable in the equation on all other independent variables (Berry and Feldman, 1985). Nonetheless, the former approach lacks sensitivity to multiple correlations while the latter cannot tell much about the influence of regressors to variances.

In this study the methods of variation inflation factor (VIF) and tolerance index (TOL) were employed. First, it is because the VIF relies on multiple correlations among regressors, rather than pairwise correlations (Fox, 1991). Second, both VIF and TOL indicate how each independent variable is explained by other regressors in terms of variance. The procedure of computing VIF and TOL is first to make each independent variable as the criterion variable regressing against all other explanatory variables. Then TOL and VIF are calculated as follows: TOL is simply the variance unexplained (1-R2). A small TOL denotes high multi-collinearity. Hair et al. (1992) suggested a cutoff for the TOL at .10. The VIF is 1/(1-R2), which measures the inflation that occurs for each regression coefficient above the ideal situation (all variances are explained) of uncorrelated predictors (Myers, 1986). In contrast to TOL, a large VIF signifies high multi-collinearity. There is no conventional cutoff for VIF (SAS User Guide: Statistics (Volume 2), 1993). According to Wetherill (1986), the VIF should not be larger than ten in order to claim the absence of perfect multicollinearity. Examination of Table 7 (see Page 129) suggests regressors do not inter-correlated to the extent that would lead to biased estimation.

Hypothesis Testing

Test of Hypothesis A

In this study the first null hypothesis is that there is no relationship between strategy training and the use of navigational aids and performance.

Figure 8 (see Page 8A-8J, Page 153-162) shows the distribution of the use of navigational tools as a whole and a break down in the control and treatment groups, respectively. In both groups the distributions of navigational tools as a whole and pop-up are normal, but the distributions of map, index and find are positively skewed.

Nonetheless, t-test procedures are robust against non-normal populations, especially when the sample size is large (Hays, 1988). A t-test indicated that there was no significant difference between the frequency of use of navigational aids between the control and the experimental groups: $t(1, 57) = .1941$; $p = .8468$. A randomization test with 65,000 permutations found that the probability of obtaining the values in the sample is equal to or greater than .8515, which is very close to the t-test result. The mean of the control group was 26.07 with a standard deviation of 12.84 while the mean of the treatment group was 25.34, the standard deviation, 15.59.

Although the performance was measured by the difference between pretest and posttest, it is still essential to look at the descriptive statistics of pretest and posttest scores. The mean of pretest scores was 9.03 with a standard deviation of 2.4, while the mean of posttest scores was 12.6 with a standard deviation of 2.76. Within the control group, the mean of pretest scores was 9.37 with a standard deviation of 2.51 while the mean of posttest scores was 12.74 with a standard deviation of 2.56. Within the treatment group, the mean of pretest scores was 8.75 with a standard deviation of 2.31 while the mean of posttest scores was 12.41 and its standard deviation was 2.96.

Figure 9A-9B (see Page 163-164) showed that distributions of pretest-posttest difference in both control and treatment groups are fairly normal. The mean improvement in the control group was 3.37 with a standard deviation of 2.76. The mean improvement in the treatment group was 3.65 with a standard deviation of 2.61.

There was a significant improvement in statistical knowledge as measured by the objective test after the treatment: t(59) = 10.18; M = 3.53; SD = 2.66; p = .00005. However, repeated measures ANOVA showed that between the strategy trained group and non-trained group the difference in pretest and posttest was not significantly different. For variation between the control and treatment groups (between subject effects): MSe = 9.9; F(1, 57) = .67; p = .207. For changes in the same group before and after treatment (within subject effects): MSe = 3.59; F(1,57) = 0.17; p = .00005.

In addition, the regression model also revealed that the strategy training was not a good predictor of use of navigational aids: F(1, 57) = .038; R2 = .0007; p = .8468. Nor was the pretest-posttest difference: F(3, 55) = 1.211; R2 = .062; p = .7332 (see Table 8A, see Page 153).

Test of Hypothesis B

The second null hypothesis of this study is that there is no relationships between overall use of navigational aids and performance. However, the weight of the evidence leans to a rejection of this null hypothesis. With the presence of two other variables--strategy training and objective use, the use of navigational tools yielded a significant result in predicting pretest-posttest difference (p = .0468) (see Table 8A). Further, pretest-posttest difference regressed against navigational tools as a whole and individual navigational tools, respectively. No significant results were found (see Table 8B).

Test of Hypothesis C

The third null hypothesis is the absence of relationships between viewing objectives and performance. After a careful examination, this hypothesis is not rejected. The regression analysis indicated that the use of objectives could not predict the pretest-posttest difference (p = .2431) (see Table 8A).

Exploratory Data Analysis

The regression model of raw scores showed that none of the interaction effects yielded significant results: F(7, 51) = .879; R2 = .1077; p = .5292 (see Table 9, see Page 132).

Question 10 in the evaluation asked "How helpful was the tutor for using Hyper-Statistics?" In the control group 12 users (44.44%) considered the tutor helpful and in the treatment group, 23 (74.19%) (see Table 10, Page 133). A Asymptotic Chi-square test showed that the perception of the usefulness of the tutor was not significantly different between two groups: X2(3, N = 58) = 6.414; p = .093. An exact permutation Chi-Square test also returned non-significant result: p = .0751.

Question 12 to 19 of the evaluation (see Appendix E, Page 114-116) centered around issues of how the subjects perceived the importance of navigational tools. In order to analyze the relationship between their perception of importance of navigational aids and the frequency of their application quantitatively, the multiple choice responses from Question 12 to 19 were transformed into numerical ordinal-level data: "A" as 5, "B" as 4 etc... Two types of regression model were applied. First, the sum of use of all navigational aids was used as criterion variable while the sum of responses from Question 12 to 19 was used as predictors. But no significant results were found: $F(1, 57) = .919$; $R2 = .0159$; $p = .3418$. Second, use of various navigational aids and responses from item 12 to 15 were broken down into four separate regression models (see Table 12, Page 135). It was found that the users' perception of helpfulness of index and map can predict their use of those aids.

Further, multiple boxplots also revealed that those who answered "a" (very helpful) in Question 12-15 tended to use the navigational tools more often (see Figure 10A-10E, PP. 165-9).

With regard to Question 20 "What aspect of the computer was most helpful for you?" the most frequent answer was "pop-up." (7 subjects, 28% in control group; 8 subjects, 27.6% in treatment group). The second most popular answer was "navigational tools in general." (6 subjects, 24% in control group; 2 subjects, 6.9% in treatment group). Only 2 subjects of the control group (8%) thought the tutor as the most helpful feature, as did two subjects (6.9%) in the treatment group (see Table 12, Page 135).

Interestingly enough, in responses to Question 18 of the evaluation (How helpful was the "objectives" button for preventing you from getting off the focus of studying in the "Hyper-Statistics?"), 13 subjects (22.4%) declared that the objective list was "very helpful" and 21 (36.2%) viewed it "helpful." However, responses in Question 20 (What aspect of the computer program was most helpful for you?) showed that only two subjects (3.44%) considered the objectives most helpful (see Table 13, Page 136).

In addition, after responses in Question 18 (How helpful was the "objectives" button for preventing you from getting off the focus of studying in the "Hyper-Statistics?") was converted into ordinal-level values, a regression model using frequency of use of objective as the outcome variable and Question 18 as the dependent variable yielded no significant findings: $R2(1,57) = .0138$; $F = .799$; $p = .3752$. Question 21 is opposite to Question 20: "What aspect of the computer was least helpful for you?" The most often cited feature was "map" (9 subjects, 45% in control group and 10 subjects, 37% in treatment group).

The responses in Question 24 (How much anxiety did you have with regard to using a computer for this study? What specifically caused you any anxiety?) were analyzed to find out whether anxiety was an interference to the training. Anxiety level in both control and experimental groups were low (see Table 15, Page 138). Because this study concentrates on using computer as a learning medium and the subject matter is not important, responses in Question 23 that concerns anxiety of statistics were not analyzed.

CHAPTER IV DISCUSSION

Findings

Results of investigations indicate that the on the average learners gained only 3.57 points in spite of the treatment. There are several possible explanations. First, the lesson which was adapted from Dr. Toothaker's text appears to be difficult for beginners. In the text there are quite a few mathematical notions that are confusing to learners who don't know the connotation of Greek symbols.

Second, the reliability of the test is low. This is most likely a reflection of varying degrees of abstractness and details in the questions. Some questions simply required recognition memory while others required inference.

Third, although financial inducement was used in this experiment, the experimenter observed that many subjects were not interested in earning five dollars. Actually, quite a few subjects just wanted to go through the experiment to earn bonus point for their class rather than trying to learn statistics.

The investigation also reveals that the use of navigational aids is a good predictor of performance in terms of improvement (difference between pretest and posttest scores). However, strategy training and viewing objectives were not found significant in relation to use of navigational tools and performance.

Strategy training does not necessarily lead to more use of navigational aids and better performance. In the pilot study many subjects did not use navigational tools shown in the tutor until the experimenter did a brief demonstration and encouraged them to try out the tools. Some subjects expressed the fear of unexpected results after pushing those buttons. In this study anxiety should not be the reason of the ineffectiveness of tutorial because the overwhelming majority of subjects reported little or no anxiety during the tutorial session (see Table 15, Page 138). This of course may be a function of participants openness to express anxiety.

It is possible that the strategy training was too long. The experimenter observed that in the treatment group the detailed instructions were not appreciated by the subjects. In contrast, the subjects in the control group liked the shorter version. Modification of the tutor in a concise manner is under consideration. Compared with the pilot study, much less users had anxiety after reading the longer revised version of the tutor.

Poor design is another possible explanation for the ineffectiveness of the tutor. Although both the tutor and "Hyper-Statistics" were evaluated by quite a few professionals including educators, psychologists, computer programmers and statisticians, they might not look at the software in the perspective of novices.

Use of navigational tools in the model yielded a significant result (p = .0468). However, the role of interaction effects in helping use of navigational tools is still unclear.

Like the map presented with multi-levels, the objective was also organized in two-levels i.e. main topics follows subtopics. A complex structure, even with only two levels, may be a stumbling block, rather than a stepping stone to novice users. It might be the reason why use of the objectives cannot predict use of navigational tools and performance.

Perception of usefulness of tools seems to be a stronger motivator than the strategy training. The regression model (Table 11, Page 134) showed that the more the users considered "index" and "map" helpful, the more they tended to use them. If those subjects who answered "b" in Question 12 and Question 15 were ignored, the preceding relationship could also be found between frequency of use of find and pop-up, and the perception of their usefulness. Multiple boxplots of Question 12 to 15 by items showed that those subjects who answered "b" ("helpful") did not necessarily tend to use pop-up and find more often. On the other hand, users who answered "a" (very helpful) definitely acted according to their belief (see Figure 10A-10E, Page 165-169). However, it is inconclusive whether the beliefs of usefulness of navigational tools lead to a more frequent use of the tools or vice versa.

Besides the perception of usefulness, readiness is another factor of effective navigation of hypertext. Ease of use should supersede power while designing hypertext for novices. Many participants considered "pop-up" the most helpful feature. The response is understandable because "pop-up text" was embedded in the program. Probably it was the easiest navigational aids for beginners (see Table 12, Page 135). It is consistent with the study of Allinson and Hammond (1989) that "map" was considered less helpful by users who were unfamiliar with the topic. It is not surprising because for beginners who were not familiar with the structure of the contents, map became detrimental rather than helpful (see Table 14, Page 137).

Limitations

There are several limitations in this study. First, as discussed above, the Cronbach Coefficient Alpha of both pretest and posttest are low.

Second, the data value is discrete in nature. It could not completely satisfy the condition of linearity. The only remedy is to increase the sample size.

Third, in this study both dependent and independent variables are random variables except the strategy training. Lomax (1992) suggested that explanatory variables should be fixed in order to do replications, repeated measures and generalization. Despite this limitation, no remedial measure will be made. Learning through hypertext should be spontaneous. It does not make sense to assign different individuals to use different times of navigational aids and objectives.

Furthermore, Norusis (1993) warned that in a pretest-posttest experiment a learning effect may occur i.e. the improvement may be resulted from the repetition of a task rather than from the treatment. In this case, after the subjects had taken the pretest, the fresh memory of the pretest questions might drive them to pay more attention to the content which occurred in the pretest. This kind of learning effect might be a hidden factor of their improvement in the posttest. Also, the pretest might orient the subjects about the protest. As a result they tended not to use the objective.

The exploratory data analysis suggested that the perception of helpfulness (Question 12 to 15 in the evaluation, Page 114-115) should have been included into the equation. If the variable that should be in the model is left out, the estimation of the beta and rho will be biased. Future research should reconstruct a model with this variable.

Last, HyperCard 2.0 was originally developed for old-fashioned small screen Macs. In this study Mac IIVXs which have 14-inch monitors were used. The size of HyperCard could not cover the full screen and left the background exposed. During the experiment, the researcher found that quite a few subjects did not know how to return to HyperCard after they accidentally clicked on the background.

Recommendations

Based on the findings of this study, it is recommended that strategy training for hypertext should be concise enough not to bore the users, but also detailed enough to tell the users what they will expect. As mentioned before, the perception of usefulness of navigational features is a fairly good predictor to the use of those tools. Thus, the training should not only demonstrate the operation of navigational features and the proper usage under different situations, but also to persuade them how important those functions are.

Moreover, the strategy should emphasize using "pop-up" and "index" rather than "map" if users are beginners. Mental construction of hierarchy is a complex phenomenon. Although some researchers such as Marchioni (1988), and Collins and Lengel (1990) argued that hypertext can help to develop high level cognitive skills, random access does not necessarily result in a coherent structure. If possible, the hypertext feature should be embedded in the main body (pop-up). Apparently easy access, in this study, was more accepted than random access by users.

Further research which incorporates the above suggestions is under consideration. All good tools require training to reach the stage of mastery. Hypertext is not an exception. Future research should pinpoint the maximization of use of navigational tools such as how to develop an effective strategy training. In addition to the frequency of feature use, the HyperCard program should record how much time users spend in different features so that the relationship between familiarity with the topic and feature use can be examined. Verbal protocol should also be applied in order to look at how ideas are developing in short term memory during the search process.

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APPENDIX A

REVIEW OF THE LITERATURE

The use of hypertext has been widely recommended by educators from many disciplines. Unfortunately, despite several decades of development in hypertext, the definition, advantages of this medium and the theories behind it is still unknown to many people. At the present time hypertext means different things to different people and the core idea of random access and the premise of knowledge structure are always neglected. To provide background, this paper discusses the nature of hypertext by reviewing historical foundations, different definitions and cognitive views of hypertext, and current status of hypertext research.

History of Hypertext

Originally, the concepts of hypermedia and hypertext were developed independently, but later merge together. With the advent of sophisticated software and hardware, hypermedia such as CD-ROMs and Laserdiscs can be randomly accessed through hypertext links. Hypertext is a form of non-sequential text for random access whereas hypermedia is a form of hypertext accommodated in various media. This section presents a brief history of hypertext, in which the milestones were marked by four major contributors, namely, Nelson, Bush, Engelbart and Atkinson.

Bush's Memex

The origin of hypertext can be traced back to Vannevar Bush's landmark article "As We May Think" (1945), in which he envisioned the creation of a "memex" or memory extender system with numerous microfiche files. The memex was based on "associative indexing," the idea that any item may be called up immediately and linked to relevant items automatically. For Bush, associative indexing was important because he believed it was the way that human mind worked:

The human mind does not work (like an index). It operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with some intricate web of trails carried by the cells of the brain. (p.106)

Bush admitted that the memex could not fully duplicate the above mental process, thus, users of memex were encouraged to take an active role. Bush did not pre-determined all "trails" or association of information. Instead, users would be expected to browse the information and build their own network of knowledge.

Nelson's Xanadu

Theordo Nelson, who coined the term "hypertext," is a faithful follower of Bush. In his article "As We Will Think," (1972) Nelson stated in the beginning that "Bush was right...It is possible that Bush's vision will be fulfilled substantially as he saw it" (p.439). Five years before he presented the paper "As We Will Think," Theodor Nelson (1967) proposed a computer system of hypertext named "Xanadu" that would allow writers to create non-sequential text. Two decades later Nelson elaborated his ambition plan by aiming at the creation of a "docuverse," a structure in which the entire literature of the world is linked (Nelson, 1988).

Engelbart's NLS

Douglas Engelbart (1968) is considered by others to be the father of hypertext. In the 1950s, Engelbart began thinking about the interaction between humans and computers. Engelbart read Bush's article and was inspired to build his own hypertext system, which was utilitised for enhancing human intellect and extending problem solving ability. This idea was reflected in the name of his first hypertext proposal in 1959--Human using Language, Artifacts and Methodology, in which he is Trained (H-LAM/T). The goal of Engelbart's project was to develop computer systems that help us think--rather than just record and retrieve data. In the '70s he developed an electronic mail document linking system and an office automation project named "oN Line System" (NLS).

Atkinson's HyperCard

Hypermedia, originally named as "multimedia," is a generic term referring to the integration of computer and other devices. A decade ago the term "multimedia" simply meant a slide show programmed by an Eagle or Arion dissolve control computer. Multimedia, in this sense, has no relationships with hypertext. The appearance of HyperCard made hypertext becomes hypermedia possible.

At the 1987 EDUCOM conference, John Schulley, president of Apple Computer, Inc., announced the advent of a new age in information technology, "the Age of Hypermedia" (cited in Beck and Spicer, 1988, p.22). It is because in that year, Bill Atkinson, a software writer at Apple Computer, Inc. made a breakthrough in hypermedia history by introducing HyperCard. HyperCard is capable of connecting different nodes within the program. A node is the basic unit of information such as a text field, button, graph, card, background, and stack. The software also has the capability of linking with an array of external devices, such as videodisc, slide projectors, tape recorders, videotape players and CD-ROM.

In an interview by Danny Goodman (1990) concerning the rationale of building HyperCard, Atkinson complained that although word processors were available, computer users lacked a learning processor. Hence, his mission was to look for tools to empower people in the act of learning. However, Atkinson did not explicitly lay out his philosophy of blending hypertext and hypermedia through HyperCard.

However, McKnight, Dillon and Richardson (1991) warned that it is a mistake to think that everything produced by HyperCard is hypertext or, conversely, that all hypertext systems have the same properties as HyperCard" (p.10) The popularity of HyperCard has led to some of these confusions. For instance, someone thought that the hypertext database, World Wide Web, was based on HyperCard (Lankes, 1993). Indeed, there are several hypertext features that HyperCard cannot support. Landow (1989) found that HyperCard cannot make a bi-directional link. Halasz (cited in Nielsen, 1987) commented that Hypercard lacks a structural overview.

Bush, Nelson, Engelbart and Atkinson as representing different philosophies of hypertext continue to attract followers today. Bush adopted the analogy between memex and human associative thinking. Nelson's dream was the creation of a gigantic relational database. Engelbart regarded hypertext as an augmentation of human problem solving ability. Although Atkinson's view is ambiguous, the fusion of hypertext and hypermedia in his HyperCard implies a multiple representation approach to learning. Resemblance of their views could be found in different definitions and cognitive theories of hypertext at the present time. Those definitions and theories will be illustrated in later sections.

Since the emergence of hypertext, many research institutes have launched projects to use this new technology as a medium of instruction and as a topic for educational research. The Stanford Shakespeare project (Beck and Spicer, 1988), the Harvard Project Perseus (Heath, 1990), the Cornell Hyperpath, and the Dartmouth Hyperteam are all examples of course programs with the applications of hypermedia (Beck and Spicer, 1988).

Hypertext has been applied to a wide variety of subjects, such as music, English, foreign languages, general science, astronomy, physics, chemistry, biology, ecology and special education (Ashworth and Stelovsky, 1989; Clymer, 1991; Dhurokopf, 1989; Eiser, 1992; Fitterman, 1989; Hall, 1989; Hasselbring et al., 1989; Jensen, 1992; Kaplan, 1992; Kunst, 1987; Larsen, 1988; McGregor, 1990; Nakajima, 1989). These packages provide realistic illustrations and even simulations. In foreign language tutorial packages, the learner can hear conversations in a simulated "foreign country" and decide how to respond under various circumstances (Kunst, 1987). In music tutorial packages the student can click on music notes to listen to the tonal variations (Crawford, 1991). Biology students have the opportunity to anatomize interior organs in a hypermedia environment without getting blood on their hands (Jensen, 1992). Chemistry students are free from the danger of explosion resulting from chemical reactions while mixing chemicals in a hypermedia chemistry lab (Smith & Jones, 1991).

Definitions of Hypertext

Given a number of different originators of hypertext, it is not surprising to find diverging definitions of hypertext. Meyrowitz (1991) listed at least ten definitions of hypertext he had heard:

(a) graphical programming; (b) outline processing, which enables users to collapse and expand multiple views of documents; (c) multimedia presentation; (d) a tool for teaching writing; (e) reference tool for online encyclopedias or dictionaries; (f) a way to focus and connect the different parts of an argument; (g) a backbone for group decision support. Some other definitions of hypertext were cited in his article, but they should be viewed as specific applications rather than the attributes of hypertext.

Schutt and Streitz (1991) regarded hypertext as a gigantic database. Although in a hypertext form of database the user can obtain a lot of information at fingertips, there is no induced learning strategy to help users filter and digest the information.

In Nielsen's Hypercard stack entitled HyperTEXT' 87 Trip Report (1988), he included both networking and virtual reality in the discussion. Since the beginning of hypertext development, developers have been searching ways to use hypertext for distance education (Seyer, 1991). Along the path of hypertext development, certain researchers suggested that hypertext should be a multi-user system or a wide-area network (Meyrowitz, 1991; Rada, 1989; Bly, Harrison, & Irwin, 1993; Lyles, 1993; Fish, Kraut, Root & Rice, 1993; Brown 1993) Although instant access is a major advantage of hypertext, random access does not necessarily mean remote access.

Another form of hypertext emerges from virtual reality (VR). Some researchers asserted that VR is an extension of interactive media in which participants are absorbed by the simulations, and VR exemplifies the principle of hypertext by delivering web learning (McCluskey, 1991; McCluskey, 1992; Henderson, 1992). No doubt virtual reality provides learner an interactive multimedia environment and realistic simulations. However, its random access is very limited.

Hypertext should be viewed as a linked information system for instant access with a set of rules of knowledge representation. Wiggins and Shifer (1990) defined hypermedia as the organization and display of information using a variety of media, merging such as text, interactive video, maps, animation, graphics, and sound (p.226). As mentioned before, the term "hypertext" is coined by Ted Nelson (1967) to denote non-sequential reading and writing of documents. Hypertext and hypermedia share a common property--both allow random access for a huge amount of information. The relationship between hypertext and hypermedia is well-illustrated by McKnight, Dillon and Richardson (1991):

Hypertext consists of nodes (or "chunk") of information and links between them...The term "hypermedia" is a more general term than "hypertext" and suggests that links exist to information held on different media. Both terms refer to a system of linked information. (p.2)

Moreover, McKnight et al pointed out that the hypertext system should have a set of rules for knowledge representation by which one forms a structure in one's mind of how the information can fit together.

Problems of Hypertext

The diversity of definitions of hypertext reflects the fact, and contributes to the problem that the development of hypertext tends to be atheoretical and technology driven (Spiro & Jehng, 1990; Brandt, 1991). Many publications concerning hypertext are descriptive and lack empirical substantiation. The advantages of hypermedia/hypertext are taken as postulates rather than being treated as a variable for study. For example, although Kaplan (1992) claimed that "misconceptions may be overcome through the use of multimedia images," his evaluation was "our faculty and students are quite excited by the new lectures, and this in itself is quite a plus" (p.54, p.55). There is no mention of any formal appraisal in his article. The introduction of new technology constantly updates the definition of hypertext. In fact, many instructors use hypertext/hypermedia only because it is available and popular. At the same time, many students like the novelty of the new technology.

In a study concerning comparison between programmed text and CAI by the State University of New York at Buffalo (1968), it was found that some students liked the text though they said the text was ineffective; on the other hand, some users found CAI effective but did not like it. To have fun in using a program and to regard it as effective are two different matters. Many HyperCard users are fascinated by this state of the art technology. In a study by Horney and Anderson-Inman (1992), they observed that although students liked reading the hypertext, they saw little evidence to suggest the students reached any insights while using the program. In addition, a pilot study of "Hyper-Statistics" (Yu, 1992) indicated that although many respondents preferred Hypercard to print version, those who liked HyperCard did not score significantly higher than the other group in a post-test. Moreover, many subjects declared hypertext as their preference over conventional text though most of them never used the hypertext features. This finding is not surprising. After Mayes et al (1990) tested their hypertext package with new users, they found that most of users left many of the functions of their hypertext system unused. Despite the above findings, many hypertext designers still include many hypertext features in their packages without formative or summative evaluation.

The problem of the diverging definitions and the lack of empirical studies are interlocked with each other. In absence of verification by empirical studies, new computer technologies are adopted without careful thoughts. Hypertext incorporates virtually every type of new technology and inflates the ambiguity of its definition. Additionally, the lack of clear definition and scope adds difficulties to empirical research in hypertext. Fortunately, several researchers have been aware of these problems and have attempted to construct theories of hypertext.

Theoretical Rationale for Hypertext

The theoretical aspects of hypertext are filled in by cognitive scientists. These frameworks suggested the ideas that:

(a) Hypertext simulates the human mind, insofar as hypertext can be thought of as an interconnected network and hypertext features as forming frames (Phillipo, 1989; Kearsley, 1988; Kozma, 1987; Loo, 1991).

(b) The mastery learning inherent in hypertext allows users to proceed at their own pace with helpful guidelines (Brandt, 1991).

(c) The active engagement in hypertext is considered a way of developing higher order cognitive skills (Semper, 1990; Marchionini, 1988; Collins & Lengel, 1990).

(d) Hypertext/hypermedia offers multiple perspectives for fitting multiple intellectual dimensions (Jenkins, 1990; Hettinger, 1988; Frankin & Kinnell, 1990; Semper, 1990).

Interconnected Network and Frame Theory

McAleese (1989) found popular use of the analogy between parallel processing in neural networks and hypertext. Cognitive theories tend to compare human perception, thinking, and decision-making to input, processing and output in a computerized system (Pylyshyn, 1989; Schwartz, 1988). Some theorists have built their hypertext systems on Minsky's (1975) parallel distributed processing by using "frame" as the analogy of knowledge presentation.

For Minsky, human memory stores all knowledge including data and their relationships in a complex unit called a frame. Inside a frame there were many slots, which are filled by slot values. When more and more slot values are accumulated by incoming data, an overall pattern is formed.

The founder of hypertext, Vannevar Bush, and many hypertext researchers (Phillipo, 1989; Kearsley, 1988; Kozma, 1987) attempted to make hypertext mimic human associative mental process. Furthermore, Loo (1991) directly applied Minsky's "frame" theory to build the information structure in his hypermedia package. Loo argued that instead of carrying fragmented information in each card and letting the user go back and forth to find out their relationships, several slots in a frame should act as the basic unit of information. In other words, a frame by itself presents both data and the relationship between data. In this way the user can stay in the same frame and uncover more information. This answers the attack that the associative nature of hypertext would lead to aimless browsing and "hyper-chaos."

However, Rockwell (1992) seriously doubted the notion that hypertext simulates human mental process:

It (hypermedia mimics human thinking process) has not been supported by evidence. I wonder if a) we really do think that way, and b) it is advantageous to access information that way, however we may think. After all, we don't build cars with legs just because that is how we walk likewise, it might be best to build information systems that work with the way we think, not like the way we think (p.10).

Engagement and Higher Cognitive Skills

Tennyson (1989) argued that the most desirable learning goal is to strengthen higher order cognitive powers such as problem solving ability and creativity. Thus, instructional technologies should create a learning environment in a meaningful context, providing the learners feel the problem worthy and challenging. Grabowski (1992) also firmly maintained that learning is the "construction of meaning"--a mental activity which the learner performs to give birth to learning (p.9).

Semper (1990) argued that hypermedia can provide a meaningful learning environment described by Tennyson and Grabowski, because students actively make meaningful choices, create their own stories, and make their own connections of information. Marchionini (1988) went further to proclaim a hypertext system as "a fluid environment requiring learners to constantly make decisions and evaluate progress, thus forcing students to apply higher order thinking skills" (p.9).

Collins and Lengel (1990) classified knowledge into four levels: data, information, ideas and wisdom. They argued that traditional education is mostly concerned with the first two levels. In contrast, hypertext makes it easy to see and make connections between data, information, and ideas. Therefore it has the potential to give learners a hand in climbing to the top of the knowledge pyramid.

There are two questionable aspects of this claim. First, Gery (1989) pointed out that many researchers do not have a true understanding of what "interactivity" means. Many of them just equate the term with questions interspersed periodically in a sequence of text or graphic display screens. Duchastel (1988) argued that simply because a learner is using a mouse to select items and link information does not make the process more active than consulting an index, turning the pages of a book, underlining passages and writing notes in the margin. Second, in regard to Collin and Lenger's view, the line between ideas and wisdom are not clearly drawn. In addition, after an extensive review, Carver et al. (1992) pointed out that little documented progress has been made in the area of accessing learning of complex high level skills with hypermedia. They asserted that technology per se does not promote active learning or the development of complex design skills.

Mastery Learning

Bloom's (1976) theory of mastery learning, is also considered a foundation of hypertext development (Brandt, 1991). The theory is based on the finding that learners who are tutored according to their own pace learn faster and/or achieve a higher level of performance than students in a classroom environment.

Based on Bloom's theory, multimedia researcher Hettinger (1988) argued that mastery learning is one of the crucial advantage of hypertext. Time is a crucial factor of learning and given sufficient time in an non-threatening environment such as hypertext, learners should be able to master the essence of the information. Self-paced learning can be done in traditional CAI programs and even textbooks. However, another important aspect of a mastery learning system is the tutoring feature.

Another piece of evidence about the effectiveness of mastery learning is provided by Anderson's intelligent tutoring system, which delivered LISP programming lessons (Anderson, Farrell & Saures, 1984). The tutoring system could diagnose users' problem and guide them to remediate their mistakes. If the learner did not respond within a time limit, the system assumed that the user did not have sufficient prior knowledge and he/she would be presented with another problem. The system has been found to be 30 percent more efficient than conventional classroom training. Another example of an intelligent tutoring system is the "Stat-Helper." For this project, cognitive scientists designed the software which analyzes student solutions to standard problems by inferring a student's intentions from the details of her/his solution and then offering diagnosis. The program allows students to interact with the computer in solving a variety of problems (Dolbear, 1988).

Given the mastery learning and the diagnosis features embedded in an intelligent tutoring system, it is no wonder some multimedia researchers (Brandt, 1991; Coyne; 1991; Dear, 1986; Merrill, 1985; Wilson & Welsh, 1986) pointed out that there is a trend to integrate the artificial intelligence and hypermedia. However, Carver et al (1992) raised the question concerning the measurement of mastery. There may be a clear way to evaluate general skills, however, in terms of complex skills, the definition of mastery is difficult. While Brandt (1991) argued that a mastery learning style of tutoring system may be suitable to some well-structured domain such as computer programming, he questioned whether the same method could be well-applied to several less structured disciplines such as history and ethics.

Nevertheless, the notion of mastery learning reminds hypertext designers to pay attention on both self-paced learning and tutoring. In a mastery learning system, the learner could only go to the next step once he/she mastered the required knowledge. In this case the system should have a guideline to inform whether the student has passed any particular stage or not. Thus, in a hypertext system feedbacks and an structural overview are essential in order to prevent the learner from premature browsing without prior knowledge.

Multiple Perspectives

Research by Piaget, Montessori, and Gardner are cited as support for using hypertext (Jenkins, 1990, Semper, 1990). Piaget (1971) focused on the internal development of a child's cognitive growth, whereas Montessori (1955) emphasized the importance of a stimulating, structured learning environment for cognitive development. Nevertheless, both of them affirmed that young children learn through their multiple senses.

Howard Gardner (1983) classifies dimensions of intelligence into seven categories: linguistic, musical, logical-mathematical, spatial, bodily-kinetic, intrapersonal and interpersonal. He pointed out that there are a lot of ways that people learn in areas within which they might be considered intelligent. A rich educational environment should involve experiences with all of these modalities.

Hettinger (1988) asserted that transfer of learning is enhanced by multi-methodological approaches for students know how the same content can be fit into different forms. Frankin and Kinnell (1990) argued that knowledge should be holistic in nature, i.e. a synthesis of rationalism and empiricism. Under this view, a more comprehensive picture of knowledge could be obtained through multiple perspectives including verbal and experiential aspects. Text-based hypertext could be viewed as a tool for verbal perspective while simulations could be thought of an experiential approach.

Inevitably, a multi-methodological approach relies highly on audio and optical hardware devices, so that text illustration, data visualization and even sound effects are presented side by side (Ogawa, Harada & Kaneko, 1991). This tendency might accelerate the trend that hypertext has been technology-driven. In addition, Jaeger (1987) questioned whether multiple representations such as graphics and sound effects are essential in CAI. He observed that many times students were captivated by the first few multi-media presentations. A few times later, students frantically press the spacebar to avoid the sound. Jaeger suggested that "maybe flashy and expensive graphic displays and sounds are ultimately a waste of time." (p.21) Binder (1989) also warned that inserting graphics for many applications might be unnecessary and will take more memory and slow down the computer.

Careful readers may observe that the above theories assume different premises of hypertext. For instance, the frame theory pre-supposes hypertext as an instant access system; the higher cognitive skill argument stresses the interactivity and the engagement of hypertext; the mastery learning approach postulates the imposition of a knowledge structure; and the multiple perspective strategy assumes hypertext must be multimedia.

Interestingly enough, in the first hypertext conference the research issues proposed by Halasz covered all of the above approaches (cited in Nielsen, 1988). Halasz suggested that search/query is the most important aspect of hypertext. Moreover, the system requires a structure to guide the query and it will lead to a high degree of interactivity.

Navigational Aids

There are different search and query strategies in a hypertext system. Lucarella (1990) distinguishes between two kinds of query: browsing which is characterized as going from where to what, and searching which is characterized as going from what to where. In the former case the user knows where he/she is in the system and he/she wants to know what is there. In the latter the user knows what he/she wants and wish to find where in the system it is.

A hierarchial map can serve the first function while an index/menu and a key word search can fulfill the second goal. There are pros and cons of these navigational aids. Conkin (1987) endorsed a graphical map as a feature of a "idealized hypertext system" because it can present a structural overview to users. However, Monk et al (1988) argued that in a system with rich contents it is impossible to include every subtopic in a single map without the problem of "visual spaghetti."

Alphabetical index is a common navigational aid in hypertext for its ease of use. Nonetheless, McKnight et al (1990) argued that index cannot achieve an optimal information searching. Because they found that many hypertext users spent greater proportions of time in the index section. This indicated a style of interaction based on leaping into parts of the text and returning to the "base" for further guidance.

Key word search is powerful if and only if the patron knows exactly what he/she is looking for. However, Lucarella (1990) pointed out that keyword search relying on Boolean logic and exact matching may not be effective because Boolean formulations are difficult to generate by people without an exact picture of their needs.

Research comparing these hypertext features has shown that a graphical map seemed to be superior to other navigational aids in most situations. Billingsley (1982) offered an alphabetical list of selection numbers, a map of database structure or no aid to the subjects. The result indicated that the map proved superior and the no aid group performed the worst. Simpson and McKnight (1990) found that in both an initial reading and an information-location task, navigation through a hypertext document by using a hierarchical map is more efficient than an alphabetical index. Moreover, Stanton and Stammers (1990) found that training time was significantly reduced in the top-down condition in which the user was exposed to a concept map for overview.

As a supplement to these findings, Allinson and Hammond (1989) found that the usefulness of various navigational aids are contingent upon situations. After they analyzed the user log of their hypertext system, it was found that for study of unfamiliar material, tour, which guides the student through a sequence of frames until the tour ends, was used most frequently and index was the second popular. For study of partially familiar material, map was the most common application and again index was the second most popular. For study of familiar material, hypertext that enables users to move around the stack was the first choice, and once again index was the second. Allinson and Hammond concluded that increasing familiarity with the topic results in a shift from system control (i.e. tour), through shared control (i.e. maps and indices) to user control (i.e. hypertext links).

Empirical studies of hypertext navigation are very limited. Further, the preceding studies might implicitly assumed that different navigational aids are mutually exclusive. Is it possible that a desirable performance is resulted from using more than one navigational aids for the same task? Further studies are definitely needed in order to provide more precise guidelines for hypertext developers.