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World Wide Web Hypertext Linkage Patterns

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The purpose of the study was to investigate the effects of various hypertext linkage patterns on the efficiency of navigating World Wide Web (WWW or Web) sites. The study also looked at the relationship between navigational efficiency and the subject's level of experience and gender, as well as any interaction effects between experience, gender, and linkage patterns. Subjects (n = 261) were randomly assigned to one of the four treatment groups based on one of the three types of hypertext linkage patters tested (linear, star, hierarchy, or random). Each subject was given specific target information they were to find on the assigned web site. Navigational efficiency was measured by counting the number of links the subject had to click to find the information and the number of times they revisited the homepage. Data were also collected through demographic and experience questionnaires and computer generated text files.

Results of the analyses showed that web sites patterned after star and hierarchy linkage patterns were more efficient to navigate for informational use than were web sites patterned after linear and hierarchy linkage patterns. Females were shown to have a much more difficult time navigating arbitrary web sites than males.

User expectations for web sites will likely increase as Internet and Web technology facilitate greater interactivity and design. Users will likely want more interactivity and easier navigation. The term navigation is used

extensively in the user interface design literature (Denning, Shuttleworth, & Smith, 1998; Nielsen & Mack, 1994; Powell, 1990; Sano, 1996) to represent how a user reaches computer screens, gives directions, or indicates decisions. Navigation in the hypertext literature has taken on the same meaning. Dillon, McKnight, and Richardson (1990) wrote that the concept of navigation is a meaningful one in the sense that one can view user actions as a movement through electronic space. Just as a sailor navigates from one continent to another, a hypertext user will navigate from a homepage to a piece of information. Both sailors and hypertext users alike typically have the option of choosing which route they take to their desired locations. A route (or a path) through a hypertext system can be explained as user movement from one hypertext document to another by way of hypertext links. Hypertext users will also determine which web sites to visit and which to avoid based, in part, on how easy a site is to navigate (Dillon, McKnight, & Richardson, 1990). Sites that are easy to navigate will no doubt outlast those that are confusing (Sano, 1996).

"Unfortunately, many web sites today appear as if they were hurried onto the net, disregarding user's needs, requirements, and preferences" (Sano, 1996, p. 13). One of the most obvious observations of this rush to the web is the naive use of hypertext linking. The hypermedia capabilities of the Web have brought hypertext's advantages to millions of people around the world. Those advantages include the ease of creating and tracing references, the support for structuring and modularizing information in a nonlinear format, and the ability to keep many threads of information alive at once (Heller, 1990). In addition to identifying the advantages to using hypertext, the reviewers of hypertext literature often list problems. The most commonly acknowledged problem in using hypertext is navigation, or more specifically, user disorientation (Conklin, 1987; Edwards & Hardman, 1989; Gray, 1990; Hammond & Allison, 1989; Nielsen, 1990). "An overall lack of planning, coupled with a new-found fascination for hypertext linking, usually results in a tangled mess of web pages, contributing to users being hopelessly lost in hyperspace" (Sano, 1996, p. 6). The problem of disorientation seems to be getting worse as the Web grows larger and becomes more popular (Stanton & Baber, 1994).

Disorientation occurs when users lose their way in their navigation through a hypertext system, are unable to formulate appropriate actions for the screen they are viewing within hypertext systems, or are unable to find information that they know is somewhere in the system (Nielsen, 1990). Overusing hypertext links, or poorly organizing hypertext links, present a

user with too many bewildering choices (Jonassen, 1996; Sano, 1996). Hypertext links are especially bothersome when they lead to irrelevant, unrelated information. Worse yet are instances where links lead to countless further links, towards no obvious end. This unorganized link approach reflects a more serious, deep-rooted problem, indicating flaws in the underlying organization of a web site. Web designs with poor hypertext linkage structures actually inhibit usability by requiring a user to traverse too many links for needed information (Gray, 1990).

User disorientation and the inability to find desired information even within small hypertext systems are genuine concerns (Chiu & Wang, 2000; Conklin, 1987; Jonassen, 1996; Kahn & Landow, 1993). Users can easily become disoriented and lost while navigating web sites precisely because of the ability to traverse in a nonlinear sequence through information. Inexperienced users may be especially susceptible to the confusion when navigating a hypertext site. A poorly designed and unstructured web site could disorient the user. Conversely, a well-designed and structured web site would allow users to quickly orient themselves. Users would be able to understand the organization of the document in which they are currently positioned in relation to the initial point at which they accessed the web site.

The navigational benefits of using a clear structure for hypertext are well documented in the research (Conklin, 1987; Jonassen, 1996; Nielsen, 1995). Clear navigational pathways and easily recognized linkage structures add predictability to the user's flow through a web site. The user can begin to formulate a mental model of where he or she has been and what comes next (Reed, Ayersman, & Kraus, 1997; Gray, 1990).

The structure of a hypertext system is, primarily, a function of its links (Horney, 1993a; Jonassen, 1996). Links provide a bridge allowing users to move from node to node within a hypertext system. They also serve to represent semantic relationships among nodes (Horney, 1991; Slatin, 1990). Many hypertext researchers have suggested that disorientation within hypertext systems could be reduced by carefully analyzing and structuring hypertext systems around the semantic relationships of the links (Horney, 1993b; Jonassen, 1990, 1991a, 1996). No research to date has examined the possibility that disorientation within hypertext systems could be reduced by designing a hypertext system based on different linkage patterns (or bridges) that users can clearly identify. The purpose of this study is to use the Web and web sites designed from the perspective of different linkage patterns to determine the degree of disorientation associated with each linkage pattern.

OTHER IDENTIFYING FACTORS

In 1985 LeMondola found that women tended to resist the use of technologies more than men. Gilliland (1990) found that females used computers less outside of school than males, and were more likely than males to self-select out of computing activities in school. One might infer from such findings that if females do not prefer to use computers and other technologies, they would not have as much experience using them. Mack's (1995) study showed that males, on a self-reported attitude scale, thought a nonlinear lesson format was clearer than females did. This assertion was supported by Beasley and Vila (1992), who found that females tended to navigate through a hypertext instructional module in a more linear fashion than did males. One aspect of the exponential growth of the Web is the increasing nonlinearity of information organization on the Internet. If females are not adept with non-linear formats, they might find certain linkage patterns easier to navigate than others.

McGrath (1992) suggested that the age factor could significantly affect a participant's approach to and success with a nonlinear medium presented by way of computer. Studies by Mack (1995) and Shin, Schallert, and Savenye (1994) proposed that college age or younger learners be used when conducting research on hypertext. Mack's study investigated the potential influence of children's video technology experiences on their use of a nonlinear discourse form. The Shin study relied on younger participants because of the need for prior knowledge of computer systems. Without the prior basic knowledge of computer systems (i.e., how to use a mouse, etc.) the results of the study could be a reflection of the learning curve involved when encountering any new technology (Kahn & Landow, 1993).

The more exposure one has to hypertext, the more efficient one might be in finding information within a web site. Both the Mack (1995) and the Shin, Schallert, and Savenye (1994) studies allude to experience as a factor in efficiently navigating in a hypertext environment. Kahn and Landow (1993) also argued for the importance of considering prior experience as an important factor in learner's success with hypertext as did Nielsen (1995), who stated that "the users level of expertise will have a large impact on how they use the system" (p. 298). Therefore the factors of gender, age and Web user experience were considered in this study.

CONCEPTUAL FRAMEWORK

Research focusing on hypertext systems in general has approached the problems of disorientation and an inability to locate desired information primarily from a structural perspective (Jonassen, 1991b; Stanton & Baber, 1994). "In viewing structure as a component of [hypertexts] the conceptualization emerges of information as space and the user as a navigator. This in turn invites a mapping between cognitive theory and [hypertext] design that is frequently accepted by researchers" (Dillon, 1994, p. 110). The structure of a hypertext system is a function of its links (Jonassen, 1996; Horney, 1993b, 1991). Links serve two purposes: (a) they provide a bridge allowing users to move from node to node, and (b) they serve to represent semantic relationships among nodes (Horney, 1993b; Slatin, 1990). While a majority of the hypertext researchers recognize the distinction between the two functions of a hypertext link, their studies focus on just the semantic relationships between nodes of information (Horney, 1993a, 1993b; Jonassen, 1991a, 1996; Sano, 1996). They do not examine the linkage structure itself.

Nearly every Web site that exists has a different structural linkage pattern (Sano, 1996). Each of these different structures will need to be recognized to avoid disorientation. The more exposure one has to various web sites, the more likely one would be able to recognize the structure of any given site they access. Gray (1990) found that over time, users do seem to have the capacity to alter their mental models of hypertext systems. This is the result of the user's accumulation of mental structures (schemata) from using different web site interfaces.

Cognitive recognition refers to a hypertext user's ability to recognize the structure of a web site. Efficient navigation occurs when a user is able to find information within a web site using the least available number of steps (movement from link to link) without having to backtrack, or return to a homepage to reorient themselves. Having to backtrack within a hypertext system is cited in the literature as error management (Stanton & Baber, 1994). Likewise, studies by Hagelberger and Thompson (1983), McKnight, Dillon, and Richardson (1989), and Gray (1990) cited returning to the homepage as the most common response to difficulties navigating through a hypertext system.

Gray (1990), Parunak (1991), and Horney (1993a) have identified a number of linkage patterns that are based on document organizing structures and on the "natural" (Horney's term) navigation patterns of users of hypertext systems. Gray (1990) found that users of hypertext systems drew on document organizing structures when they were asked to construct mental models of hypertext systems they navigated. Parunak (1991) developed

six topological structures to characterize hypertext navigation between links: (a) linear, (b) hierarchy, (c) hypercube and hypertorus, (d) directed acyclic graph, (e) clumped, and (f) arbitrary. Horney's study (1993a) provided significant evidence that users may have natural navigational tendencies. His study traced the path of hypertext authors using their own systems. Five patterns of navigation were found: (a) linear, (b) star, (c) extended star, (d) side trip, and (e) chaotic.

There is currently no evidence that hypertext systems, such as those used in Web sites, have been intentionally organized around cognitively recognized linkage patterns. Web sites constructed using the linkage patterns identified by Gray, Parunak, and Horney would likely be cognitively recognizable to most hypertext users. One question examined in this study is whether web sites constructed using one linkage pattern are more navigationally efficient than web sites constructed using a different linkage pattern.

Although there is evidence that clear navigational pathways and easily recognized linkage structures add predictability to the user's flow through a web site (Gray, 1990), and that hypertext users may have natural navigational tendencies (Horney, 1993a), no studies have examined navigational efficiency of web sites. Current web developers have not resolved the problem of disorientation and inability to locate desired information within their web sites. Web sites that are efficient to navigate will allow users to get to desired information quickly. Similarly, users of efficient web sites will be able to quickly orient themselves within web sites.

PURPOSE OF THE STUDY

The purpose of the study was to: (a) investigate the efficiency in navigating Web sites constructed using different hypertext linkage patterns; (b) identify the differences between experienced and inexperienced Web users in their efficiency in navigating web sites constructed using different hypertext linkage patterns; (c) identify the differences between males and females in their efficiency in navigating web sites constructed using different hypertext linkage patterns; and (d) to identify any interaction effects between gender and experience on the efficiency of using any of the linkage patterns.

METHODOLOGY

Participants

The participants used in this study were 261 undergraduate and graduate students enrolled in one section of Management and Quantitative Methods 220—Business Organization and Management and one section of Marketing 230—Introduction to Marketing Management, in the College of Business. The same instructor taught both courses. The participants in this study were chosen for their convenience to the researchers.

Instrumentation

Two separate instruments were used to collect data for this study. The Demographic and Experience questionnaire was used to collect background information from the participants regarding gender and experience with using the Web. An activity sheet was also used in the study. The activity sheet used by participants had one question. The question required finding the location of the answer to a closed-task item within the assigned web site and reporting the URL where the answer was found. This activity sheet was used to verify whether or not the student correctly located the requested information.

Materials

Web sites. Four distinct web sites, based on the hypertext linkage patterns identified in the literature (linear, star, hierarchy, and arbitrary), were constructed for the study. Each of the four web sites used in this study included 25 nearly identical HTML documents, differing only in the use of the hypertext links. Inclusion of hypertext links on the HTML documents for each of the four web sites corresponded to the hypertext linkage pattern of those sites. For example, the homepage for the hierarchical web site had links to six other HTML documents. In contrast, the homepage for the linear web site had a single link to one HTML document. Both the star web site and the hierarchy web site homepages provided the participants with six hyperlinks to other HTML documents. The arbitrary web site homepage provided two links. The linear web site homepage provided one link. The content of the text used for this study, "Management History and Theories," was converted from a text assigned for the two business classes from which the participants were chosen. The text, written by Griffin, was titled *Management* (1999).

The hypertext linkage patterns provided the guidance for participant navigation through the four web sites. The Internet browser was modified so that the participant could not leave the assigned website or use a bookmark or history list. The entire menu bar of the browser was eliminated and the browser's tool bar consisted of only two buttons: back and forward. The address bar of the browser was available to the participants. However, because participants were not familiar with the naming scheme of the HTML documents used in the study, navigation of the four web sites was limited to the hypertext links presented on each of the HTML documents.

Software. A Visual Basic Script (VBScript) was installed on the website to provide the necessary program language decoder for the VBScript code that was included on each of the pages in the four web sites. The VBScript code was added to the web pages for data collection purposes and is described in further detail in the data collection section of this article.

To count the number of clicks for each participant, an ActiveX control named ObjectFactory was used. ObjectFactory is a program that calls an application name as a parameter and then calls the shell function. Using VBScript and OBJECT statements, an object of this OLE server was created that allowed text to be written to a file. The file that was created represented each person's navigational trail through the web sites.

Procedure

Participants (n = 261) were randomly assigned to navigate one of four web sites: 25.3% (n = 66) to linear (L), 24.9% (n = 65) to star (S), 25.5% (n = 66) to hierarchy, and 24.5% (n = 64) to the arbitrary site. Participants were not informed of their group or the linkage pattern descriptions of any of the web sites.

After collecting demographic and experience data, each participant was given an activity sheet that consisted of one closed-task question. Participants were then assigned the task of finding the location of the answer to the closed-task item on their assigned web site and recording that location on the activity sheet. The answer to the question was given to the participants prior to receiving the activity sheet to rule out a knowledge effect. The participants were informed that the purpose of the study was to evaluate navigational efficiency of different linkage patterns and not participant knowledge of material. The participants were allowed a maximum of 10 minutes to find the location of the answer to the question on the activity sheet

Data Collection

Data were collected through three means: demographic and experience questionnaires, activity sheets, and computer generated text files. The computer generated text files were used to collect data on participant's navigation through the web sites in the study.

The ability to record backups was crucial for this study of hypertext linkage patterns. Stanton and Baber (1994) reported that the most common form of user action in hypertext systems was backtracking to previous nodes. They considered this an undesirable feature and labeled it error management. Backward movements are considered revisits. Similarly, Hagelberger and Thompson (1983) and McKnight, Dillon, and Richardson (1989) found that if users encounter difficulties in finding information within hypertext systems, they tend to return to the homepage and begin their search again. Returning to the homepage is a restart. Both revisits and restarts are fundamental in this study of hypertext linkage patterns to calculating the efficiency with which one navigates a web site.

A new methodology for collecting navigational information from web site usage was developed for this study. Computer generated text files were the primary means to record participants navigating the four Web sites used in this study. The text files that were created with the combination of the ActiveX control and the VBScript code consisted of the numbers (1-25) that were assigned to each HTML document. Essentially, every time a participant accessed an HTML document that document's assigned number was written to a text file along with the time at which the document was first accessed. For example, the number one (1) represented the homepage of each of the web sites. Every time a participant accessed the homepage of their assigned web sites, the number 1 would be written to a text file along with the access time (e.g., 12:08:12 PM, 1). Each document was accessed and appended in the order of it's corresponding number and access time to that text file. Backups (revisits) would then be recorded as well as forward movements. A separate text file was created for each of the participants.

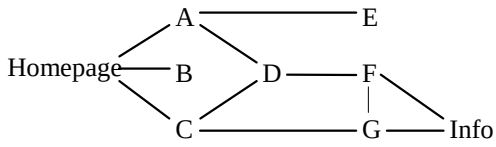
Data Analysis

Many studies have focused on the study of the processes and patterns of interaction rather than only the products of such interactions (Liebscher & Marchionini, 1988; Marchionini, 1989). Marchionini (1989) proposed using a state map to compare individual search patterns to an electronic encyclopedia. A variation of this technique was used in this study to identify

and analyze the paths taken by participants as they navigated the four web sites. A description of the procedure for analyzing these paths follows.

First, for any given closed WWW site, there are a finite number of paths from the homepage to a given piece of information. A closed WWW site is one in which there are no links to other web sites, only internal web pages. The homepage is defined as the initial page at which the user starts his or her search. On the Internet, an individual can arbitrarily enter a WWW site at any point, not necessarily the intended home page. For the purposes of this study, the homepage was designed to be the location at which the participant entered the web site. The participants in the study were limited to nodes within their assigned web sites. Each of the four web sites was designed as a closed web site with no links between them, and no links to other web sites.

Second, for all paths from a homepage to a given piece of information, there can be computed: (a) the total number of possible paths and; (b) for each possible path, the number of steps that must be taken. Figure 1 provides an applied example of this rule.



#Steps	Path
4	H- C- G- Info
4	H- C- D- F- Info
6	H- C- D- F- G- Info
5	H- A- D- F- Info
6	H- A- D- F- G- Info
6	H- A- D- C- G- Info
7	H- A- D- C- G- F- Info

Figure 1. Example of web site hypertext link pattern

Third, paths must begin at the homepage and end up at the desired piece of information. The page where the desired information is located is called the target page. Any paths that end up back at the homepage are considered restarts. Any backward movements are considered revisits.

Finally, for the purposes of this study, navigational efficiency is defined as the number of steps taken in the final path to the piece of information

conditioned by the number of revisits committed from the homepage and the number of restarts. A mathematical ratio called the Navigational Action Efficiency ratio was developed to measure this. The reason for naming this ratio Navigational Action Efficiency rather than Navigational Efficiency relates to the fact that web users are performing physical actions when they use links to move from one node to another. The data that were collected were the actions of the participants. This ratio is discussed in detail later in this article.

The collection of the path data was pertinent to answering research questions one and four: "Are any World Wide Web hypertext linking patterns more efficient than the others for finding closed-task information;" and "Is there an interaction effect between gender and experience on the efficiency in finding closed-task information using any of the linkage patterns?"

***Outcome measures*.** Four outcome measures were considered for the path data: (a) final path,(b) total number of restarts, (c) total number of revisits, and (d) navigational action efficiency. Navigational action efficiency was computed according to the following equation:

$$\text{NAE} = \frac{\text{\# of steps in final path taken without restarts + total \# of revisits}}{\text{Total \# of steps in an Optimal (shortest) path}}$$

The Navigational Action Efficiency ratio (NAE) could be equal to or greater than one but never less than one. This ratio was used to compare the efficiency of user navigation within the four different linkage patterns of the web sites in the study. The total number of restarts included all those paths that arrived back at the homepage before following the final path to the desired piece of information. The total number of revisits included all backups including those taken on the way to a restart.

SUMMARY OF THE FINDINGS

The study's data were analyzed using *t*-tests, Analyses of Variance, and Analyses of Covariance with an alpha level of .05 for the rejection of the null hypothesis. Descriptive statistics were used in reporting frequencies, percentages, means, and standard deviations as reported from the questionnaire and Navigation Computation Program output.

Each of the 261 participants was randomly assigned to navigate one of the four web sites. Males comprised 54.8% of the participants while females

comprised 45.2%. The average age for both the male and female participants was around 22 years. Nearly 89% of the females rated themselves as being somewhat experienced or less while only 69% of the males similarly rated themselves.

Final Path Steps

Because there was only one possible path for a user to navigate to the target page in the linear, star, and hierarchy web sites, the overall mean number of final steps for both genders for these sites was equivalent to the optimal number of steps for these sites. Only the arbitrary web site varied in the number of final steps. The overall mean number of steps for the arbitrary site was 6.80 (*SD* = .80). It took females fewer steps than males to arrive at the target page on the arbitrary site. The 29 females assigned to the arbitrary site had a mean number of final steps of 6.76 (*SD* = .79) while the 35 females assigned to the site had a mean of 6.83 (*SD* = .82).

Restarts

A restart occurs when a user goes back to the homepage either through revisits (backing up) or by pressing the home key in the WWW browser. Because the home key in the browser used for this study was turned off, a restart could only occur through revisits. Overall, the most restarts occurred within the arbitrary web site. The least number of restarts occurred in the hierarchy web site. Both male and female participants assigned to the linear and hierarchy web sites averaged less than one restart. Both male and female participants assigned to the star and arbitrary web sites averaged close to one restart. Females assigned to the arbitrary web site averaged close to two restarts. On average, females had more restarts than males in all of the four web sites in this study.

Web users who rated themselves “somewhat inexperienced” or less averaged more than one restart. Self-rated “very inexperienced users,” “inexperienced users,” and “somewhat inexperienced users” averaged 1.07, 1.24, and 1.03 restarts. Experienced or very experienced web users had, on average, less than one restart. Experienced users averaged .70 restarts, and very experienced users averaged .18 restarts. Those individuals who reported themselves as “somewhat inexperienced” or less, and had been assigned to either the arbitrary or star web sites, tended to have more restarts.

Revisits

A revisit occurs when a user goes to an HTML document that he or she has already visited. Because the majority of users were able to locate the desired information using the optimal number of steps, revisits were not as common in the star and hierarchy web sites. The optimal numbers of steps for these two sites were 4 and 3 respectively. The arbitrary and linear web sites required more steps for the optimal path and had higher overall means for the number of steps in the final path. The higher the number of optimal steps, the greater the number of documents encountered enroute to the desired information. Because each HTML document presented the participants with hypertext links, the greater the number of documents encountered, the higher the number of links encountered. Thus, these participants had more navigational routes to decide from resulting in a greater number, and more normally distributed, number of revisits.

Overall, the most revisits occurred within the arbitrary web site (M = 24.20). The least number of revisits occurred in the hierarchy web site (M = 1.67). Males had, on average, more revisits in the hierarchy web site. Females had, on average, more revisits than males in three of the four web sites in this study. It is also notable that females had, on average, over 10 more revisits on the arbitrary site than did males.

Web users who rated themselves experienced or less averaged more than 10 revisits overall. Only those participants in the study who rated themselves as very experienced averaged less than 10 revisits. Very inexperienced users, inexperienced users, somewhat inexperienced users, and experienced users averaged 13.52, 14.72, 10.98, and 11.28 revisits respectively. Experienced or very experienced web users had, on average, less than one restart. Experienced users averaged .70 restarts, and very experienced users averaged .18 restarts. Those individuals who reported themselves as "somewhat inexperienced" or less, and had been assigned to either the arbitrary or star web sites, tended to have more restarts.

Navigational Action Efficiency Ratio

The Navigational Action Efficiency (NAE) ratio was used to compare the efficiency of users' navigation among the four different linkage patterns of the web sites in the study. Since final steps, revisits, and restarts condition the parametric properties of the NAE, the ratio could be greater than one or greater than one. Web sites that have efficient web linkage patterns

will have user NAE ratios that are close to one. Because of this, the distribution properties of the NAE in this study are not normally distributed either within web sites or overall. For this study, the variable NAE (overall) is both positively skewed (2.11) and positively kurtotic (4.84). Further analyses of the distribution properties of this variable find similar values within the four web sites.

The statistical procedures used in this study require variables that are generally normally distributed. The positive skew and kurtosis of NAE could compromise the utility of these statistical procedures in this case. Consequently, to reduce the skewness and kurtosis of the variable NAE, a transformation was performed using the Log_{10} function. A new variable, NAE2 was created.

Research Question #1 Analysis

Are any WWW hypertext linking patterns more efficient than others for finding closed-task information? Analysis of the data showed that the linear, star, and hierarchy hypertext linking patterns were all more efficient for finding closed-task information than an arbitrary hypertext linking pattern. The star and hierarchy hypertext linking were also more efficient than the linear hypertext linking pattern.

An Analysis of Variance (ANOVA) procedure was used to compare the mean navigational action efficiency ratios of the four web sites in the study, and to determine if a significant difference existed among these four groups. The ANOVA procedure was run using both the original variable NAE and the transformed variable NAE2. All statistical procedures performed with the transformed variable produced nearly identical results as those performed with the original variable. No nonsignificant differences became significant differences using the transformed variable NAE2. Because the transformed variable produced nearly identical results as the original variable, the values reported and interpreted in this study are from the original variable NAE.

A statistically significant difference was found to exist between the four web site groups, F (3, 257) = 30.24, p = .00. See Table 1 for ANOVA Summary. A Tukey's-B posthoc comparison test was performed to determine which web site linkage patterns were more efficient for finding closed-task information.

Table 1
ANOVA Summary for Navigational Action Efficiency by Web Site

Variable	Source of Variation	SS	df	MS	F	Sig.
NAE	Between Groups	570.11	3	190.04	30.24	.00
	Within Groups	1614.83	257	6.28		
	Total	2184.95	260			

Participants assigned to the star web site (M = 1.72) and participants assigned to the hierarchy web site (M = 1.56) had statistically significantly lower navigational action efficiency ratios than the participants assigned to both the linear web site (M = 3.61) and the arbitrary web site (M = 5.17). Participants assigned to the linear web site also have statistically significantly lower navigational action efficiency ratios than the participants assigned to the arbitrary web site. There was no statistical difference between the star web site and hierarchy web site navigational action efficiency ratios.

Overall the participants assigned to the arbitrary and linear web sites tended to have higher navigational action efficiency ratios than did the participants assigned to the star and hierarchy web sites. The participants assigned to the arbitrary web site had higher navigational action efficiency ratios than the participants assigned to the other three web sites.

Research Question #2 Analysis

Is there a difference between experienced and inexperienced WWW users in their efficiency in finding closed-task information within web sites constructed using different hypertext linking patterns? Analysis of the data found no significant difference between experienced and inexperienced WWW users in their efficiency in finding closed-task information within web sites constructed using different hypertext linking patterns. An ANOVA procedure was used to compare the mean Navigational Action Efficiency scores of the five experience groups and to determine if a significant difference existed among these five groups. There was no statistically significant difference in Navigational Action Efficiency among the five experience groups, F (4, 256) = .78, p = .54.

Subsequently, the data file used in the study was sorted by type of web site and once again subjected to an ANOVA procedure. This time the purpose was to compare the mean navigational action efficiency ratios of the

five experience groups for each of the four web sites separately. Once again, no groups were reported to show a significant difference at the .05 level.

Research Question #3 Analysis

Is there a difference between males and females in their efficiency in finding closed-task information within web sites constructed using different hypertext linking patterns? Analysis of the data showed that there was a significant difference between males and females in their efficiency in finding closed-task information within the arbitrary web site. Males had an easier time of navigating this type of web site than did females. There was no significant difference between males and females in their efficiency in finding closed-task information within the linear, star, or hierarchy web sites.

Independent-samples *t*-tests (2-tailed) were used to compare the overall mean navigational action efficiency ratios of both males and females and to determine if a significant difference existed between the two. The t-test findings showed no group was significantly different, t (259) = -1.26, p =. 21. Further t-tests were computed to compare mean navigational action efficiency ratios of both males and females for each of the four web sites used in the study. Male participants had statistically significantly lower navigational action efficiency ratios within the arbitrary web site than did females t (62) = -2.25, p = .03. No statistically significant differences between males and females existed within the linear, star, or hierarchy web sites.

Research Question #4

Is there an interaction effect between gender and experience on the efficiency in finding closed-task information using any of the linkage patterns? Analysis of the data showed that there was no interaction effect between gender and experience on the efficiency of using any of the linkage patterns. There was a combined effect between gender and type of site on the navigational action efficiency ratio, controlling for prior experience. While it has been shown that females had more difficulty navigating within the arbitrary web site, the interaction effect is most likely the result of the strong statistical correlation between web site type and navigational action efficiency discussed previously.

For research question four, a 2 x 4 Analysis of Variance of Gender by Web Site using experience as a covariate (ANCOVA) was performed (Table 2). The covariate experience was not statistically significant F (1, 252)

= 2.45, p = .12, nor was the main effect of gender, F (1, 252) = .95, p = .33. This was not surprising for in previous statistical procedures, experience did not make a difference on navigational action efficiency. However, the main effect of type of site was significant F (3, 252) = 24.56, p = .00.

Table 2
2 x 4 ANOVA Summary of Gender by Web Site with Experience as Covariate

NAE	Source of Variation	SS	df	MS	F	Sig.
Covariate	Experience	15.01	1	15.01	2.48	.12
Main Effects	(Combined)	602.35	4	150.59	24.56	.00
	Gender	5.84	1	5.84	.95	.33
	Type of Site	594.30	3	198.10	32.31	.00
2-Way Interactions	Gender Type of Site	45.93	3	15.31	2.50	.06
Total		2184.95	260	8.40		

These results are not surprising considering the effect that web site type had on the NAE, and the fact that male participants had statistically significantly lower navigational action efficiency ratios within the arbitrary web site than did females. The adjusted mean navigational action efficiency ratios for the linear (M_{adj} = 3.61), star (M_{adj} = 1.72), hierarchy (M_{adj} = 1.56), and arbitrary (M_{adj} = 5.17) web sites, were identical to the simple ANOVA.

Controlling for experience, gender did not statistically significantly affect navigational efficiency within the linear, star, or hierarchy web sites. Because gender was found to significantly effect navigational efficiency only within the arbitrary web site, the interaction which approached significance between gender and web site type could be attributed to the strong relationship between web site type and NAE. Males and females performed nearly equally within the linear, star, and hierarchy web sites. On the arbitrary web site, female NAE ratio scores increased more than that of the male NAE ratio score.

CONCLUSIONS

The following conclusions are based on the execution of the study and analysis of the data collected for the study:

- Web sites patterned after the star and hierarchy linkage patterns are more efficient to navigate for informational use than are the linear and arbitrary web sites. The hierarchy web site had the lowest navigational action efficiency ratios and thus appears to be the most efficient to navigate.
- Informational web sites constructed with arbitrary linkage patterns will be more difficult to navigate than web sites constructed using star, linear, or hierarchy linkage patterns.
- Females have a much more difficult time navigating informational arbitrary web sites than do males. Females in the study had less experience using the web than did males. They also produced more restarts and revisits on a majority of the web sites. Although experience was not found to be a statistically significant factor, there was evidence to suggest that it may account, at least in some part, for the higher number of restarts and revisits.
- The methodology used in the study for gathering navigational data from web sites will provide web developers with an empirically consistent process for evaluating their web sites' navigational efficiencies.
- Developing informational web sites according to linkage patterns rather than solely through semantic relationships may produce web sites that are more efficient to navigate.

DISCUSSION

A navigationally action efficient web site is one where its users are able to quickly get to information they desire or one where they will quickly discover that the information is not there. These web sites allow users to quickly orient themselves in relation to their point of departure (typically the homepage). Web sites that are inefficient to navigate result in users getting lost or disoriented in the information space. They are unable to locate desired information. Users of inefficient sites will follow some links only to discover that they really did not want to go to wherever the link leads. Consequently, they have to return to locations where they have previously been (a revisit). In some cases a user will end up retracing his or her steps all the way back to the point at which they entered the web site (a restart).

This study looked at gender and experience as possible factors influencing the efficiency with which one navigates a web site. This next section discusses the relationship between these two factors and navigational efficiency.

Gender

Analysis of the data for the linear, star, hierarchy, and arbitrary web sites shows that there is a significant difference between males and females in their efficiency in finding closed-task information only within the arbitrary web site. This finding is consistent with Mack's study (1995), which showed that males thought a nonlinear lesson format was clearer than females did. This finding is also supported by Beasley and Vila (1992) who found that females tended to navigate through a hypertext instructional module in a more linear fashion than did males.

LeMondola (1985) found that women tended to resist the use of technologies more than men. There is evidence that gender differences in attitudes toward computers begin developing as early as preschool (DiAmico, Baron, & Sissons, 1995) and persist through life. Gilliland's (1990) research supported this, as he found that females used computers less outside of school than males, and were more likely than males to self-select out of computing activities in school. One can theorize from such findings that if females do not prefer to use computers and other technologies, they will not have as much experience using them. With the advent of the Web and its companion browsers, computer use is becoming more and more nonlinear. If females do not prefer to use computers, than one may infer that nonlinear formats such as hypertext are going to be more difficult to them. The finding that females had more average restarts, revisits, and higher navigational action efficiency ratios than males did provides support for this theory.

Experience

Analysis of the data found no statistically significant difference between experienced and inexperienced Web users in their efficiency in finding closed-task information within web sites constructed using different hypertext linking patterns. However, the data did show that as experience increases, the mean navigational efficiency ratio decreases. While the results were not statistically significant, the fact the NAE ratios were lower among those participants who rated themselves as experienced may be important.

Research indicates that mental models may influence user performance in hypertext systems (Halasz & Moran, 1983). When confronted with a new, unfamiliar situation, people will try to find a similar situation that they are already familiar with so they can use knowledge they already have to deal with the situation. Borgman (1986) found that computer users must

have a mental model of the computer system to be able to operate computers. Because hypertext systems are computer-based, users of hypertext systems will rely on mental models when using or navigating in a hypertext environment. The more exposure one has to various web sites, the more likely one would be to recognize the structure of any given site they access. Gray (1990) found that over time, users do seem to have the capacity to alter their mental models of hypertext systems. This is the result of the user's accumulation of mental structures (schemata) from using different web site interfaces. "The user interface acts like a navigational filter that either clarifies and facilitates the use of the system or acts as an impediment, preventing use of the system" (Jonassen & Grabinger, 1990, p. 17).

The findings of this study suggest that web users who have more experience have better navigational performance. These web users, as a result of spending more time using the Web, have acquired mental models of the numerous web site interfaces they encounter. Consequently, experienced web users are able to quickly recognize the structure of web sites and navigate web sites more efficiently than inexperienced web users.

SUMMARY

Starting a linearly structured article is difficult for most people. Organizing one's thoughts, developing an outline, and collecting one's ideas is difficult. It can be an even greater problem if there is no apparent structure to the information. The same can be said of the WWW. WWW sites constructed for informational use need to be organized so that users are able to locate the information. Information placed on web sites is typically in a nonlinear format. For some Web users, the capability to access information nonlinearly is confusing and frustrating. Some Web users have difficulty locating information in an efficient manner. They become disoriented. This problem is compounded by the fact that many web sites today appear as if they were constructed haphazardly and rushed onto the net. "An overall lack of planning, coupled with a new-found fascination for hypertext linking, usually results in a tangled mess of web pages, contributing to users being hopelessly lost in hyperspace" (Sano, 1996, p. 6).

Business leaders, faculty planning web courses, administrators planning web pages for their institutions all need to take notice. There is now evidence to suggest that users will be less disoriented, and will be able to locate information within web sites more efficiently if the web sites are constructed using the star or hierarchy linkage patterns. Such web sites will be

easy to learn, efficient to use, easy to remember, pleasant to use, and will result in fewer user errors.

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