December 2003

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Abstract

One category of Web application is an informational sites, which can be in the form of online newspaper, service manual, online electronic books, online help, online tutorial, and the like. One big target for designing a Web application in this category is to enable the user to search for information as quickly as possible. When user is doing his Web activity, he may develop some sort of mental model. This mental model could be about how a Website works, how the Internet works, how the information is structured on the website, or some other mental models related to given task. During his Web navigation to search for particular information, user may need some sort of wayfinding to ease his tasks. The existence of wayfinding cues could lead to the formation of user's mental models. This paper observes the role of user's mental model on his information search performance. A 2 x 2 factorial design is used to test the hypotheses. The first factor is the presence or absence of wayfinding cues, and the second factor is whether subjects are presented with the same Websites or different Websites during the experiment.

Keywords: Online help, online tutorial, mental model, navigation, wayfinding, mental model load

Introduction

The World Wide Web (WWW) is a vast collection of interconnected documents. Its foundation is based on the concept of hypertext. It consists of hypertext, Internet, and multimedia (Rumpradit and Donnell 1999). The non-linear structure of hypertext enables users to jump from one part to another part quite easily. They may "posses some form of mental representation for a document type that provides information on the likely structure and organization of key elements within it" (Dillon, 1991, p. 913). However, the users may not have a clear conception of relationships within the system, not knowing where to go next, knowing where to go but not knowing how to get there, and not knowing where they are in the overall structure of the document (Elm and Wood, 1985). Researchers have called this problem as disorientation (e.g. Ransom *et al*, 1997; Rumpradit and Donnell, 1999; Park and Kim, 2000). This disorientation problem mainly caused by unfamiliarity of subject matters, getting distracted from viewing a large number of items, unfamiliarity with the structure or conceptual organization of the hypertext network, and general inexperience of using the system (Foss, 1989).

Discussing about any system (whether it is an application program or computer system in general), we have to consider three parties involved, which are the system's designer(s), the users, and the system itself. A designer's model (conceptual model) is a model of a system created by its designer. System image is what actually seen to the users, and it includes all of the documentations and instructions that come together with the system. A model formed by a user as the result of observing/working with a system is called a user's mental model. It is a model that a user has in his/her mind about how the system works. Norman (1986) showed how these three models are relating to each other; however, there is no direct connection between conceptual model and user's mental model. From software engineering, it is said that any system should be designed with the human-centered design paradigm. Fuchs-Frohenhofen, et al. (1996) stressed that cognitive compatibility is an important aspect of human-centered system design. Cognitive compatibility means that the structure of the human-machine interface of any application should match the cognitive structure of the users who are using a system.

Mental Model

Mental model is "a knowledge that the user has about how system works, its component parts, the processes, their interactions, and how one component influences another" (Fein, et al. 1993, p. 157). This mental model is supposed to help people in learning and understanding complex situation. It synthesizes several steps of a process and organizes them as a unit (Allen 1997). Mental models are "what people really have in their heads and what guides their use of things" (Norman 1983, p. 12). They are "the bridge between the work environment to be controlled and the mental processes underlying this control" (Rasmussen 1990, p. 43). They serve to qualitatively model the effects of changes in a system (William et al. 1983). It allows us to "both understand problem situations and predict consequences of action contemplated for solving the problems" (Marchionini 1989, p. 56).

Mental models are created for a purpose – they do not exist as some sort of optional extra in the user's head (Green 1990). Norman (1986) cautions that the user's model is not formed from the conceptual (designer's); it result from the user interprets the system image. Its purpose is to assist users in finding appropriate actions to achieve their goals (Rasmussen 1990). Furthermore, Fisher (1991) pointed out that mental model is a cognitive construct that describes a user's understanding of particular domain in the real world by stating that

> "… these models are formed by experience, self exploration, training, instruction, observation, and accidental encounters. In systems that operate at the 'human-computer communication' level, the model will be centered around the properties of a computer system" (p. 21).

When a system is deployed (released) its conceptual model remains persistent until designer rebuilds it. However, the mental model of a particular user may change every time he comes across with the system's new feature. Moreover, between users they may have different mental model on the same system. Tatcher and Greyling (1993) showed how their subjects have different views when they were asked to describe what the Internet is. Some of them described the Internet as a collection of computers link to each other, some described it as a collection of applications, other viewed it as a centralized database, and several other different views. Several researchers also showed the discrepancy between conceptual models and users' mental model. On their study on how people conceptualize the web, Stronge and Park (2001) showed mental model of their subjects were encyclopedia or library; whilst according to the designer, the conceptual model was a telephone. Veldof and Beavers (2001) used library tutorial to show how online tutorial should be designed as a learning environment, not a searching environment which most of their subjects assumed. User's mental models of search engines also show this mismatch (Muramatsu and Pratt 2001).

Mental model is incomplete (Norman 1983). However, mental models change as users gain more experience (Hawk and Wang 1999). Users might change their mental model while constructing it (Waern 1990). It is believed that experience users' models should be closer to match the designer's model than those of novice users. The closer a user's mental model to a designer's conceptual model the better his performance should become (Kellog and Breen 1987). Empirical study done by Moody et al. (1996) and Muramatsu and Pratt (2001) supported this claim. Exposing users to similar things over time may influence their mental model. Dillon (1991) has showed that those who used to use certain text type possess a superstructure or model of that text which enables them to predict where information is located with high level of accuracy.

Navigation and Wayfinding

Navigation is an incremental real-time process that integrates physical activity (called locomotion) and decision-making (Jul and Furnas 1997). It is not merely physical translation through a space, but there is also a cognitive element involved. This cognitive element is referred to as wayfinding; it involves mental representation, route planning, and distance estimation (Darken et al. 1999).

Wayfinding describes the process of reaching destination, whether in a familiar or an unfamiliar environment. It is a spatial problem solving (Down and Stea 1977), and it is a user's ability to maneuver in electronic space (Kerr 1990). Making a journey and reaching a destination are wayfinding goals. If users make a journey for the first time in an unfamiliar destination, they are confronted with a problem they need to find a solution. The solution is a plan of action.

Different wayfinding strategies may be employed depending on the availability of the collectible information. For example, if only sensory information is available to the users, they have to perform a much more exhaustive spatial information search to reach the destination than if they followed route directions in memory (that is, memory information). Thus, the type of spatial information available to the users is influential in determining the wayfinding strategy (Chen and Stanney 1999).

Spatial Knowledge

Spatial information users have about their surroundings is integrated as users' spatial knowledge. To look further on spatial knowledge, most researchers agree that spatial knowledge comprises landmark knowledge, procedure knowledge, and survey knowledge (Thorndyke and Hayes-Roth 1982, Darken and Sibert 1996, Jul and Furnas 1997).

Landmark knowledge, also known as place knowledge (Hirtle and Hudson 1991), represents information about the visual details of specific locations in an environment. It includes "the salient aspects of places encoded in a declarative form" (Kim and Hirtle 1995, p. 242). This knowledge presumably takes the form of perception icons and images (or the sensory data they represent). This type of knowledge can be acquired directly by viewing objects in the environment.

Procedure knowledge, also called route knowledge or primary spatial knowledge, represents information about the sequence of actions required to follow a particular route. At minimum, this knowledge consists of a series of procedure description of starting points, anchor points, subsequent landmarks, intermediate stopping points, and a final destination. This knowledge is derived directly from the experience of navigating the represented route (Thorndyke et al. 1982).

Survey knowledge, also called configuration knowledge or secondary spatial knowledge, represents the configuration relations among locations and routes in an environment. This type of knowledge encodes the topographic properties of the space, including the locations of objects with respect to a fixed, global coordinate system, the inter object distance. Survey knowledge concerns with "the spatial layout of the salient places" (Kim and Hirtle 1995, p. 242). Survey knowledge is not available from direct experience, but it is acquired directly from the map or through the study of other media (Thorndyke et al., 1982).

In a Website, icons, menus, and coloured-texts can be used to provide users with landmark knowledge. Procedure knowledge can be obtained by following links or submenus, e.g. Insert → Picture → From File. A geographical structure a Website has, although it's hidden, can also be used to locate an institution running a particular Web server (Dieberger, 1995). Survey knowledge can be gathered from other users' help, by using a hotlist of interesting pages collected by other users.

Mental Model and Wayfinding

Researchers have compared the way users browsing hypertext system and the Web to that of a person navigating and wayfinding through a physical environment (e.g. Parunak, 1989; Dillon et al. 1990 and 1993; Jul and Furnas, 1997; Spence, 1999; Hodkinson et al. 2000). Browsing in hypertext system includes many of the same task as wayfinding in physical spaces such as: finding user's current location, planning the route that will accomplish user's task goals, and execution of the planned route ((Garling and Golledge, 1989) Kim and Hirtle, 1995).

It is said that user's mental model is formed as a result of user interact and interpret the system. Anything presented on screen can be used to perfecting user's mental model. Hence colours, fonts, and graphics can be utilized to shape up user's mental model. Researchers have used colours, fonts, and graphics have used wayfinding cues to ease their subjects' mental activities before their physical activities took place (e.g. Kerr, 1990; and Ling and Schaik, 2002). Different wayfinding cues have also been tested as wayfinding cues including (internet speed) traffic light in the form of simple hyperlink annotation (Campbell and Maglio, 1999), graphics level of detail, label placement (Devlin and Bernstein, 1997), reserved area, link colour, mouse pointer, popup (Weinreich and Lamersdorf, 2000), and contextual aids (Park and Kim, 2000).

Web Applications

Web applications can be grouped into seven categories: informational, interactive, transactional, workflow, collaborative work environments, online communities and market places, and Web portals (Ginige and Murugesan 2001). This categorization does not meant to rigidly divide those Web applications into these categories, because one application may fall into more than one category.

Developing a simple Website is a snap for an expert. However, a big question arises: does this expert really care about how user will interact with his Website, or perhaps he just simply doesn't care at all. All he want to have on his Website is perhaps a very fancy, flashy, and colourful screen design, without taking care of its usability, not including security, accessibility, scalability, compatibility, maintainability, reliability, and operability. Not to mention cultural, privacy, moral, and legal aspects (Ginige and

Murugesan 2001). For the purpose of this paper, two types of informational Website widely available will be presented as an illustration. The first type is online help, and the second type is online tutorial.

Online Help

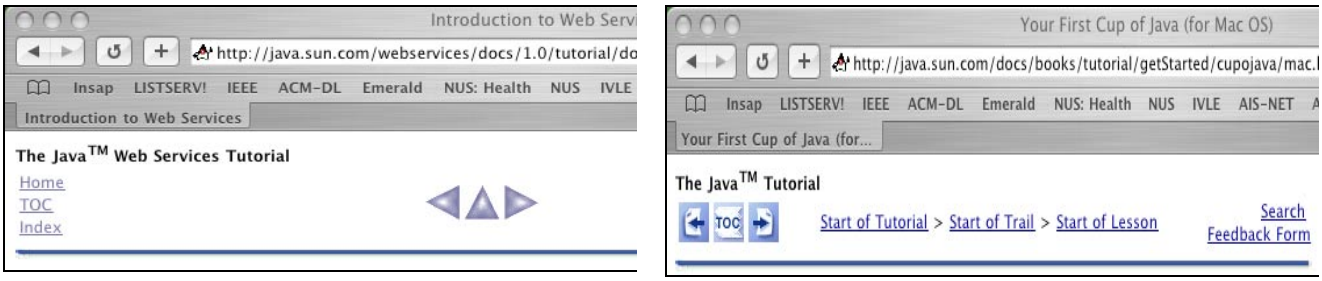
Online help is designed to give a useful help when a user has difficulty to proceed with his activity. However, it is, often, not easy to use, if it is not rather confusing. Perhaps the most common style is the use of index. By looking at the word 'index', user would expect a list of character 'A' to 'Z', which is commonly found in textbooks, to show the first letter of each index word. However, this is not always the case. Figure 1a and Figure 1b show different screens when a user clicks an Index on the Netscape Help and on the Microsoft Office Help respectively (both are running in Macintosh OS X). Netscape Help directly shows more complete list than Microsoft Office Help does. On the other hand, Microsoft Office Help simply shows the first letter of index word users can choose from. A user has to click on the first letter of index word (# Z) in order to see the available option for this particular index. For Netscape Help, a user has to scroll down to see the index starting with a letter not shown on the screen. These two examples show that users need to take different steps to achieve the same goal. Furthermore, it seems that user has an "obligation" to remember all of these different steps needed to get the same result, or arrive at the same destination.

a. b.

Figure 1. Two Different Approaches to Show an index of online Help

Online Tutorial

Online tutorial is now common. It gives a great help to those who have difficulties in learning particular subjects. As with online help, users may expect to employ the same mental model every time they face online tutorial interface. However, this may not be the case either. Figure 2a and Figure 2b show two screen shots from two different online tutorial modules provided by the same company, which is **http://www.sun.com**.



a. **b.**

Figure 2. Two different screen shots from The Java™ Web Services Tutorial and the Java™ Tutorial

By looking the two pictures presented in Figure 2, user will notice that these two interfaces were designed differently. Although they may employ the same conceptual model, the way the information is presented on the interface may suggest different mental model need to be employed by the user.

The above examples suggest that applications designed by the same people, or the same group of people, may employ different conceptual model, which in turn force the user to employ different mental model. This may cause an increasing load on the user mental model.

Mental Model and Web Design

Several factors have been described as successful Web factors, e.g. Ozok and Zalvendy (2001), Ranganathan and Ganapathy (2002), and Aladwani and Palvia (2002). Compared to a textbook, there are more varieties of the design of Websites. The structure of textbooks is almost the same, although sometimes readers can expect a little variation. It is common to notice that textbook structure contains cover page, copyright page, preface, table of content, introduction, chapters, references, and index. Some may have a dedication page and appendixes. Thus, when readers open a textbook they will utilize the same mental model about a textbook structure. Therefore, no additional load on their mental model is necessary. However, this is not the case for Websites.

The very first front of any Website faced by users is a visual sensory. Unfortunately, visually, no two Websites are identical, even for those Websites employing the same information structure. This situation creates a problem that every time use open a new Website – one which they never seen before - there is often, if it is not always, discrepancy between what he expects to see (based on his experience) and what he actually sees on the screen. For this reason, a mental model load is defined, that is an additional mental effort to match existing mental model with the one needed to learn a new system.

Propositions

From a user's point of view, using online help is one way to find information related to his problem. In general, information seeking is a complex process comprising several activities, both mental and physical. Mental activities include combination of several specific mental models related to a particular information problem that can be described functionally and structurally (Marchionini, 1989). Functionally, this combination of mental models controls search by

> "…extracting key concepts from the information problem, identifying criteria for search process, selecting candidate information sources, monitoring lookup (search) and examination procedure, and using result to modify itself" (p. 56).

Structurally, an information-seeking system includes

> "... a set of mental models associated with various information sources (databases and accompanying search systems), a set of mental models pertinent to a particular information problem (task domain knowledge), an historical record of past applications of the information seeking system (self awareness which allows analogy and checks context), and a set of rules for combining these components and monitoring progress" (p. 56).

Physically, what users do when they are seeking for information is just following a route by clicking a link or icon toward the information they are trying to search for. After finding what they are looking for, they may continue with other information, or just simply exit the process. Therefore, basically, when users work with informational Website, the main load will be on their mental activities, although they may never realize it. In order to ease mental activities, the following proposition is proposed:

P1: The use of similar visual structure for different informational Websites will ease user's mental model load, which in turn will increase a user's information search performance.

In the physical world, spatial knowledge is easy to acquire. For people who already familiar with a particular environment, to name a few landmarks is an easy task. For people who never visit a new place, existence of a particular landmark can be acquire indirectly by getting more information on the survey knowledge. However, in the Web, this may not be happening. If users never visit a Website, it is hard for them to spell out what landmark knowledge they have about that Website. It is also impossible to get survey knowledge from that Website because it is almost never provided. What users can do about picturing a new Website

is to hope that this Website has common wayfinding cues, like menu system or links that lead to different page. In the light of this situation, the following is proposed:

P2: The use of pertinent wayfinding cues for a particular informational Website will ease user mental model load, which in turn will help user to improve his information search performance.

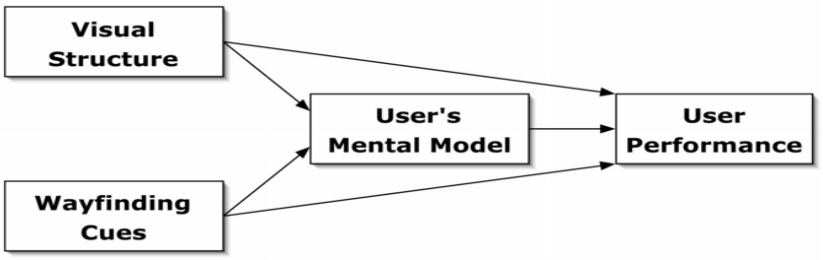


Figure 3. Research Model

Research Model and Hypotheses

Figure 1 and Figure 2 show how visual structure, e.g. how information is presented to the users, and the use of specific wayfinding cues, e.g. icons, and text colour may influence users mental model, which in turn may influence their search performance. Following this situation, the following research model is proposed. Independent variables are visual structure and wayfinding cues on informational Websites. Dependent variable is user performance that can be expressed in term of speed and accuracy /correctness (e.g. Rumpradit and Donnel, 1999). User mental model will be acting as a mediating variable. Figure 3 shows the proposed research model. To answer the above propositions, the following hypotheses are proposed:

H1: Website visual structure relate positively with user performance.
H2: Wayfinding cues provided on a Website relate positively with user performance.
H3: Subjects presented with the same visual structure will have better search performance than those who are presented with different visual structure.
H4: Subjects presented with landmark information will have better search performance than those who are not presented with landmark information

Methodology

To test the above hypotheses, laboratory experiment will be conducted. In that way, user's mental model can be manipulated by providing the subjects with experimental informational Websites. Every subject will be shown 2 Websites, whether they are using the same visual structure or different visual structure. Half of the subjects will be presented with wayfinding cues, and the other half without wayfinding cues, except default link colour. Therefore, a 2 x 2 factorial design will be used. Each subject will be given the same task, which is to find a number of information provided on the Websites. In order to observe any mental model load subjects may suffered from viewing different Websites, scaling technique (Kellogg and Breen, 1987) will be used, so that any quantitative difference in both Websites mental model can be captured. Therefore any additional mental model load can be measured.

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