NAVIGATING BACKWARD: CONCRETE VS. ABSTRACT REPRESENTATION IN HYPERTEXT BUTTONS

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Abstract: The users of instructional hypertext programs must rely on the mechanisms provided by designers for access to the functions of the programs, including functions typically called "navigation," or moving between the various displays and states offered by the program. Such access is often provided by means of "buttons," or selectable hot spots on the display, and the design of these buttons cari either help or hinder users' efforts to navigate the program. When navigation involves returning to a previously visited display or state, or navigating backward, users are particularly prone to misinterpret the meaning of navigation buttons.
Two preliminary studies are discussed, one showing that designers of 130 surveyed HyperCard (TM) stacks make less consistent choices for "specific" navigational functions than they do for "general" navigational functions, and the other demonstrating that subjects make fewer errors in choosing navigation buttons for "specific" navigational functions when the representation of the buttons is concrete (i.e.., a miniature image of the destination for the navigational move) than when the representation is abstract (i.e.., a form of arrow).

Résumé: Les utilisateurs de programmes hypertexte doivent se fier aux instructions données par ses dessinateurs pour accéder aux fonctions des programmes comme la fonction 'navigation', soit le déplacement entre différentes pages de présentation. Ce déplacement est souvent effectué par l'utilisation de boutons. Le modèle du bouton peut soit aider ou nuire aux efforts de l'utilisateur lors de la navigation. Lorsque la navigation implique le retour aux pages de présentation précédentes, les utilisateurs sont particulièrement portés à mal interpréter la signification des boutons.
Deux études sont présentées ici. La première démontre que les dessinateurs de 130 cartes HyperCard TM font des choix de façon moins constante lorsqu'ils effectuent des fonctions de navigation spécifique que lorsqu'ils effectuent des fonctions de navigation génerale. La seconde étude démontre que les sujets font moins d'erreurs de choix de boutons de navigation lors de fonction spécifique de navigation lorsque le bouton est représente de façon concrete (image miniature qui illustre la destination) que lorsque le bouton est représente de façon abstraite (une forme de flèche).

Hypermedia and Navigation

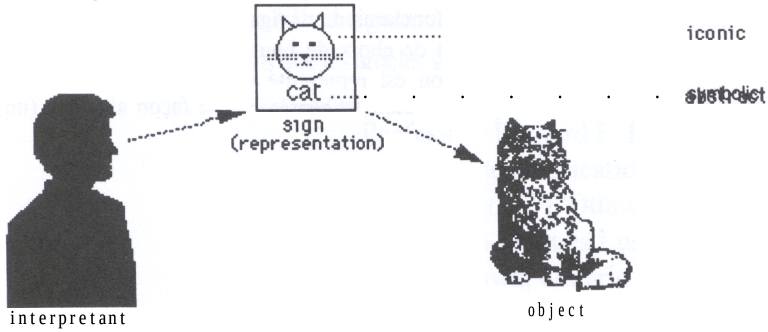
Even though people using hypermedia programs are usually sitting still in front of computer displays, they are said to be "moving through" the programs and sometimes "getting lost!' in them (Apple Computer, 1989; Edwards & Hardman, 1989). They are observed to use strategies similar to those people use in physical wayfinding, including using "landmarks", or easily recognizable screen displays, in order to orient themselves in relation to the rest of the available information (McKnight, Dillon & Richardson, 1993). Although legitimate questions have been raised concerning the sufficiency of physical wayfinding terminology to describe interactions between humans and hypertexts (Landow, 1990; Stanton & Baber, 1994), such terminology is nevertheless useful for designers who must provide the means by which users interact with hypermedia programs.

Designers of instructional hypermedia often focus on the teaching and learning aspects of such programs to the exclusion of considering the navigational task facing the learners who will use the programs (Fry & Soloway, 1987), but the visual elements that operate as intermediaries between the program and the learners comprise a sign system that must be understandable if the programs are to be usable (Mullet and Sano, 1995).

Representation and Hypermedia Sign Systems

A sign is a representation of a thing, tangible or intangible, called an *object.* The object of a sign is called its *referent,* since it is the thing to which the sign refers. .See figure 1. A sign only functions as a sign when someone, called the *interpretant,* recognizes that sign as a representation of the object (Noth, 1990). In a hypermedia program the *sign* may be an arrow on the screen, the *object* may be a concept ("moving forward through the displays in this program"), and the *interpretant* will be the user of the program.

Figure 1: Sign, object and interpretant relationship.



By definition signs are representations, and representations may take different forms, of which Bruner (1966) defines three: enactive, iconic and symbolic. Although Bruner discusses the representation of knowledge, not specifically of signs, his definitions of the three forms of representation will help clarify our discussion of the forms of signs.

Enactive Representation

Enactive representation is used when we must represent "things for which we have no imagery and no words" (Bruner, 1966, p. 10), like playing tennis or riding a bike. Enactive representation is most applicable to discussions regarding the interaction of hardware and hypertext (Kay, 1989), and to animated icons (Baecker, Small & Mander, 1991), both beyond the scope of this study.

Iconic Representation

Iconic representation "depends on visual or other sensory organization and upon the use of summarizing images" (Bruner, 1966, p. 10-11), or pictures. In the case of computer interfaces, we may describe pictures as any visual representation which is not a part of some existing symbol system used for writing.

At this point the terms used for describing representations of knowledge and the common terms used to describe elements of computer sign systems become confusing. Iconic representation is the form used for computer icons when the computer term "icon" is used correctly, but not every iconic representation (even in the computer interface) is an icon (Horton, 1994). The authors of this study do not presume to coin new terms either for computer interface elements or for iconic representations. Instead we will use the term "pictorial" to refer to iconic representations on hypertext navigation buttons.

Symbolic Representation

Symbolic representation is "representation in words or language" (Bruner-, 1966, p. 11). In the case of computer interfaces all elements drawn from existing symbol systems for writing are symbolic representations. Text labels on navigation buttons are the examples of such symbolic representations with which we are presently most concerned. Function and Form in Hypermedia Sign Systems

The function that a navigation button performs when it is selected is distinct from the form, or representation, of that button on the computer screen. Once a hypertext designer has made the decision that users of the program will be able to return to the screen display just previously viewed, he has decided on a *function,* or capability for action -- in this case, navigation -- to be offered to the user. That function may be represented in any number of ways, not all of them visual (e.g., a recorded voice might recite the options available and prompt users to press certain keys to select one as happens in the currently ubiquitous telephone menuing systems.) In the event that a function is represented visually, it may take one of the types of forms discussed above or a combination of those types (in the case of buttons containing both pictorial representations and text labels, or symbolic representations). It is clear that the form of a navigation button influences the ease with which users may perceive its function (Boling, Beriswill, Xaver, Hebb, Kaufman & Frick, 1996; King, Boling, Anneli, Bray, Cardenas & Frick, 1996), apart from whether or not the function was well-conceived.

Consistency in the Forms Designers Use for Navigation Buttons

In a prior study (King, et al., 1996) we discovered that people who had some experience using HyperCard (TM) stacks were not always able to perceive the functions of navigation buttons displaying "standard" pictorial representations (the ones available in the HyperCard authoring system). Subjects' performance was significantly better when the buttons displayed text labels, either alone or in conjunction with the pictorial representations. We speculated that part of the trouble might be that different designers choose different pictorial representations for the same functions. If users of instructional hypermedia programs often see different images on buttons that have similar functions, or see the same image on buttons that perform different functions, they might not develop any reliable background knowledge for guessing at the function of a button in an unfamiliar program, even if they have encountered the image on that button before. We conducted a survey to discover whether or not most designers of the instructional HyperCard stacks we reviewed were using pictorial representations consistently or inconsistently with other designers of similar products.

Methodology

Collecting and Classifying the Buttons

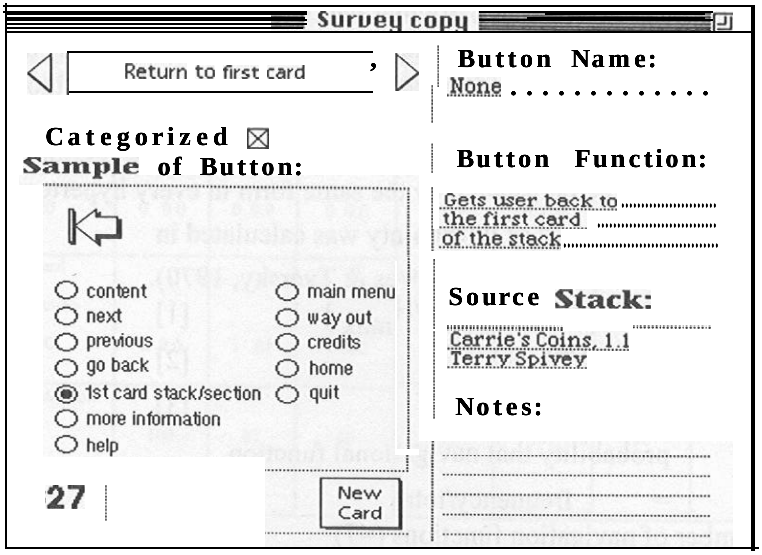
We collected 130 readily available HyperCard stacks from the School of Education computing environment at Indiana University. The majority of these stacks were ones classified as "educational" from a large collection of shareware widely disseminated across the Internet. Electronic mail messages alerting students to the presence of this shareware collection had been circulated through the network in the months before our prior study (King, et al., 1996), and since the subjects for that study were drawn from the School of Education we reasoned that some of the HyperCard stacks with which they had experience would have been these, or ones similar to these.

One sample of every button from each of the 130 stacks was collected into a single HyperCard stack which was created for this purpose. As each button was collected the researcher also entered into the data stack a description of the function that button represented in the stack from which it came was collected. Two researchers reviewed this collection individually, then reviewed and discussed the collection together to develop a definition list for the major functions represented by the buttons (as they had been described at the time of their collection).

A second stack was created in which all the collected icons appeared. The nine navigational functions were listed on every card.

To establish interrater reliability a third researcher, who had not participated either in gathering the icons or in developing the navigational function list, went through this second stack and classified each icon into a single function using a definition list. Following the third rater's classification, all three raters agreed that two functions, "home" and "quit," were identical. Those functions were collapsed into the single function "home," after which interrater reliability was .97. Of the discrepancies remaining those involving navigation were all related to confusion in the backward navigation functions and were resolved through clarification of the definition list,

Figure 2: Classification stack into which buttons were copied for Study I, showing a collected button, its original description, its origin and the reviewer's classification of the button.



Determining Consistency

From the original 1111 buttons collected we selected only those which had been classified as navigational. Of those, we selected the ones using pictorial representations in the form of arrows. We chose to focus on arrow forms since they fit Easterby's description of "figural goodness" (1970), they are used across cultures and time to represent directional motion (Dreyfuss, 1972), and they were selected for use by designers on nearly 40 percent of the buttons in our sample. This selection process left us with a total of 427 buttons in the final study.

These 427 buttons fell into seven functional categories: 1) "next," 2) "previous," 3) "home," 4) "main menu," 5) "way out," 6) "go back," and 7) "1st card of section." These same buttons fell into eight formal categories: (see Table 1) 1) right-facing arrow (A), 2) left-facing arrow (B), 3) upward-facing arrow (C), 4) downward-facing arrow (D), 5) right-facing arrow with vertical bar (E), 6) left-facing arrow with vertical bar (F), 7) curved left-facing arrow (G), and 8) doubled left-facing arrow (H). The formal categories are illustrated in Table 1. All variations of a certain formal type were categorized together; e.g., black arrows and white arrows and arrows shaded to look dimensional were all classified as type "A" providing they had a straight stem and the head faced to the right.

We determined the consistency with which designers chose pictorial representations for navigational functions by measuring the reduction in uncertainty for a user faced with a particular button displaying an arrow. Uncertainty regarding the function of a particular navigation button is maximum for the user of multiple hypertexts if different forms (or types of arrows) are used to represent the same function, like "go back," in every one of those hypertexts. Uncertainty is somewhat reduced when navigation buttons with the same function share the same form across hypertexts, and uncertainty is entirely reduced if the same function is represented by the same form in every hypertext. Formulas 1 - 5 show how reduction of uncertainty was calculated in Table 1, where H = uncertainty (Coombs, Dawes & Tversky, 1970).

$$H_{red} = 100\ [(H_{max} - H_{obs})/H_{max}] \quad [1]$$

$$H_{max} = -\log_2 (1/n) \quad [2]$$

$$H_{obs} = -\sum Pi (\log_2 Pi) \quad [3]$$

Pi = probability that navigational function i occurs = frequency/total [4]

n = number of navigation functions (=7)

Table 1: Summary of reduction in uncertainty for 8 arrow forms representing 7 navigational functions (n = 427).

FORM	A	B	C	D	E	F	G	H
								
	n =	n =	n = 5	n = 2	n = 2	n = 11	n = 50	n = 3
	f P	f P	f P	f P	f P	f P	f P	f P
Function								
next n = 124	105 1.0	0 0,0	0 0.0	2 1.0	2 1.0	0 0.0	0 0.0	0 0.0
previous n = 97	0 0.0	91 .95	2 0.4	0 0.0	0 0.0	2 .19	0 0.0	0 0.0
home n = 96	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	2 .04	0 0.0
main menu n = 69	0 0.0	2 .02	2 0.4	0 0.0	0 0.0	3 .27	5. 30	0 0.0
way out n = 26	0 0.0	2 .02	0 0.0	0 0.0	0 0.0	0 0.0	7 .14	0 0.0
go back n = 20	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	1 .09	13 .26	3 1.0
1st card of section n = 40	0 0.0	1 .01	1 .02	0 0.0	0 0.0	5 .45	13 .26	0 0.0
% reduction in uncertainty	100	87	46	100	100	36	25	100

Results

Of the eight forms, we discovered that four displayed no uncertainty (or 100 percent reduction in uncertainty) within our sample. Of these, three forms

(D, E and H) were infrequent in the sample (less than 1 percent each). The remaining form, the right-facing arrow (A), accounted for almost one fourth of the total sample. Another form, the left-facing arrow (B), displayed an 87 percent reduction in uncertainty and was represented in the sample almost as frequently as was the right-facing arrow (A).

The remaining three forms (C, F and G) displayed low reduction in uncertainty, or a high probability that users encountering these forms would have seen them used to represent different functions before. Of these forms, the left-facing arrow with vertical bar(F) and the doubled left-facing arrow (G) are the same forms that accounted for 75 percent of the total error in our previous study (King, et al., 1996).

Discussion

We had expected to find that designers, especially designers of shareware and non-commercial stacks like those in our sample, would be inconsistent in their choices of forms to represent navigational functions. Instead we found them to be 100 percent consistent in some cases and very inconsistent (a low of 25 percent reduction in uncertainty) in others. We had also speculated that designers might be less consistent representing backward navigational functions, or functions involving a return to some location, than in representing other kinds of navigation (Nielsen, 1995). However, although all the forms displaying less than 15 percent reduction in uncertainty in this sample were forms representing backward navigation functions, the left-facing arrow (B) was a notable exception in that it was used almost as consistently as the right-facing arrow (A) in a similar number of instances.

To explain the difference between our expectations and our results, we speculated that some of the functions designers are trying to represent may be more difficult to match with forms than are other functions. Maccia (1987; 1988) distinguishes between "knowing that," or general knowledge, and "knowing that one," or specific knowledge. In the physical wayfinding analogy we have already discussed, "knowing that" would be equivalent to the knowledge that my destination is "someplace where I can buy food." In contrast, "knowing that one" would be. equivalent to the knowledge that my destination is "the little yellow grocery store on the comer." Since hypertexts are. defined by links between nodes, neither of which have true spatial equivalents in the physical world, and since users perceive themselves to be moving between those links McKnight, Dillon, &Richardson, 1993), a user in our analogy could very well end up in one location wanting to' return to "the little yellow grocery store" but be presented only with the choice to go to "some one of the places where you were last week."

Applying the concepts of specific and general knowledge to the design of forms, we may draw upon Wileman's (1993) "ways to represent an object." These range from concrete, in which the image attempts to mimic its referent as faithfully as possible, to abstract, in which the pictorial elements are simplified and reduced until they bear little resemblance to the referent and eventually become verbal symbols, or words. An abstract pictorial representation ***must*** be used for general knowledge, ***since*** "knowing that" has no visual or physical presence of its own from which to draw the concrete representation. Abstract pictorial representations may also be used for specific knowledge, but in the case of "knowing that one" the designer does have another choice -- concrete pictorial representation. The designer may represent the function, "return to the little yellow grocery store," as a concrete image of the little yellow grocery store.

Concrete versus Abstract Representations for Backward Navigation

It may be that the conscientious attempts many designers make to be consistent in creating the forms of navigation buttons for hypertext lead them to make inconsistent choices in the forms of buttons for specific navigation because it is difficult to match a specific function like "Go back to that menu that I saw just after I got into this section," with an abstract, or general, form like an arrow.

There is precedence both for questioning consistency in the interface (Grudin, 1989) and for using concrete pictorial representations as navigational aids in hypertext, called *miniatures* (Nielsen, 1990). In addition several principles of visual perception argue for the possibility that concrete pictorial representations will offer usability advantages for navigation. Humans are known to have impressive recall over extended periods of time for images they have seen previously (Paivio, 1971). We are likewise able to recognize objects even when they have undergone considerable transformation (Winn, 1993), although this facility is specifically described for transformation of viewing angle rather than for reduction in overall size of the image. Since the miniaturization of an image involves no angle transformation, recognition may be expected to be high until the resolution of the image deteriorates significantly. If recognition and recall of the destination screen is relatively easy, we might expect users to call on their "landmark" knowledge to select the appropriate concrete pictorial representation for backward navigation more effectively than they could interpret an abstract representation for the same navigation.

We decided to conduct a second, preliminary study to test the merits of pursuing our line of reasoning regarding concrete and abstract representations. This second study was designed to discover whether users of hypertext would make fewer errors in selecting navigation buttons when those buttons contained concrete representations, or miniatures, than when they contained abstract representations -- in this case arrows.

Methodology

Instrument

A paper instrument consisting of a series of screens from a hypertext program was created. Although the program did not actually exist, the researchers drew up a program structure diagram and created simulated screens to represent the main menu, two subsection menus, and content screens from the two subsections.

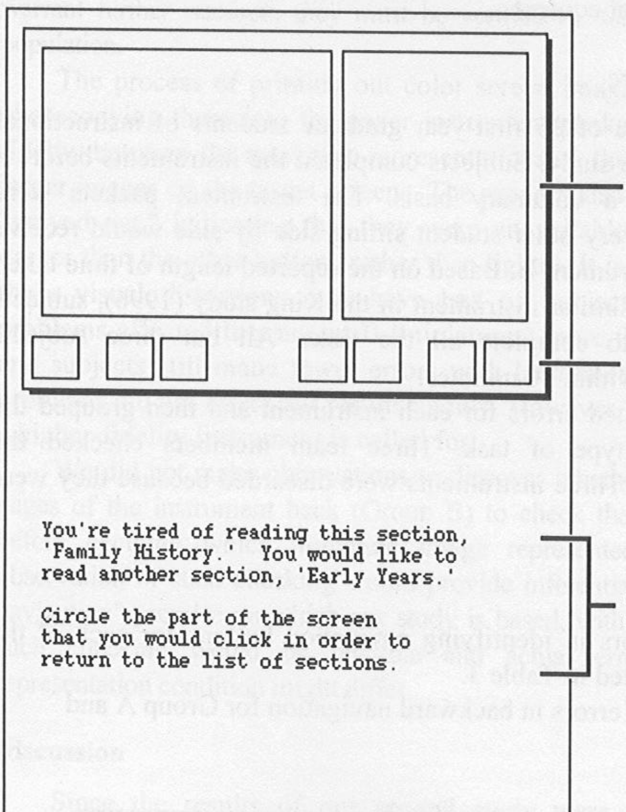
Navigation buttons representing the functions "quit," "more information," "help," "main menu," "go back," "previous," and "next" were included on each screen. Two versions of the instrument were prepared, Instrument A and Instrument B. In Instrument A every navigation button displayed abstract pictorial representations. In Instrument B concrete representations (miniature versions of the destination screens) were substituted for the "main menu" and "go back" arrows on those buttons. Since we hoped to observe the effect of concrete versus abstract pictorial representation without the demonstrated error reduction resulting from the inclusion of text labels (Boling, et al., 1996; King, et al., 1996), the navigation buttons in both Instruments A and B contained pictorial representations only (see Table 2).

Table 2: Summary of functions, functional definitions, and the concrete and abstract pictorial representations used on instruments A and B.

Form	Functional Definition	Concrete Representation (instrument A)	Abstract Representation (instrument B)
quit	leave the program	(same as instrument B)	
more information	view a display with more detail regarding the information the user is seeing now, including content-related help	(same as instrument B)	
help	view instructions for using the program itself (non-content-related help)	(same as instrument B)	
main menu	return from the current display to the primary menu display of the program		
go back	return from the current location to the primary menu display of the current section		
previous	return to the most recent display viewed	(same as instrument B)	
next	advance to the next designated display in the program sequence	(same as instrument B)	

One screen was depicted on each of 28 pages of the instrument with text below describing the user's context, a specific task to be completed, an the instruction to circle the part of the screen that would help perform that task. For example, "You're tired of reading this section, 'Family History.' You would like to read another section, 'Early Years.' Circle the part of the screen that you would click in order to return to the list of sections" (see Figure 3).

Figure 3: Diagram of the layout for each page of the instrument used in the concrete versus abstract buttons study.



Tasks requiring the use of all navigation buttons were included in the instrument, although we intended to measure only errors in backward navigation tasks (those requiring selection of the "main menu" or "go back" buttons). The additional tasks were included so that subjects would not begin to focus on backward navigation and so that they had a chance to see certain screens before they were asked to try and navigate back to those screens. Through an error in assembling the instrument packets, 3 out of the 16 backward navigation tasks appeared in the packets *before* the subjects saw the screens to which they were navigating. These tasks were not included in the final count of backward navigation data.

A paper instrument was selected over a "live," computer-based hypertext program in order to reduce the potential confounding effects of subjects getting lost when they made incorrect choices of navigation buttons (McNight, Dillon & Richardson, 1993), and to ensure that data could be collected on a sufficient number of controlled backward navigation instances. A simulated program was used to ensure that our subjects would be exposed to a program they had never seen, and would, therefore, be attempting to perceive the functions of buttons without prior learning in that context.

Subjects and Procedure

A convenience sample of 35 first-year graduate students of instructional technology was used in the study. Subjects completed the instruments before a regular class session on a voluntary basis. The instrument packets were presorted to ensure that every other student sitting side by side would receive either Instrument A or Instrument B. Based on the reported length of time taken by subjects to complete a similar instrument in the King study (1996), subjects were given 20 minutes to complete all the tasks. All but three subjects completed the instrument within 20 minutes.

Researchers tabulated errors for each instrument and then grouped the errors according to the type of task. Three team members checked the tabulations independently. Three instruments were discarded because they were incomplete.

Results

Mean number of errors in identifying navigation buttons for each of the treatment groups are reported in Table 3.

Table 3: Mean number of errors in backward navigation for Group A and Group B.

Group	Mean	Standard Deviation
Group A - abstract pictorial representations (arrows): n = 18	9.61	3.759
Group B - concrete pictorial representations (miniatures): n = 14	6.92	4.340

A one-tailed *t* test revealed a significant difference between Group A and Group B ($t = 1.838$, $p < .05$), with the subjects who saw concrete representations (miniatures) making significantly fewer errors in identifying buttons for backward navigation than subjects who saw abstract representations (arrows).

Limitations of the Study

The sampling technique used in this study is sufficient only for a preliminary exploration of the issues. Although the results of the study are encouraging enough to warrant further research, they must be verified by sampling from a more general population.

The process of printing out color screen images in black and white, then photocopying them into the paper instrument packets resulted in some loss of fidelity between the miniature representations on the navigation buttons and the larger images on the target screens. The process also caused buttons which were "grayed out," indicating that they were unavailable at the moment, to appear darker than the other buttons rather than lighter. It is unclear what effect, if any, these visual distortions may have had on subjects' performance. Since the problems affected Instrument B (miniatures) more than Instrument A (arrows), and subjects still made fewer errors with Instrument B, we speculate that the problems did not affect our results unduly. However, repetition of the study with a higher-fidelity instrument is called for.

We did not make observations to discover whether or not subjects turned the pages of the instrument back (Group B) to check the image on a previous page before deciding which miniature image represented the right choice. While observation of such checking would provide inferential support for the "landmark navigation" premise on which our study is based, with an electronic instrument no such checking would be possible and actual error rates for the concrete representation condition might differ.

Discussion

Since the results of our second study were significant in spite of its limitations, we believe there is reason to investigate the use of concrete representation in hypertext navigation more closely. Such an investigation would include a larger and more precise version of this study, as well as studies focusing on the design issues and alternatives for such concrete representations.

Implication of the Use of Miniatures for the Design of Screen Displays

Given the current and continuing size and resolution limitations of computer displays, screen images used for representing navigation functions must be reduced to as little as 100th or less of their original size in order to be useful as buttons. The problems of creating miniature images that are simultaneously discriminable one from another and sufficiently like the original to be recognized easily are known to designers (Nielsen, 1995; Rubens, 1989), and faced the researchers in this study as well. The primary implication for designers of using miniatures for navigation is that the original screens, particularly "landmarks" screens, will have to be designed with respect to the properties they will exhibit in miniature as well as those they exhibit at full size.

For this study we reduced the entire screen display for use on a given button. An alternative strategy would be to choose a small portion of the original display, probably an easily recognized visual element, and reproduce it full-size on the navigation button. Providing such visual elements were not simply symbols (which would move them into the abstract, or general knowledge, category of representations), such elements might take advantage of users' "landmark" knowledge to facilitate navigation without the drawbacks associated with creating viable miniatures of full screens.

Interaction of Concrete Representation and Text Labels on Navigation Buttons

The use of text labels has been shown to improve users' performance in all navigation functions, including backward navigation (Boling, et al., 1996; King, et al., 1996). The combination of miniature screen representations and text labels might yield greater improvements than the use of either on alone, or the use of text labels with abstract pictorial representations.

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