DOCUMENT RESUME

ED 436 172 IR 019 797

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TITLE Screen Miniatures as Icons for Backward Navigation in Content-Based Software.
PUB DATE 1999-02-00
NOTE 9p.; In: Proceedings of Selected Research and Development Papers Presented at the National Convention of the Association for Educational Communications and Technology [AECT] (21st, Houston, TX, February 10-14, 1999); see IR 019 753. For previous study, see EJ 552 563.
PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Comparative Analysis; Computer Graphics; *Computer Interfaces; Computer Software Development; Courseware; Design Preferences; Error Patterns; *Hypermedia; Multimedia Materials; *Navigation (Information Systems); Postsecondary Education; *Screen Design (Computers); Users (Information); Visual Stimuli
IDENTIFIERS Graphical User Interfaces; *Iconic Representation

ABSTRACT

Users of content-based software programs, including hypertexts and instructional multimedia, rely on the navigation functions provided by the designers of those program. Typical navigation schemes use abstract symbols (arrows) to label basic navigational functions like moving forward or backward through screen displays. In a previous study, the use of concrete representations (screen miniatures) to indicate backward navigation functions was found to significantly reduce the number of errors users made in backward navigation. The current study tested this claim using a more diverse sample of 35 adult subjects representing different ethnicity, nationality, and educational background, and an electronic instrument instead of the original paper instrument. A HyperCard(TM) stack was developed in two versions--one with screen miniatures, and one with arrows to represent certain backward navigation functions--and used to test subjects' ability to choose the correct button for a particular backward navigation event. Subjects using the screen miniatures made significantly fewer errors than did subjects using arrows. (Contains 28 references.) (Author/MES)

Screen Miniatures as Icons for Backward Navigation in Content-Based Software

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Abstract

The users of content-based software programs, including hypertexts and instructional multimedia, rely on the navigation functions provided by the designers of those programs. Typical navigation schemes use abstract symbols (arrows) to label basic navigational functions like moving forward or backward through screen displays. In a previous study conducted by Boling, King, Avers, Hsu, Lee & Frick (1996) the use of concrete representations (screen miniatures) to indicate backward navigation functions was found to reduce the number of errors users made in backward navigation significantly. The current study tested this claim using a more diverse sample of subjects and an electronic instrument instead of the original paper instrument. A hypercard™ stack was developed in two versions, one with screen miniatures and one with arrows to represent certain backward navigation functions, and used to test subjects' ability to choose the correct button for a particular backward navigation event. Subjects using the screen miniatures made significantly fewer errors than did subjects using arrows.

Icons for backward navigation in content-based software

Graphical user interfaces as they are used in most interactive content-based software rely on representations within that software to supply the users with its basic functions. Representations, or signs, are fundamental elements of communication. Signs communicate by virtue of " ... a three-way relation between the representamen (that which represents), the sign's object (that which is represented), and its mental interpretant (the situated intelligence that performs the necessary substitution of signifier for signified)" (Mullet & Sano,1995; p.171). In human computer interface design, the critical process of representation depends on establishing a clear relationship between a representamen and its object for the users. To interact with an information system, users need to draw a connection between each representamen and its corresponding system function.

A common functional element in content-based programs is the hyperlink, or electronic connection between one screen representation and another. Hyperlinks are often represented as text, and for navigation they are often represented as icons or buttons with pictorial symbols on them. Users have to decode these signs (or representamens) correctly or else they risk error in navigating the program, which frequently results in frustration with the programs. The degree to which the visual signs in a program are easily decoded by users of the programs (or interpretants) can therefore be a critical factor in the successful use of such programs (Norman, 1988).

The navigation metaphor

Hyperlinks allow users to retrieve information or pursue a content-related experience (taking a quiz, for example) by invoking various content nodes of the system as unique screen displays. This control by users over the sequence of screen displays is often described as *navigation* through an information space (Nielsen, 1990).

The navigation metaphor has been criticized as inappropriate because considerable differences exist between information space and physical space (Landow, 1990; Mayes, Kibby & Anderson, 1990). Stanton and Baber (1994) point out that physical space is static so the landscape, or physical space, metaphor can not capture the flexibility of hypertext. Maps that have been adapted from physical navigation to provide the hypertext users with navigational aids have also been criticized because in complex programs they can only provide an incomplete picture of the hyperspace (Stanton, Taylor & Tweedie, 1992). Consequently, the users might employ sub-optimal search strategies while depending on a map (Kim & Hirtle, 1995) or might even get lost in the program (Stanton & Baber, 1994).

In contrast, Canter, River and Storrs (1985) assert that there are fruitful and direct parallels between navigating concrete environments and navigating data. Kim and Hirtle (1995) even propose that a spatial metaphor can be used as a framework for explaining and designing tools analogous to navigational aids in physical environments that alleviate disorientation problems in hypertext systems. Their view is supported by the results of

Edwards and Hardman's (1993) experiment to determine how individuals cognitively represent a database in the form of a hypertext document. Edwards and Hardman conclude that individuals appear to be attempting to create cognitive representations of hypertext structures in the form of a survey-type map. McKnight, Dillon and Richardson (1993) have also documented people's use of easily recognizable screen displays as "landmarks" in a process similar to physical wayfinding while they are using hypertext documents.

The navigation metaphor is intuitively compelling. Many readers of this study will recognize themselves in the user of a content-based program who says or thinks, "I just saw it a couple screens ago -- now how do I *get back there*?" Lakoff and Johnson's (1980) discussion of orientation metaphors as a fundamental construct in the human conceptual system suggests that we could have predicted McKnight, Dillon and Richardson's (1993) observations. People's metaphorical speech concerning printed texts reveals a form of ontological metaphor at work; specifically, "A text is a terrain." Consider the statement, "I found that article *pretty slow going*, but I managed to *work my way up* to the discussion section where I *got bogged down* and had to *backtrack* several times in *order to make my way through* the author's explanation." Previously cited observations of users interacting with hypertexts further suggests that, whether or not such a view ignores some of the unique properties of hypertext, users are employing the conceptual "text as a terrain" metaphor to them. The authors of this study will therefore use navigation as a way to describe and reason about the design of pictorial hyperlinks in content-based software.

The trouble with navigating backward

It is clear that backtracking is important in navigating in hypertext environments. Stanton & Baber (1994) found that the most common form of user action in hypertext systems is backtracking to previous nodes; such backtracking serves as an error management activity. Schroeder and Grabowski (1995) found that users had considerable orientation problems in a hypertext system where no explicit backtracking function was provided. Boling et al. (1996) found that users made more navigational errors when they were "going backward," or returning to a previously-visited node, than they made in "going forward," or choosing a destination they had not visited before.

Seeking to explain the higher error rate for backward navigation, Boling et al. (1996) examined over 400 navigation buttons drawn from 130 instructional hypercard stacks. They discovered that designers of the hypertext products reviewed were highly consistent in their choice of button representation for forward and backward navigation involving only one "step," or the difference between linearly adjacent screen displays. However, there was a high degree of inconsistency in the designers' choice of button representation for navigating backward to a specific departure point or screen. What accounts for the observed consistency in designers' choice of representation for single-step backtracking as well as single-step forward navigation? What accounts for the high degree of inconsistency in designers' choice of representation for navigating backward to a specific departure point/screen?

General vs. specific destinations in navigation

Boling et al. postulate that designers' consistency *and* inconsistency lie in the nature of the two types of navigation tasks. They argue that the above two types of navigation, single-step navigation and specific-destination-backward navigation tasks can be viewed as representative of two types of knowledge -- general knowledge (knowing that) and specific knowledge (knowing that one) (Maccia, 1987; Maccia, 1988). General knowledge (knowing that) is knowledge or knowing that is "not bound to particular persons, places, events, things or their interrelationships" (Frick, 1997b). In contrast, specific knowledge (knowing that one) is knowledge or knowing used to "discern the specific features that make some entity unique - what sets it apart from all else" (Frick, 1997a, p. 113).

In the context of navigation, general knowledge suffices for tasks that involve moving by certain rules from the specific location or screen display one is seeing now to a different location/screen display that is unknown in advance. In the physical wayfinding analogy, "knowing that" would be equivalent to arriving at a place after following a navigational instruction like "Go one block down and turn right." In hypertext, an example of "knowing that" would be to "go from this logical screen display to the next one or the previous one." In both cases, the fact that they have arrived at a certain location or screen display is more important than whether or not they recognize the particular location or screen display.

In the context of navigation, specific knowledge is involved in such tasks of moving from where one is now to another specific location or screen display that one has visited previously. In the physical wayfinding analogy, "knowing that one" would be equivalent to arriving at "my house" after following the navigational instruction, "Go to your house." In the hypertext context, an example of "knowing that one" would be to arrive at the menu screen after following the instruction, "Go to the menu screen for this section." In both examples, what is important to users is that they have arrived at the specific place/screen display that was intended and that they have *not* arrived at any other one.

Concrete representations of screens as landmarks

Darken and Sibert (1996) define landmark knowledge as "static information about the visual details of a specific location." As such, landmark knowledge is indeed a form of specific knowledge in which the wayfinder remembers or recognizes a distinct element in the environment and relies on that element as a central location or departure point to further explore the rest of the environment. We argue that users of hypertext programs could rely on the distinctive visual features of specific screen, in the form of concrete pictorial representations on hyperlink buttons, as a form of landmark wayfinding for backward navigation.

Landmark knowledge may be useful in hypertext navigation if, and only if, people can recognize that they have seen distinctive visual features of the specific screen displays involved. Past research in visual recognition has provided ample and encouraging evidence in this regard. Empirical studies show that humans have remarkable recognition memory for visual images they have previously seen (Standing, 1973; Paivio, 1971). More impressively, people are capable of recognizing visual images even when these images have undergone substantial transformation (of size, not orientation) subsequent to the first viewing (Winn, 1993).

Since people do seem to use landmarks in hypertext, and they are capable of recognizing a seemingly limitless number of images as ones they have seen before, the authors speculate (as did Boling, et al., 1996) that miniature representations of screens might function more effectively as representations of backward navigation to specific locations than do abstract representations, like variations of left-facing arrows or text-based buttons of the "Return to submenu" type. The use of miniatures for backtracking is not unprecedented in hypertext applications, although the examples known to the authors have been "history list" type implementations (Ayers & Stasko, 1996; Nielsen, 1990; van Dam, 1987).

Such representations would preserve the context and much of the distinctive detail in the previously-viewed screen, which would not happen if only a portion of the screen were represented on the button. Screen miniatures would also obviate the necessity for designers to struggle with the difficult task of representing "low imagery" verbs like "to return" (Rogers & Oborne, 1987) and allow them to use images that stand for nouns ("that screen/location") instead of verbs ("go back") (Krull, 1988).

Concrete representation for navigation backward to specific destinations

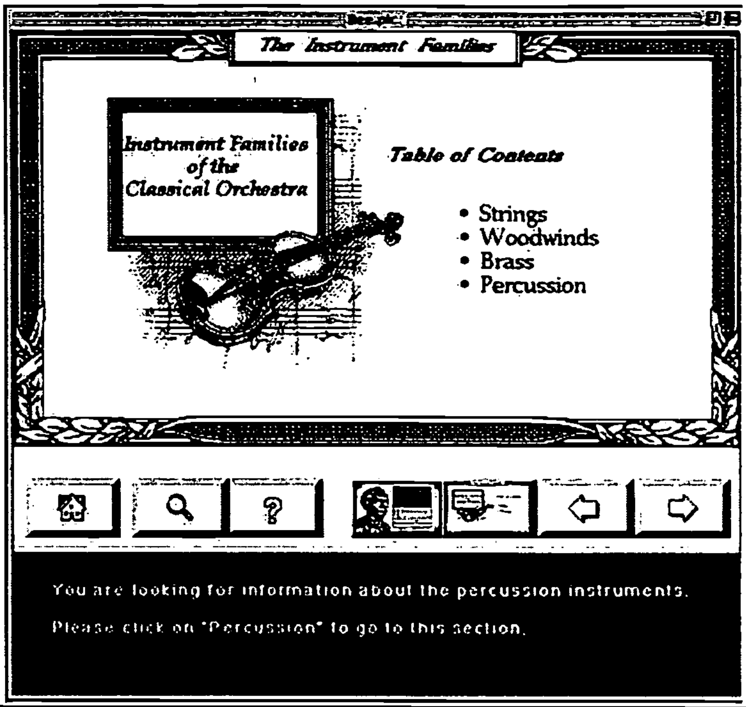
In light of the above evidence, the authors argue that the use of specific imagery (a picture of the specific location or screen display where the user wants to go) should be more helpful to the user than the use of abstract or general imagery (arrows) in representing specific navigational functions. We expected that users would make more errors in choosing navigation buttons for specific backward navigation when the buttons contained abstract symbols (arrows) than when they contained concrete representations of destinations (screen miniatures).

Method

Instrument

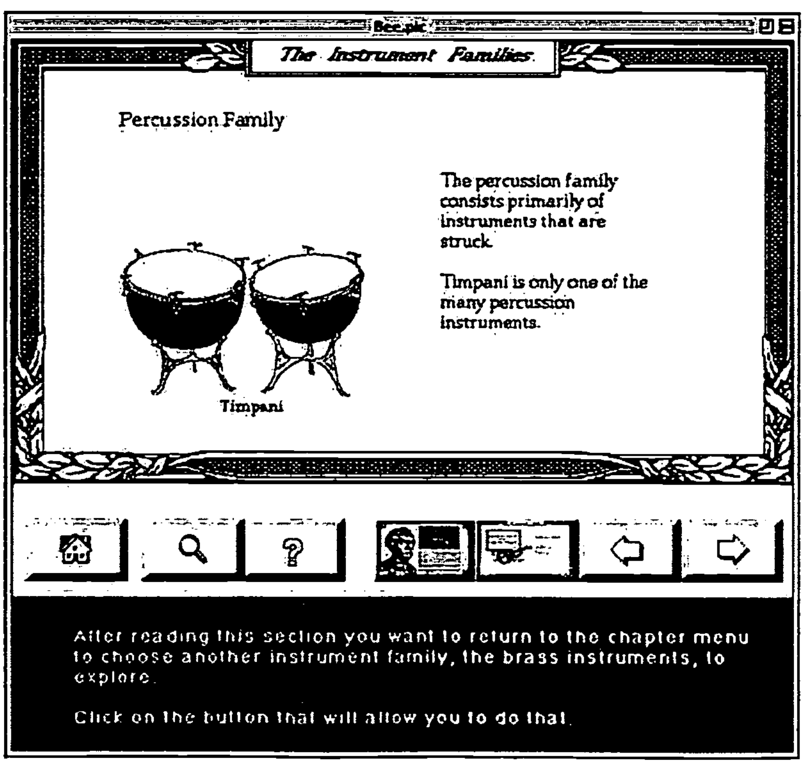
To test the hypothesis, a mocked-up hypertext program was developed by adapting a commercial product, Beethoven™. The screen of the instrument was divided into an upper part that showed the actual screen from the hypertext program and a lower part where the subjects were presented a navigation task (see Figure 1).

Figure 1. Screen from study instrument showing part of the linear navigation path preceding an actual navigation



Subjects were given the same set of 28 navigational tasks. To ensure that subjects had previously visited the screens to which they would later be asked to navigate "backward," subjects pursued a simulated navigation path through a series of two to four related screens before they were presented with a real navigational task (see Figure 2).

Figure 2. Screen from study instrument showing a backward navigation task.



The tasks provided the context for a navigational action, sometimes backward navigation, and then requested the user to click the button that s/he would choose in order to perform this action (see Figure 2). For example, a typical task would read:

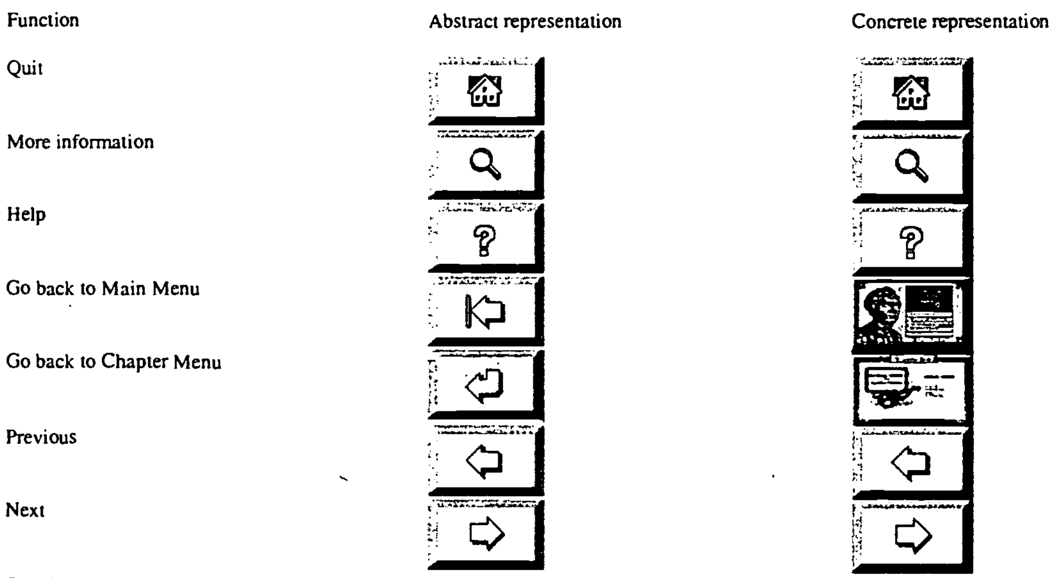
> After reading this section you want to return to the chapter menu to choose another instrument family, the brass instruments, to explore. Click on the button that will allow you to do that.

A separator screen was built in between the tasks. Subjects could click a button on this screen to go to the next task whenever they were ready.

Although this study concentrated on the errors made in backward navigation, the tasks involved buttons of all major navigation functions to prevent the subjects from focussing only on the backward navigation buttons. The start and end time of the experiment, the time spent on each screen, and the names of the buttons clicked by the subject were recorded in a log file as subjects completed the instrument.

Two versions of the program were developed to measure the effectiveness of concrete and abstract representation in the use of buttons for backward navigation. Both versions provided seven typical hypertext functions represented by a set of buttons. These functions were "quit", "more information", "help", "go back to main menu", "go back to chapter menu", "previous", and "next." The only difference between the two versions of the instrument was that "the go back to main menu" and "go back to chapter menu" buttons were represented differently. In one version these functions were represented by abstract pictorial representations (arrows). In the second version they were represented by miniaturized images of the screens to which they were linked (see Figure 3).

Figure 3. Comparison of all buttons appearing in two versions of the study instrument with their respective functions.



Subjects and Procedure

Thirty-five subjects representing different ethnicity, nationality, and educational background participated in this experiment. The gender ratio of the 35 subjects was 63% female to 37% male. The majority of the participants were between 20 and 29 years old (77%). Twenty percent were between 30 and 39 years old. One participant (3%) was between 50 and 59 years old. Nearly a quarter of the participants (22%) were enrolled in undergraduate programs, 75% were enrolled in graduate programs. Three percent (one participant) were not students. Half of the participants were majoring in varying fields in education (51%) while the remaining half were distributed among several other subject areas (see Table 1).

Table 1. Proportions of participants with different majors in the sample

Major	Participants (Number/Percent)	
Business	3	8.6 %
Computer Science/Telecommunications	3	8.6 %
Education	18	51.3 %
Library and Information Science	3	8.6 %
Natural Sciences	2	5.7 %
Other	6	17.2 %

All participants in the study reported that they had used graphic browsers before. Likewise, all participants except one had experiences with application programs that utilized navigational tools similar to those presented in a short demographic survey that they filled out after completing the instrument. Almost three fourths (74.3%) of the participants had no prior experience with hypercard. The remaining 25.7% who had used hypercard before reported to be either relatively inexperienced (14.3%) or moderately experienced (11.4%). No participant considered himself as very experienced in using hypercard. Thus, the participants could be considered as having some experiences with iconic representations for navigation. However, their familiarity with the default hypercard icons used in this study was fairly low for most of the subjects.

Subjects were randomly assigned to one of the two treatment conditions. Subjects were not aware of the differences between the two versions of the program. They only knew there were different versions and they were assigned to one of them. A test session took about 20-25 minutes including the time required for introducing the instrument.

Subjects were introduced to the instrument through an opening screen on the instrument that described the tasks they would encounter in the instrument. They then worked at the computers individually. The researchers did not sit next to the subjects so as not to influence the subjects inadvertently with body gestures or verbal signals.

Results

To ensure that the random assignment to the two treatment groups (see the methodology section) yielded no major differences between the groups, Pearson's chi square was calculated for gender, age, and prior experience with graphical browsers and hypercard. No significant differences between the groups were found for any one of the variables.

Mean number of errors and response time

According to our hypothesis, we expected the participants in the concrete pictorial representations group (miniatures -- Group B) to make fewer errors in backward navigation than the participants in the abstract pictorial representations group (arrows -- Group A). This expectation was confirmed. The mean number of errors in identifying navigation buttons for each of the treatment groups is reported in Table 2.

Table 2. Mean number of errors in identifying navigation buttons for each of the treatment groups

Group	Mean overall	Standard Deviation. Overall
Group A - abstract pictorial representations (arrows) N = 18	10.39	4.865
Group B – concrete pictorial representations (miniatures) N = 17	4.59	3.743

A one-tailed t-test revealed a highly significant difference between Group A and Group B for the number of backward navigation errors ($t = -3.937$, $p < .000$). For all navigation tasks, Group B who used concrete pictorial representations made fewer errors than Group A who saw abstract pictorial representations.

No differences between the two groups were found in the mean response time to the backward navigation tasks.

Discussion

The results of this study suggest that concrete pictorial representations may provide a less ambiguous means for backward navigation than do abstract representations. Providing screen miniatures on navigation buttons helped the users select the appropriate button for backward navigation, possibly by supporting their use of landmark navigation. In contrast, the group who saw the abstract pictorial representations made more mistakes relating navigational functions to the different symbols represented on the buttons.

Considerations for designing screen miniatures

Special consideration needs to be given to the design of screen miniatures for navigation buttons. In this study, some participants commented that it was difficult for them to distinguish between the miniatures representing the main menu and the chapter menu since they looked similar at the first glance. Nielsen (1990) made a similar observation. He criticized HyperCard's graphical history list that showed miniature pictures of the last 42 screens visited, pointing out the screen miniatures could easily be confused since they looked too similar. Thus, screens functioning as landmarks (that is, destined to appear as miniatures on buttons) would need to have some unique visual features that retain their distinctiveness even after undergoing considerable reduction in size.

Miniaturization of an entire screen display results in the loss of detail and, most probably, recognizability. One solution to this design problem might be to reproduce only a small portion of the original screen display on the navigation button. This design approach was used in Mosaic G, a derivative of NCSA's Mosaic 2.5, the popular browser for the World Wide Web (Ayers & Stasko, 1996). It may also be observed in any number of Web site designs where a portion of a logo or image map is repeated on subordinate site pages as a hot link back to the main page of the site. No empirical data has been reported on this form of navigation so far as we are aware at the time of writing. From a gestalt-psychology perspective, however, one could anticipate that showing parts of the screen without their surrounding context might not be very helpful providing concrete "landmark" signs (Easterby, 1970). Consequently, in the current study the authors created miniatures of entire screens, relying on distinctive elements of the full size screens to retain enough detail that they were functionally recognizable. Further study on the possibilities and limitation of partial screen landmarks is warranted.

Limitations of the study

The scenario of the study was not authentic. In an authentic hypertext environment, users get feedback on their navigation immediately and generally have the chance to correct their errors right away. The subjects in this study were directed to go through the hypertext stack in a predetermined sequence and did not receive feedback for the errors they made. The advantages of this approach were that error rates for respective navigation buttons could be recorded consistently, and the structured paths reduced the potential confounding effects from subjects getting lost in the hypertext program or learning the program's structure.

Future Research.

Research should be conducted to study subjects' performance with screen miniatures in authentic tasks and authentic contexts. Such studies might also examine the speed and ease of learning of the meanings of abstract versus concrete navigation buttons.

Comparison of screen miniatures versus detailed textual links may also be warranted. While one might expect faster recognition of individual concrete images (screen miniatures) over recognition of textual links, the time difference might be offset by the fact that the screen miniatures require users both to recognize them and to remember whether the information they seek exists at that previously-visited location. Textual links might carry more helpful semantic content that ultimately reduces either the time required to make a choice, or errors in navigation, or both.

Summary

Backward navigation to a screen/location visited previously is a frequently used navigation function within content-based software. The use of screen miniatures may be a fruitful design strategy for reducing error in this type of navigation, and might be considered as an option for backward navigation even though other navigational functions within a single program are represented differently.

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