World Wide Web Navigation Aid

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Abstract

The challenge for the World Wide Web user is to discover and rediscover useful information from very rich but also very diversified sources in the Web environment. The Web browser is a key interface to facilitate Web information access. In this paper, a framework is proposed to identify and investigate key factors that determine the Web browser's ability to assist users in performing various information retrieval tasks. Design guidelines to help overcome the limitations associated with human information processing and the Web environment are introduced. Based on these guidelines, an online history tool (MEMOS) is developed to support user browsing, organization, and rediscovery tasks in both intra-sessional and inter-sessional information retrieval. Empirical tests of user performance with the MEMOS tool are analysed in the context of our framework. We show that the MEMOS tool was perceived to be more useful than the history mechanisms used in popular Web browsers, but its benefit was most significant for inter-sessional support. Using sessions previously saved through the MEMOS tool to tackle specific retrieval questions was significantly faster and more accurate than trying to use standard rediscovery methods.

1. Introduction

The World Wide Web has the ability to present vast amounts of diverse, complex, multimedia information that is richly interconnected and cross-referenced through hypermedia links. Unfortunately, when navigating through such large hypermedia documents, users may encounter several problems. It is easy to become entangled in a large and complex web of decentralized, unstructured, and largely irrelevant information. Web users can become disoriented when overloaded with massive amounts of information, much of which may be irrelevant. This disorientation, or tendency to lose one's sense of location and direction, is often a consequence of searching through large nonlinear documents (hypermedia).

Web information retrieval can be improved through four general strategies : 1) the user can be educated and trained to use current support tools more effectively; 2) the Web environment can be improved to provide more effective searching and navigation mechanisms; 3) Web sites can be designed to better facilitate information access; and 4) the client-side Web browser can be improved to provide a more effective common interface to the complex Web environment. The focus of this paper is on improving Web information retrieval through the client-side Web browser. The Web browser is the primary vehicle for a user to navigate through

the Web information space. As the Web continues to grow at a phenomenal rate, an increasingly important question is how can we make a browser more efficient and effective when the complexity of the Web environment, user tasks, and human information processing limitations are all taken into consideration. In this paper, a theoretical framework is introduced to identify and investigate key factors that determine the Web browser's ability to facilitate information access in the very rich, but diversified Web environment. Information retrieval tasks are identified as well as the main limitations that hinder these tasks. We seek to investigate how well the Web browser fulfils its objective to facilitate information access. Researchers and developers may use this framework to explore and study the effectiveness of the browser interface between users and the Web. As an example, we will apply our framework to examine the ability of user interaction histories to facilitate browsing, organization and rediscovery tasks. Web navigation is often a recurrent task where more than half of the pages accessed are revisits, so effective use of navigation histories can be powerful tools for navigation support. However, the history mechanisms that are available through current commercial Web browsers have not fulfilled their potential for user support. In particular, contemporary browsers lack proper integration between short term (within a navigation session) and long term (between navigation sessions) support. We propose a new tool (MEMOS) to facilitate navigation, help prevent disorientation and encourage information organization for effective future rediscovery.

The structure of the paper is as follows: A theoretical framework for evaluating Web browser functionality is introduced in section 2. The design principles of a new history tool (MEMOS) is discussed in section 3. Section 4 outlines the experimental studies designed to test the efficiency and effectiveness of the MEMOS tool, and the data analysis is presented in section 5. Finally, our findings and conclusions are summarised in section 6.

2. A Framework for Evaluating Web Browser Functionality

In the World Wide Web information retrieval environment, Web browsers serve as an interface between users and Web information sources. Users strive to accomplish various information retrieval tasks, which are hindered by limitations associated with human information processing and the Web environment itself. The browser should facilitate user tasks by addressing the limitations acting upon the users through its various tools and functions. Design guidelines should be used to develop tools that aim to fulfill the objective of the Web browser, and evaluation of such tools is based on performance measures. Figure 1 shows a generalized overview of the Web information retrieval environment. This provides a framework for understanding and evaluating Web browser functionality.

2.1 The Web

The objective of the Web is to provide information sources. It consists of a very large collection of hypermedia documents stored on Web servers throughout the world in a complex network structure. Although specific Web sites that act as search engines and directories have been developed to help users find information on an extensive number of topics, the Web still presents several limitations that hinder effective searching and navigation.

Limitations associated with the Web environment

In traditional database systems, search is by well defined attributes and searches are

deterministic in nature. Web information is in hypermedia form, which is characterized by an unstructured network representation. Searching for relevant information by using exact key words or phrases through Web search engines is challenging since people tend to use a variety of words to express the same concept, and the same word can be used in an unpredictable variety of contexts. In
addition, an individual may use different words to describe a particular concept at different times. This may make it quite difficult to locate a previously visited page through a Web search engine, particularly after more time has elapsed since its initial access.

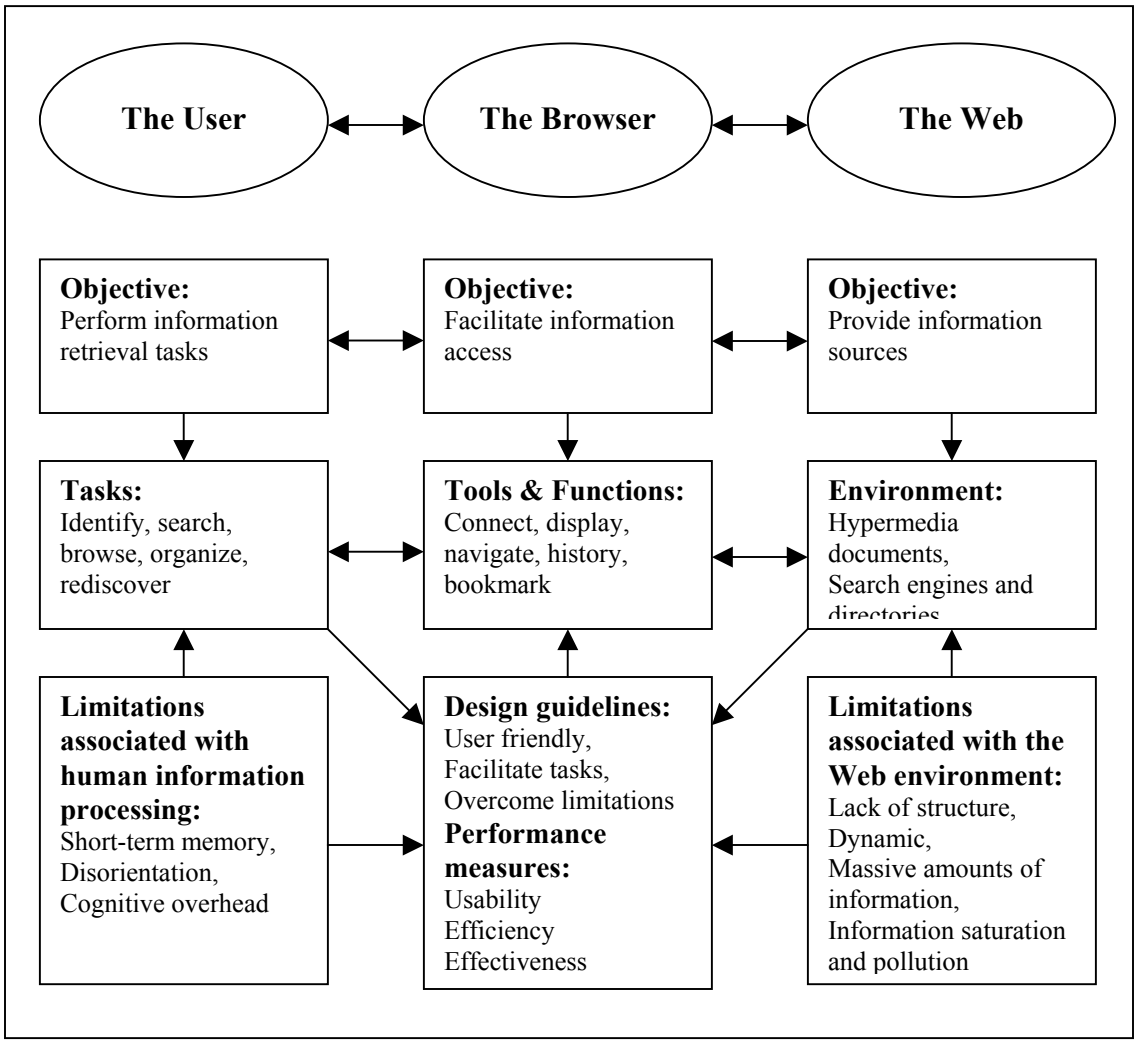

Figure 1 : Web Information Retrieval Framework

The Web is a highly dynamic environment which can not be covered by any single search engine. Although software robots that update Web search engines traverse the Web to keep track of its diverse data, these updates are time consuming and cannot be run on a very frequent basis. No search engine has a complete and up to date index of all available Web pages. It is

virtually impossible for the user to ascertain that he/she has examined all relevant Web information.

Despite the negative consequences of the above limitations, it is the shear volume of information on the Web that most notably hinders its effective information retrieval. The Web provides access to massive amounts of information, and is still growing at a phenomenal rate. When vast quantities of information lead to information overload, the user can no longer comprehend the information due to its sheer volume (Keyes et al. 1989). December (1994) further divides this information overload concept into information saturation and pollution. Information saturation arises when there is so much information that a user cannot adequately compare the value of available information sources on a particular topic. Information pollution occurs when redundant, erroneous, or poorly maintained information obscures high quality or valuable information. Sorting out and deciding what is important (saturation) or correct (pollution) can be a difficult and time consuming task. Although tools such as search engines can assist in initial Web page evaluations, the user must ultimately view the information in order to decide the relevance of Web information sources.

2.2 The User

The Web user needs to perform various information retrieval tasks while coping with limitations associated with human information processing.

Information retrieval tasks

Tasks are actions to fulfill Web user needs, while limitations create barriers to successfully completing these tasks. Shneiderman et al. (1998) proposed a four-phase framework for text searches: formulation, action, review of results, and refinement. Although this framework is specific to textual database searching, its concepts can be applied to a more generalized model of information access. During the formulation phase users must consider their information needs and clarify their goals, at least at a general level. The user explicitly conducts the search during the action phase, and examines the retrieved information to determine its relevance during the review phase. Finally, the results of the review phase are used to refine the "intellectual neighbourhood" (Marchionini 1996) in the refinement phase. Shneiderman et al (1998) recognize that an important aspect of refinement is supporting successive queries. Users should be allowed to review, alter and resubmit earlier searches. Greenberg and Cockburn (1999) state that while it is important to help people navigate within the Web, it is equally important to allow users to return to pages that they have already seen. Tauscher and Greenberg (1997) found that approximately 60% (sd =9%) of all accessed pages have been previously visited. Given the importance of revisiting Web pages, we extend the Shneiderman et al (1998) framework to include organization of information to facilitate future access and rediscovery of previously accessed information. Based on this literature, we propose a new model for Web information retrieval, where the following five tasks are defined :

- *Identify* : Web users must initially identify their information needs ("*formulation*" in the Shneiderman et al. framework, 1998).
- *Search* : Web users need to search for Web sites that may contain relevant information ("*action*" in the Shneiderman et al. framework, 1998).

- *Browse* : Web users need to browse the content of Web sites to determine the relevance and importance of the information in the current context ("*review*" in the Shneiderman et al. framework, 1998).
- *Organize* : Web users need to organize information about Web sites in a meaningful manner for future access.
- *Rediscover* : Web users need to rediscover previously accessed information.

The above tasks, which are shown in Figure 1, often follow the same sequence or iterative cycle. Once information needs are identified, users search for information to meet these needs. This information must be browsed to evaluate its relevance, and relevant information about the source is organized to facilitate future rediscovery.

Limitations associated with human information processing

When detecting new information, humans initially process this information by entering it into short term memory. If the information remains in short-term memory long enough, it may be transferred to a long-term store. Information in long term memory is in a inactive state, and must be retrieved or activated in order to be used. Once activated, the information again becomes part of short term memory (Anderson 1985). However, it is commonly accepted that short term memory has restricted capacity. Miller's work (1956) on chunking and the magic number seven emphasized that people are extremely limited in how much information they can recall. We have a much greater capacity for recognition than for recall. In a Web environment, using recall to rediscover previously accessed information is difficult. Retrieval cues are necessary to facilitate recognition rather than to force limited recall.

Humans do not have the time or the capacity to evaluate all possible Web information sources. As previously mentioned, users may no longer comprehend Web information due to its sheer volume. Other negative consequences of information overload include disorientation and cognitive overhead. Disorientation is the tendency to lose one's sense of location and direction in a nonlinear document (Utting and Yankelovich 1989). This "getting lost in space" problem arises from the need to know where one is in the network, where one came from, and how to get to another place in the network (Balasubramanian 1994). Nielsen (1990*b*) suggests that this is one of the major usability problems with large scale hypermedia environments such as the Web. Human limitations on short-term memory can lead to the following navigation problems:

- arriving at a particular point, and forgetting what was to be done there
- neglecting to return from a digression
- neglecting to pursue a planned digression
- not remembering what has been visited or altered

Cognitive overhead is the additional effort and concentration necessary to maintain several tasks or trails at one time (Utting and Yankelovich 1989). For example, a user examining a particular Web page may notice an outside link that looks interesting. The user must decide if following this link is worth the distraction and time necessary to download the page. If the user decides to view this page, he/she may find another link on this new page that looks interesting. A decision must be made whether to pursue this new material and once again this latest page may lead somewhere else. Cognitive overhead is due to the need to make decisions as to which links

to follow and which to abandon, given a large number of choices (Balasubramanian 1994). After a few "sidetracks", the user may find it difficult to recall the location as well as the content of the pages visited, due to short-term memory limitations. Cognitive burdens also arise when trying to navigate back to a previously visited page (Tauscher 1996). Users taking long sidetracks may not be able to recall the path they took, and become disoriented after losing their sense of location and direction.

Disorientation and cognitive overload are magnified when conceptual and mental models differ. A conceptual model is presented to the user by an outside source, while a mental model is the user's unobservable personal model of the information space (Carmel et al. 1992). Mental models will differ among users and may change over time. When the conceptual model is significantly different than the user's mental model, it becomes difficult to navigate the hypermedia space. For example, a mental model may cause a Web user to expect a particular page sequence when backtracking to a previously visited site. When the Web browser presents a different sequence of pages, the user can become disoriented and have difficulty navigating the hypermedia space.

2.3 The Browser

Users primarily interact with Web information through a Web browser interface. The goal of the browser should be to facilitate the completion of user tasks by addressing the limitations acting upon the user. Currently, Web browsers provide the following basic tools and functions :

- *connect* users to Web information
- *display* Web page content
- allow users to *navigate* among Web pages
- provide a *history* of user navigation
- allow users to *bookmark* Web pages for future access

Design guidelines should be used to develop tools that aim to fulfill the objective of the Web browser interface. Generally, browser tools should be user friendly, facilitate user tasks and help overcome limitations associates with human information processing and the Web environment. Evaluation of such tools is based on performance measures for usability, efficiency and effectiveness. This section examines the capabilities and shortcomings of current browser tools and functions within the context of the user tasks and limitations outlined in our framework.

Identify

Recent versions of popular Web browsers (Netscape's Navigator and Microsoft's Internet Explorer) contain pre-loaded hierarchically organized bookmarks (called "favorites" in Microsoft's Internet Explorer) that allow the user to directly access some popular Web sites. Microsoft's Internet Explorer also contains pre-loaded channels that deliver Web content to the user, similar to subscribing to a popular Web site. A home page, which automatically appears when the browser is loaded, can be set up to display personalized information such as local weather, news, stock prices, etc. For example, Netscape helps users to set up their personalized start page through the "My Netscape" option. These features provide easy and direct access to some basic information sources, and may help general users to identify their information needs. However, most Web users seek more specific information, limiting the usefulness of these pre-

loaded general information links.

Search

Search engines are not a component of the Web browser, however recent browser versions allow the user to quickly link to popular search engines by providing a search icon directly on the main tool or menu bar. Search engines allow the user to enter key words or phrases which are checked against the associated database of Web pages. Although most search engines attempt to display their results in order of decreasing relevance and provide short descriptions for each resulting URL (page address) link, the user must ultimately determine the usefulness of the information by browsing through the individual information sources. Browsers have attempted to facilitate the switching between searching and browsing tasks by allowing the user to toggle between search engine results and Web page display through window partitioning (Microsoft's Internet Explorer) or multiple windows (Netscape's Navigator).

Browse

The most basic function of a Web browser is to display the multimedia and hypermedia content of Web pages for user browsing. Users can easily jump within or between Web pages through hypermedia links. However, this ease of forward navigation can quickly lead to disorientation or a feeling of "getting lost in hyper-space", and result in a heavy memory burden. Browsers can support backward navigation through various history mechanisms, such as "Back" buttons, go lists and history lists. Information is gathered during the browsing task to create a history record, which is used during the rediscovery task to help the Web user to get back to a desired previously accessed page. These mechanisms and their deficiencies are discussed in more detail under the rediscovery task below.

After an initial searching task, users must browse through Web pages to properly assess their relevance in the current context. Browsers offer a "find" function which allows the user to quickly locate a key word or phase within the page. This function may be useful to evaluate the importance of the page if its relevance is not immediately obvious. The desired key word or phase may be located near the bottom of the page within a different context. Unfortunately, current Web browsers do not offer any other mechanisms to help reduce the heavy memory load inherent in most search evaluations. For example, no facilities are provided to allow users to make notes for Web page evaluation and comparison.

Organize

Web browsers provide various levels of information organization support in their history lists and bookmarking mechanisms. Although the information for bookmarks and history lists are both collected during the browsing task, bookmarks differ from history lists in that the user must explicitly specify that a page is to the bookmarked when it is the current document displayed within the browser, whereas history lists are updated automatically. Most browsers offer hierarchical organization options with their bookmarks, which enables users to browse through their personal site repositories more easily. A hierarchical organization that is used to classify different chunks of information according to their similarities or successive detail can be a powerful tool for managing complexity (Ossher, 1987). The potential to reduce complexity with hierarchical organization is particularly evident when data are largely qualitative (Archer et al.

1996). Bookmark hierarchies are user-defined and their structure and content may be modified at any time. A user-defined hierarchy can be an effective means for organization, since the individual explicitly defines the information space to match their personal mental model. Rearrangement or regrouping of sites according to user-defined categories is not possible within current browsers' history lists, which are discussed in more detail in the rediscovery task below.

Bookmarking can be a very useful tool, however, cognitive burdens arise when the user must make a conscious decision to save or not to save each currently displayed page for potential future use. Users may not recognize the relevance or importance of a particular Web page until later, when its connection with something of interest suddenly becomes apparent (Nielsen 1990*a*). At this point the relevant URL address may already be lost from the history stack.

Bookmark lists tend to be smaller and more manageable than inter-sessional history lists. However, users tend to add large numbers of URLs to their bookmark lists due to the difficulty of finding locations on the Web (Nielsen 1990*a*). As the number of bookmarks in a list increases, manual URL classification and organization can become difficult and tedious to maintain. Users may need to classify a large set of URLs at once when merging bookmark hierarchies, consolidating search engine results, or simply integrating URLs that have not been classified at bookmark creation. Classifying bookmarks at this time may prove to be difficult due to list length, duplication, and uninformative page titles.

Rediscover

A user history is a log of the user's past interactions, which is gathered during the browsing task and used during the rediscovery task. History tracking mechanisms provided by Web browsers include the "Back" button, Go List, History List and Bookmarking. Although users may rediscover previously accessed information through the traditional searching and browsing methods outlined above, user histories can be used to greatly simplify this task. Most Web browsers incorporate some history support within navigation sessions (intra-sessional) and between navigation sessions (inter-sessional). Traditional intra-sessional history mechanisms include Backtracking and History Lists. Backtracking allows the user to retrace their navigation path one page at a time, whereas a linear history list lets the user scan for, select and jump directly to the desired page. Recent Web browsers have incorporated inter-sessional support with their history lists by saving user navigation histories over the past few days or weeks. Bookmarking is perhaps the most popular inter-sessional history mechanism provided by Web browsers.

History mechanisms can be very effective tools to facilitate the rediscovery task. Used properly, these mechanisms rely on recognition of previously visited sites rather than recall. However, there are some cognitive issues that are currently limiting their effectiveness. Current Web browsers interpret a user's intra-sessional history of accessed URLs as a push-down stack. Therefore, the history stack is not a true trace of the user's navigation pattern. Depending on how pages are accessed, stacks may lose important information or contain unnecessary duplication. Users may be surprised when pages stored in the history list do not follow their conceptual navigation model, which is a representation of which pages the user has visited and their order of access. A user's conceptual navigation model is important in providing predictive power to help reduce disorientation in complex information structures.

The "Back" button, which has changed little from the version first seen in NCSA's

Mosaic browser, is the predominant history mechanism, accounting for more than 30% of all navigation acts (Tauscher and Greenberg 1997). Apart from the poor mental models people have of its actual behavior (Greenberg and Cockburn 1999), the "Back" button is inefficient in retrieving distant pages (Cockburn and Greenberg 1999). Tauscher and Greenberg (1997) found that there is approximately a 20% chance that the next page visited by a Web user will be more than six pages back from the currently displayed page. While the "Back" button may be appropriate for returning to recently viewed pages, it requires several time consuming button-clicks and page displays to revisit more distant pages.

The history list of Microsoft's Internet Explorer organizes user histories in folders for previous days and weeks, and attempts to group pages visited within a particular site on a particular day. Rearrangement or regrouping of sites into meaningful user-defined hierarchies is not allowed. Netscape Navigator's History Window lists the Web pages visited during the last specified number of days (default history expiration is 9 days). Users may view, sort, and search the list by title, location (URL), first visited, last visited, expiration, and visit count fields. However, like Internet Explorer, users may not edit or modify any of the information, and sites cannot be rearranged or grouped into meaningful topics. History lists can also quickly become very long and unmanageable, especially if one computer and browser is shared by many users, such as in a typical household. List length can be kept under control by decreasing the browser's history expiration option, but this is no help for users who find themselves searching for information that was accessed weeks or months before, not days before.

3. MEMOS : Supporting Web Information Browsing, Organization, and Rediscovery

From the above framework, it is clear that while current Web browsers attempt to facilitate the main user tasks, they do not adequately overcome the limitations associated with the Web environment and with human information processing. Browsers require more useful tools to help reduce the negative consequences of information overload. Memory load is heaviest during the browsing task and mechanisms are needed to facilitate navigation, help prevent disorientation and encourage information organization for effective future rediscovery. Current Web browsers do not gather history information appropriately during the browsing task for effective use during the rediscovery task. Our objective is to design a more useful history mechanism to overcome these deficiencies.

Nielsen (1990*b*) suggests that interaction histories can be used to help users understand and recognize their present location within complex hypermedia structures. Tauscher (1996) agrees that improved history mechanisms can help to minimize Web navigation problems by : a) making it easier to locate information, b) reducing the number of pages being visited overall, c) informing users where they have been and where they are, and d) improving total response time by allowing the user to jump directly to a desired page. Since approximately 60% of all accessed pages are re-visits (Tauscher 1996), history mechanisms can be powerful aids to navigate the Web environment and minimize user disorientation. However, the framework introduced in the previous section outlines several deficiencies and limitations of current Web browser history mechanisms. New tools, that aim to better facilitate information browsing, organization and rediscovery, need to be designed and evaluated. From our framework, the design of such tools should follow guidelines that promote user friendliness, facilitation of tasks and overcoming of limitations associated with human information processing and the Web environment. Tauscher

and Greenberg (1997) propose some specific guidelines for the design of history mechanisms in Web browsers, however have not implemented or verified these guidelines. Our task was to develop a history tool based these guidelines in the context of our framework in order to support user browsing, organization and rediscovery. Through implementation and testing, based on the performance measures specified in our framework, we are able to verify the guidelines developed by Tauscher and Greenberg (1997).

We have developed a history tool called the Memory Extender Mechanism for Online Searching (MEMOS) for Netscape Navigator, using a combination of JavaScript (Netscape Communications) and Java (Sun Microsystems Inc). MEMOS provides memory support within a session and between sessions by providing both intra and inter-sessional navigation information. Users can utilize the intra-sessional history tool to navigate among pages within a particular session, or save and edit all or part of a navigation session for future inter-sessional use. MEMOS was designed to minimize the negative consequences of information overload, and encourage retrieval through recognition rather than the more cognitively demanding recall task. Some of the main features of the MEMOS tool are outlined below, followed by a snapshot of MEMOS during a navigation session in Figure 2. These features are organized by Tauscher and Greenberg's (1997) guidelines, which are quoted in bold. Some differences between the MEMOS tool and existing Web browser history mechanisms are also highlighted. A more detailed description of the MEMOS tool and its development process is provided in Head (1997).

Guideline 1 : "maintain records of URLs visited and allow users to recall previous URLs from those records". Since the majority of Web page accesses are revisits, the primary requirement of any history list tool is to allow the user to view and select items from their list. MEMOS history items appear in descending order of recency since users have a natural tendency to scan lists from the top down.

Guideline 2 : "it should be cheaper, in terms of physical and cognitive activity, for users to recall URLs from a history mechanism than to navigate to them via other methods". If a history tool makes it more difficult to revisit pages than other navigation mechanisms, it will not be used. Physical activity may include clicking a hyperlink or button, opening a menu, selecting a menu item, or issuing a keyboard command. Cognitive activity may include recalling a URL, scanning a history list to recognize a page title, retracing one's steps to a previous URL, or recalling how to navigate to a particular page from the current one. In our design, the MEMOS window occupies less than half the screen, thereby allowing the user to scroll through the history list and view corresponding page content in the main Netscape window (see Figure 2). The user can therefore employ a "trial-and-error" approach if he/she is unsure of the desired page's title or URL by clicking on sample entries in the MEMOS list. This reduces the cognitive burdens of recall and recognition. MEMOS is always visible until the user selects to "Hide" or minimize its window, whereas users must toggle between windows when using Netscape Navigator's history tool.

Guideline 3 : "a selectable history list of the previous 6-10 URLs visited provides a reasonable set of candidates for reuse". MEMOS provides a scrollable recency history list that displays ten history items at one time. MEMOS history list may also be cleared at any time by selecting the "Clear" button. This is useful when users change or modify searching topics. In

Netscape Navigator clearing of the history list is a more cumbersome task, which can be performed through the browser's preference settings, or by explicitly deleting each item within the list.

Guideline 4 : "other strategies for presenting the history list, particularly pruning duplicates and hierarchical structuring, increase the probability of it containing the next URL". Lists may double or triple in size without increasing coverage if duplicates are included. Although by pruning duplicates MEMOS does not preserve true temporal order, this does not increase the difficulty of locating an item on the list. Depending on how Web pages are accessed, the Netscape Navigator push-down history stack may contain much unnecessary duplication.

Guideline 5 : "history based on recency is not effective for all possible recalls because it lists only a few previous events". History lists may also be frequency ordered, where the most revisited page appears at the top of the list and the least visited at the bottom. Frequency ordering is not a good representation of the user's navigation mental model, but it enables easy access to popular sites. Since users may have preferences for different history representations, and preferences may change over time, MEMOS supports both recency and frequency access methods. Access counts are given in brackets beside each entry in the frequency list. The user may jump to any item in either the recency or frequency list (only one item from either list can be selected at one time). Netscape Navigator 4.x provides a "visit count" column in its history list, which gives information on Web page access frequency. However, the user must re-sort the list accordingly when switching between recency and frequency ordering. MEMOS provides both history representations in one view without the need for list re-sorting.

Guideline 6 : "history items should have a meaningful representation". Title tags of pages may be absent or nondescriptive (e.g. "Introduction", "Table of Contents"). In these cases, URLs may convey more information. MEMOS allows the user to easily view and toggle between these page descriptors.

Guideline 7 : "allow end-user customization of history data". The MEMOS tool allows users to change page title descriptions within the history list to give them personalized meaning by clicking on the "Edit" button. A change in one list (recency or frequency) will automatically be reflected in the corresponding site in the other list. Current Web browsers do not allow users to edit or modify any of the information within their history stacks.

The above features proposed by Tauscher and Greenberg (1997) focus on the development of intra-sessional history mechanisms with the purpose of reducing memory load. These guidelines do not consider the need to support users between navigation sessions (inter-sessional). From our framework, outlined in Section 2, we have realized the importance of supporting both intra- and inter-sessional navigation for efficient and effective browsing, organization and rediscovery task fulfilment. We extend the Tauscher and Greenberg (1997) guidelines for the design of history mechanisms in Web browsers to include user support between navigation sessions.

Extended Guideline : history mechanisms should provide support between navigation sessions. An inter-sessional dimension is added to MEMOS that allows the user to save a navigation session by clicking the "Save" button. The user enters a session name under

which the session will be saved and may also include a session description or comments. Unwanted Web subspaces may be removed from the list, and pages may be organized into a three level user-defined hierarchy. Once saved, the session is added to the user's session file for future navigation support. Each user has his/her unique session file, so irrelevant information from multiple computer users is not shown. A sample session file is shown in Figure 3. This interface follows the familiar Windows "File Manager" format with folders and indentation indicating a grouping of lower level sites or hierarchies. Hierarchical abstraction used in this history tool extends previous research by Archer et al. (1996).

4. Experimental Studies

4.1 Hypotheses

Following our analysis of current browser deficiencies, we have developed an intra- and inter-sessional history tool (MEMOS) based on specific design guidelines. Evaluation of the MEMOS tool and verification of the Tauscher and Greenberg (1997) design guidelines is achieved through experiments that gather performance measures for usability, efficiency and effectiveness. The objective of our experiments was to evaluate the performance of the MEMOS tool against standard Netscape Navigator 3.0 history mechanisms under various information retrieval goals:

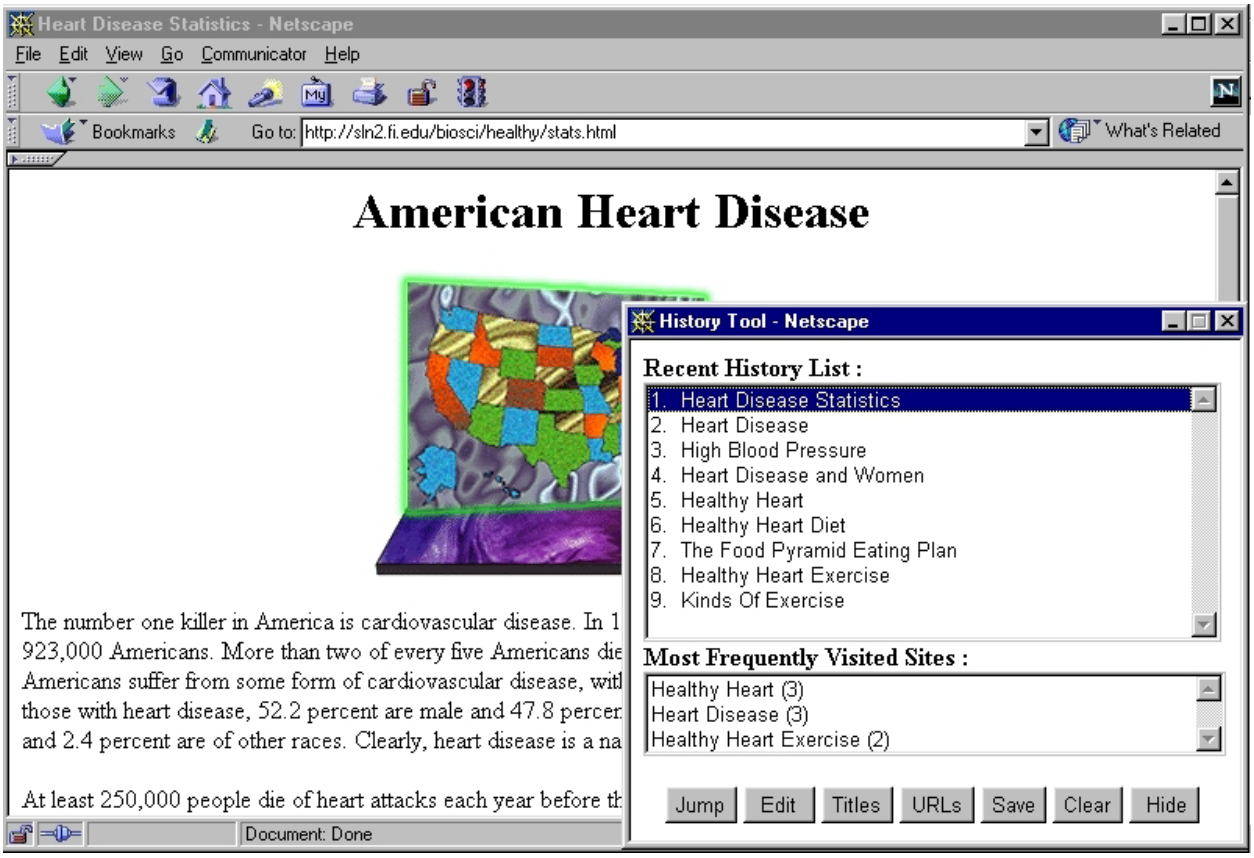

Figure 2 : MEMOS Intra-Sessional History Tool

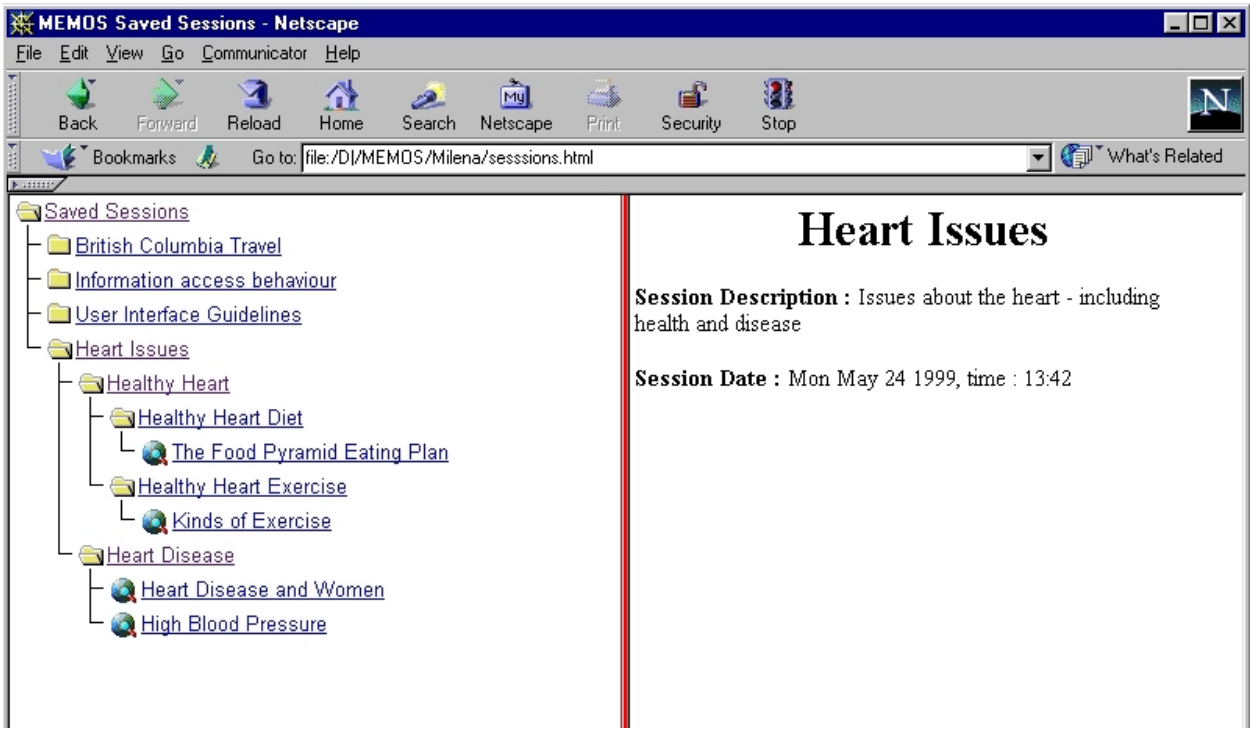

Figure 3 : MEMOS Saved Session File

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Intra-sessional Efficiency

H1 : Intra-sessional Efficiency

From our framework, we realize that cognitive burdens arise when trying to navigate back to a distant page. Users taking long sidetracks may have difficulty recalling the path they took, and become disoriented after losing their sense of location and direction. Although the "Back" button is the most predominantly used navigation tool, it is inefficient in retrieving distant pages. In addition, some pages previously visited during a navigation session, may be unreachable with a stack-based "Back" scheme. Based on the discussion in our framework, we hypothesize that the intra-sessional MEMOS tool, which allows the user to jump directly to a previously visited

page using a complete recency or frequency list, will lead to more efficient specific information retrieval.

Inter-sessional Efficiency and Effectiveness

$H2_A$: Inter-sessional Efficiency

$H2_B$: Inter-sessional Effectiveness

From our framework, we recognize that the Web is a vast hypermedia environment with no comprehensive search facility. Specific information retrieval through a Web search engine is challenging since different people can use a tremendous variety of words to express the same concept, and a particular individual may use different words to describe a particular concept over time. It may be quite difficult for an individual to find a previously accessed page through traditional Web search engines, particularly when more time has elapsed since its initial access. Browsers have responded to this problem by providing bookmarking facilities that allow users to save pages for future retrieval. Unfortunately, as indicated by our framework, bookmarking may often result in unsatisfactory results. Users may neglect to bookmark pages they wish to return to, and bookmark lists may become long and tedious to maintain. The inter-sessional MEMOS tool allows users to automatically save all pages visited during a navigation session and facilitates maintenance by encouraging organization into user defined hierarchies at the end of each session. Therefore, we hypothesize that the use of the inter-sessional MEMOS tool will lead to more efficient and effective specific retrieval.

MEMOS Perceived Ease of Use and Usefulness

H3 : Intra-sessional Perceived Ease of Use

H4 : Intra-sessional Perceived Usefulness

H5 : Inter-sessional Perceived Ease of Use

H6 : Inter-sessional Perceived Usefulness

From our framework, we find that history mechanisms provided by current Web browsers do not adequately fulfil their objectives to facilitate information access by overcoming limitations associated with human information processing and the Web environment. Intra-sesisonal tools, such as stack-based backtracking or lists, may result in unnecessary duplication and loss of information. Cognitive burdens and inefficiencies increase when users must backtrack to revisit a more distant page. Inter-sessional tools, such as bookmarking, are effective only if the user remembers to explicitly bookmark the currently displayed page. Cognitive burdens increase as bookmark lists become longer and more difficult to maintain and organize. Based on the discussion in our framework, we hypothesize that the MEMOS tool will be perceived as being more useful than corresponding browser history mechanisms, since the MEMOS tool provides complete history information. Intra-sessional browser tools lose information through their push-down stacking methods, and inter-sessional browser tools require constant explicit user actions to save history information. We also hypothesize that the MEMOS tool will be perceived as being easier to use than corresponding browser history mechanisms, since the MEMOS tool helps to decrease cognitive burdens. When users wishes to revisit a distant page, the intra-sessional MEMOS tool allows a direct jump to the desired page, or facilitates a more efficient "trial-and-error" approach to rediscovering the page. The ability to change page descriptions within the history list should also facilitate quick recognition and decrease cognitive burden.

The inter-sessional MEMOS tools encourages organization at the end of each navigation session, thereby reducing the cognitive burden of organizing a lengthy list long after its initial access.

Hierarchical Organization Perceived Ease of Use and Usefulness

H7 : Hierarchical Organization Perceived Ease of Use

H8 : Hierarchical Organization Perceived Usefulness

From our framework, we recognize that user-defined hierarchical organization of information can effectively reduce complexity. Current browser intra-sessional history mechanisms do not allow for rearrangement or regrouping of sites according to user-defined categories. Bookmarking mechanisms provide this option, but classification of these lists may prove to be difficult if not classified at bookmark creation, due to list length, duplication, and uninformative page titles. We hypothesize that the ability to organize a saved session in a user-defined hierarchy will be perceived as being easy to use since MEMOS encourages organization at the end of each navigation session, when session content is still fresh in the user's memory. It is also predicted that the ability to organize a saved session in a user-defined hierarchy will be perceived as being useful since hierarchically stored information should facilitate future access.

Intra-sessional Usage

H9 : Intra-sessional Usage

From our framework, we recognize that the potential for intra-sessional support of the MEMOS tool is greatest when the user seeks to rediscover a distant page. Pressing the "Back" button, which is the most predominant navigation act, is effective for retrieving pages that are reachable with only a few clicks. However, pressing the "Back" button becomes time consuming and inefficient when trying to rediscover more distant pages. The results from an initial pilot study suggest that users tend to have longer sidetracks when engaged in a general retrieval (an exploratory session with a general information seeking objective) rather than a specific retrieval (a directed session with a precise information retrieval objective). Our framework indicates that users taking long sidetracks may more easily become disoriented and require appropriate navigation support. Therefore, we hypothesize that the intra-sessional MEMOS tool will be used more often in general retrieval than in specific retrieval, since it is the more appropriate navigation aid to rediscover distant pages.

4.2 Experimental Tasks

Subjects performed various general and specific retrieval tasks during two experimental sessions, spaced approximately one week apart. Two sessions were required to adequately evaluate the MEMOS tool. The MEMOS short-term intra-sessional support could be evaluated within the first session (comparison with the "Back" button, Go List and History List), but a time lag was necessary to assess the long-term inter-sessional support (comparison with bookmarking). During this study, specific retrieval was defined as a closed task, whereas general retrieval was an open task. A closed task has a specific objective that is often decomposed into sub-goals, and an open task has a general objective and is considered more exploratory, vague, and non-specific than a closed tasks. Literature has also used the terms "analytical" (goal directed, systematic and characterized by iterative query reformulations) and "browsing" (heuristic, opportunistic and is characterized by scanning, observing, navigating and monitoring) to classify information

seeking strategies (Liebscher and Marchionini, 1988; Marchionini and Shneiderman, 1988; Marchionini 1998). We followed the general retrieval classification outlined by Cove and Walsh (1988) and Salomon (1990), where a broad goal governs the consulting of sources, and users can reformulate goals in the course of browsing. During specific retrieval, subjects were asked to find answers to precise questions, where a time constraint of 5 minutes was imposed on half of the questions. During general retrieval, subjects were given a broad topic to explore, without any time constraint.

During this experiment, information resources for general and specific retrieval were limited to Web pages. Web pages on two broad topics (health/fitness and British Columbia travel) were downloaded to a local server. Local storage of pages dramatically reduced Web page retrieval times, thereby allowing this variable to be controlled with minimal variance. The AltaVista Personal7 search engine (Digital Equipment Corp. 1997) was installed on the local server to allow keyword searching within the specified set of pages. This search engine's appearance and behaviour was identical to its popular Web counterpart, AltaVista Search7 (http://altavista.digital.com), and a sufficient number of pages (approximately 6,000) were downloaded to give the experimental setting a real "online feel".

4.3 Experimental Design

During the first session of our experiments, a three-by-two unbalanced analysis of variance design with repeated measures was used. The experimental design is shown in Table 1. In this experiment, Factor A represented the information retrieval goals (general retrieval, specific retrieval, and specific retrieval with time constraint levels) and Factor B represented MEMOS availability (navigation with MEMOS and navigation without MEMOS levels). The standard browser history mechanisms were available to the user regardless of MEMOS availability. All subjects were asked to perform a general retrieval session with MEMOS and a general retrieval session without MEMOS. After each general retrieval session, a specific retrieval question was asked which used the same factor level for Factor B (with MEMOS or without MEMOS) but different topic (health/fitness or British Columbia travel) than the previous general retrieval session. Half of the subjects (group 1) performed specific retrieval without a time constraint while MEMOS was available, and with a time constraint while MEMOS was not available. The second half of the subjects (group 2) performed specific retrieval with a time constraint while MEMOS was available, and without a time constraint while MEMOS was not available. Since subjects were not performing sessions for all three information retrieval goals for both levels of the MEMOS availability factor, this was an unbalanced design. This design was chosen to keep the experimental sessions within an average of one hour per subject.

Table 1
Experimental Design for Session 1 of the MEMOS Experiment

	Factor B (MEMOS availability) :	
Factor A (information retrieval goals) :	With MEMOS	Without MEMOS
general retrieval	group 1, group 2	group 1, group 2
specific retrieval	group 1	group 2
specific retrieval with time constraint	group 2	group 1

Subjects were asked to return a week later to perform four specific retrievals, where questions were derived for each subject based on the pages visited by the individual during the first experimental session. A one-factor balanced analysis of variance design with repeated measures was adopted for this part of the experiment, where the applicability of MEMOS was the factor. Two specific retrieval questions were based on previously saved MEMOS sessions, and were not immediately obvious or directly attainable from the pages that were saved during the first session. The subjects were required to search approximately two levels deep from a specified saved page (URL link) in order to obtain the answer. This means that approximately two hyperlinks had to be selected from a saved page to reach the desired pages. Specific retrieval questions that were not based on previously saved MEMOS sessions were based on pages that the subject viewed during a previous general or specific retrieval session but had not saved with the MEMOS tool. These questions were tested and evaluated independently to ensure no bias towards or against the use of the MEMOS tool.

4.4 Subjects

During the full study, a total of 24 subjects performed appropriate general and specific retrievals during their first and second sessions. Subjects were business students from undergraduate and graduate programs. Participation in the experiments was voluntary, and subjects were paid a flat $10 for their time and effort. Subjects estimated that their average level of Web experience was 5.8 on a 7-point scale. Twenty-five percent had used the Web for less than a few months, and 54% had more than one year of Web experience. Two general topics were used throughout the experiments: health/fitness and British Columbia. Subjects estimated that their average level of familiarity (prior to their first session) was 4.5 for health/fitness, and 3.0 for British Columbia, on a 7-point scale (where 1 is not at all familiar and 7 is very familiar with the topic).

During the first session, a brief (approximately 5-10 minutes) Web-based tutorial was provided to familiarize the subjects with traditional browser history mechanisms as well as the new MEMOS tool. This tutorial was followed by a 10 minute demonstration of these mechanisms. Subjects performed a quick navigation session where they tried each of the history mechanisms under the guidance of the experimenter. Features of each tool were reiterated by the experimenter during this demonstration.

5. Data Analysis

A summary table of hypothesis results is shown in Table 2. Hypotheses 1, 2, and 9 were tested by analyzing direct performance measurements collected during the sessions. Hypotheses 1 and 2_A evaluated the specific retrieval efficiency of using the MEMOS tool in comparison with not using the MEMOS tool (for intra- and inter-sessional support). Retrieval efficiency was measured by the time spent to complete the task, the number of pages visited, and the number of pages revisited. Higher efficiency was reflected by shorter task completion time, fewer pages visited and revisited to achieve the retrieval goal. Hypothesis 2_B examined inter-sessional effectiveness, where effectiveness was measured by the ability to find a correct answer to a specific retrieval question. Hypothesis 9 evaluated the intra-sessional usage of the MEMOS tool, where the actual usage (access statistics) of each history mechanism were collected. Recommended techniques for analyzing unbalanced designs (Appelbaum and Cramer 1974), using a regression approach to ANOVA (Neter et al 1985) were followed where applicable in the

analysis of these hypotheses.

Hypotheses 3 to 8 examined user perceptions (perceived ease of use and usefulness), and were tested by analyzing subjective measurements (ordinal data on a 7-point Likert scale) collected from questionnaires. Questionnaires were based on the scales developed by Davis (1989) to measure perceived ease of use and usefulness. Numerous researchers have tested these scales and have shown them to be robust and to exhibit convergent and discriminant validity, internal consistency, replication reliability, and test-retest reliability (Davis 1989; Adams et al. 1992; Hendrickson et al. 1993; Subramanian 1995). However, changes may be necessary to some of the variables, so they are applicable to the given situation (Subramanian 1995). A detailed description of our measurement scales and their derivation is provided in Head (1997). For the perceived ease of use and perceived usefulness constructs used in this study, the Cronbach alphas were .804 and .829 respectively. This reliability defends the use of these literature-supported constructs. Perceived ease of use and usefulness measures used in our 7-point Likert scale questionnaires are summarized in Appendix A. Hypotheses 3 to 6 examined the perceived ease of use and usefulness for the MEMOS tool (for intra- and inter-sessional support) compared to corresponding browser history mechanisms. For these hypotheses, each question was tested using the Wilcoxon Matched-Pairs Signed Rank test. Hypotheses 8 and 9 evaluated the hierarchical option of the MEMOS tool, where questionnaire questions were tested using the one-sample one-tailed Wilcoxon test. We chose nonparametric tests for these hypotheses since these techniques are free of assumptions concerning the underlying population distribution. We had more confidence in these tests than in others that require restrictive and somewhat unrealistic assumptions. An aggregate score was calculated for both perceived ease of use and usefulness scales. The last item of each measure ("easy to use" for perceived ease of use; "useful" for perceived usefulness) was given twice the weighting of other items, since it was an overall scale for the grouping.

Table 2
Hypotheses Summary Results

Hypothesis	**MEMOS Result**
H1 : Intra-sessional Efficiency	- no improved specific retrieval efficiency compared to standard intra-sessional history mechanisms
$H2_A$: Inter-sessional Efficiency	- significant improvement in specific retrieval efficiency over standard inter-sessional history mechanisms
$H2_B$: Inter-sessional Effectiveness	- significant improvement in specific retrieval effectiveness over standard inter-sessional history mechanisms
H3 : Intra-sessional Perceived Ease of Use	- significantly more flexible and less confusing than the Go List, but overall ease of use measure not significant - significantly easier to use than History Window
H4 : Intra-sessional Perceived Usefulness	- significantly more useful than the Go List or History Window
H5 : Inter-sessional Perceived Ease of Use	- significantly more flexible and less confusing than Bookmarks, but overall ease of use measure not significant
H6 : Inter-sessional Perceived Usefulness	- significantly more useful than Bookmarks
H7 : Hierarchical Perceived Ease of Use	- hierarchical organization was significantly easy to use
H8 : Hierarchical Perceived Usefulness	- hierarchical organization was significantly useful
H9 : Intra-sessional Usage	- significant use during general retrieval, not specific retrieval

MEMOS Intra-Sessional Efficiency (Hypothesis 1)

Descriptive statistics for MEMOS intra-sessional efficiency are shown in Table 3. Our findings indicated that the intra-sessional potential for this tool was not realized due to its relative lack of use. The MEMOS tool is not fully integrated into the Netscape interface, and subjects commented that it was "easy to forget that it was there since it wasn't immediately visible in the browser toolbar". Therefore, using MEMOS to navigate within a particular session did not improve specific retrieval efficiency when compared to not using the MEMOS tool (specific retrieval time: $p>0.05$; number of pages visited: $p>0.05$; number of pages revisited: $p>0.05$), and Hypothesis 1 was not supported. Spearman Rank coefficients showed there was no significant correlation between specific retrieval time and topic familiarity ($r_s= -0.12$, $p>0.05$), general retrieval time and topic familiarity ($r_s= 0.12$, $p>0.05$), or previous Web experience and specific retrieval time ($r_s= 0.12$, $p>0.05$) or general retrieval time ($r_s= 0.02$, $p>0.05$).

Table 3
MEMOS Intra-Sessional Efficiency (H1)

	General Retrieval				Specific Retrieval			
	MEMOS available		MEMOS not available		MEMOS available		MEMOS not available	
Performance Measurement	**mean**	**s.d.**	**mean**	**s.d.**	**mean**	**s.d.**	**mean**	**s.d.**
Time (seconds)[b]	727	212	567	293	375	280	301	152
Number of pages visited	36	21	26	14	11	9	10	7
Number of pages revisited	14	11	10	7	5	3	4	3

Notes :

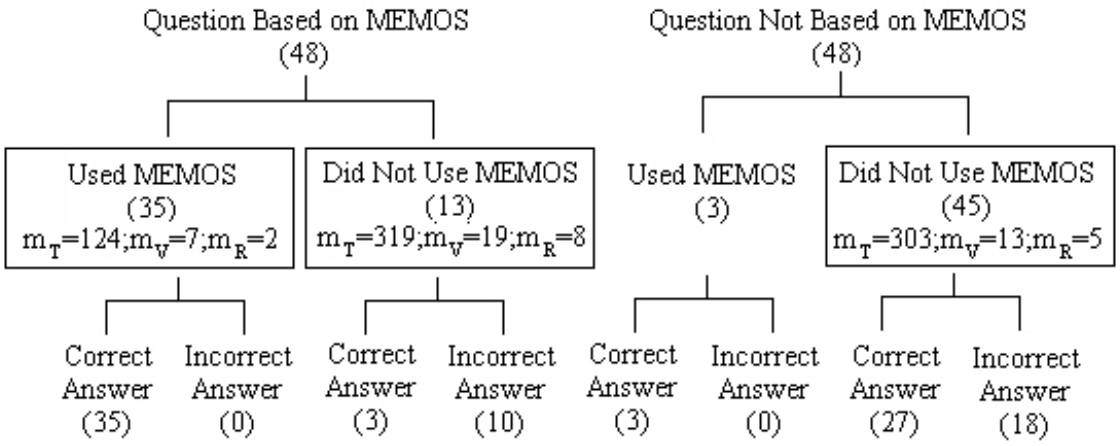
a) mean = estimated sample mean, s.d. = sample standard deviation

b) time is the time taken to accomplish the general or specific information retrieval

MEMOS Inter-Sessional Efficiency and Effectiveness (Hypotheses 2_A, 2_B)

Analysis of inter-sessional efficiency and effectiveness characterized Session 2 questions by the method used for finding their answers (shown in Figure 4). From the 96 questions asked (24 subjects x 4 questions), 35 were answered using the MEMOS tool when the question was based on previously saved sessions. Thirteen questions that were based on saved session were not answered with the help of MEMOS. From the questions that were not based on MEMOS, three managed to find a correct answer through a previously saved session. These cases were considered chance and unintentional results, and were not included in the analysis. Therefore, specific retrieval questions were analyzed according to the following three categories :

- Question based on MEMOS, and MEMOS used to find answer (Based/Used)
- Question based on MEMOS, and MEMOS not used to find answer (Based/Not Used)
- Question not based on MEMOS (Not Based)



Notes :

a) m_T = sample mean of specific retrieval time (seconds), m_V = sample mean of number of pages visited, m_R = sample mean of number of pages revisited

b) sample size is indicated in parentheses (number of cases that fall into the appropriate category)

Figure 4: MEMOS Inter-sessional Efficiency and Effectiveness ($H2_A$, $H2_B$)

A one-factor analysis of variance was performed to test if there was a difference in the specific retrieval time spent among these three categories. The results were significant ($F=12.89$, $p<.001$), indicating a difference among the means (of the time taken to accomplish specific retrievals) for the three categories. Using the Tukey-Cramer method (Neter et al. 1985) to determine which means differed, paired comparisons indicated that the differences between the Based/Used (average time of 124 seconds) and Based/Not Used (average time of 319 seconds) and between Based/Used and Not Based (average time of 303 seconds) was significant ($p<.001$). There was no significant difference in information retrieval time when MEMOS was not used, whether the question was based on a saved session or not. A similar analysis was performed for the total number of pages visited and revisited during specific retrievals. As with information retrieval time, these results illustrated a significant difference ($p<.001$) between the Based/Used and Based/Not Used and between Based/Used and Not Based. Therefore, the use of MEMOS, when answers could be found through a session file, resulted in faster information retrieval times with fewer pages visited and revisited.

In terms of effectiveness, we hypothesized that the MEMOS tool would lead to more effective specific retrieval (measured by the ability to find a correct answer to a specific retrieval question) during the inter-sessional navigation sessions. Figure 4 shows that subjects were able to find correct answers 100% of the time (35 out of 35 cases) when using the MEMOS tool, but only 52% of the time (30 out of 58 cases) when MEMOS was not used. Therefore, effectiveness was significantly improved ($F=31.96$, $p<0.001$) when using a MEMOS saved session to answer specific retrieval questions. Subjects commented that MEMOS is a "great long-term recall tool" that "makes it easier to find specific information in the future".

MEMOS Perceived Ease of Use and Usefulness (Hypotheses 3, 4, 5, 6)

Tables 4 and 5 show the inter-sessional and intra-sessional results from the perceived ease of use and usefulness statistical analysis. Three questions from the questionnaire given in the first

session were used to examine MEMOS intra-sessional perceived ease of use. Respondents agreed that MEMOS provides more flexibility than the browser intra-sessional history tool (Go List), since it allowed the user to jump back from either a recency or frequency list, and offered additional editing, viewing, and saving options. Comments made by subjects also suggested that finding a desired page though the Go List was more confusing than using the MEMOS tool because of unnecessary duplication and loss of information. Specifically, subjects stated that they "did not like the way the browser eliminated entries with back and forth actions", "were confused about how pages were filed within the Go List", and "liked the organized and logical display within MEMOS". However, MEMOS was not shown to be significant on the overall ease of use question when compared to the Go List. Subjects remarked that they often forgot about the MEMOS tool during a navigation session since it was not fully integrated into the Netscape interface. However, the aggregate perceived ease of use measure indicated an overall significant preference ($p<.01$) for the MEMOS tool over the Go List. The MEMOS tool was very significantly preferred ($p<.001$) over the browser's History Window in all ease of use aspects. The History Window had to be activated as a sub-menu in the main menu bar, which was shown to be more inconvenient.

Table 4
Questionnaire Descriptive Statistics (H3, H4, H5, H6)

	INTRA-SESSIONAL									**INTER-SESSIONAL**					
Question[1]	MEMOS			Go List			History Window			MEMOS			Bookmarks		
	m	med	sd	m	med	sd	m	med	sd	m	med	sd	m	med	sd
Perceived Ease of Use:															
Flexible	5.5	6	1	3.1	3	1.7	2.1	2	1.2	5.7	6	1.2	3.6	4	1.5
Confusing	2.3	2	1	3.7	3	2	4.2	4	1.9	2.2	2	0.9	3	3	1.7
Easy to Use	5.5	6	0.9	4.8	5	1.6	3.3	3	1.4	5.7	6	1	5.4	6	1.5
Perceived Usefulness :															
Easy to find desired page	5.8	6	1.1	3.8	4	1.9	2.9	3	1.7	5.9	6	1	4	4	1.8
Fast at finding desired page	5.5	6	1.3	3.8	4	1.9	3.2	3	1.7	5.8	6	1.1	3.9	5	1.8
Effective for general retrieval	5.5	6	1	3.2	3	1.8	2.1	2	1.2	6.2	7	1.1	3.9	4	1.5
Effective for specific retrieval	5.8	6	1.2	3	3	1.6	1.8	2	1	6.2	6	0.9	4.7	5	1.6
Useful	6	6	0.9	3.7	4	2.1	2.4	2	1.4	6.2	6	1	4.4	5	1.6

1. Questionnaire questions asked users to rate the corresponding navigation aids on the degree to which they agreed with the perceived ease of use and usefulness measures. A 7-point Likert scale, which ranged from "strongly disagree" (Likert score = 1) to "strongly agree" (Likert score = 7), was used.

Notes :

a) m = sample mean, med = sample median, sd = sample standard deviation

Table 5
History Tool Perceived Ease of Use and Usefulness Comparison (H3, H4, H5, H6)

	INTRA-SESSIONAL						INTER-SESSIONAL		
Question[1]	Go List vs. MEMOS			History Window vs. MEMOS			Bookmarks vs. MEMOS		
	p	sig.	Pref.	p	sig.	Pref.	p	sig.	Pref.
Perceived Ease of Use (PEOU) :									
Flexible	.000	***	M	.000	***	M	.000	***	M
Confusing	.011	*	M	.001	***	M	.012	*	M
Easy to Use	.051	ns	-	.000	***	M	.352	ns	-
Aggregate PEOU	**.001**	**	**M**	**.000**	***	**M**	**.023**	*	**M**
Perceived Usefulness (PU) :									
Easy to find desired page	.000	***	M	.000	***	M	.001	***	M
Fast at finding desired page	.001	***	M	.000	***	M	.001	***	M
Effective for general retrieval	.000	***	M	.000	***	M	.000	***	M
Effective for specific retrieval	.000	***	M	.000	***	M	.000	***	M
Useful	.000	***	M	.000	***	M	.002	**	M
Aggregate PU	**.000**	***	**M**	**.000**	***	**M**	**.000**	***	**M**

1. Questionnaire questions asked users to rate the corresponding navigation aids on the degree to which they agreed with the perceived ease of use and usefulness measures. A 7-point Likert scale, which ranged from "strongly disagree" (Likert score = 1) to "strongly agree" (Likert score = 7), was used.

Notes :

a) Wilcoxon Matched-Pairs Signed Rank test used for comparison of scores between different history mechanisms to test for significant differences, with the following null and alternate hypotheses :

Null Hypothesis ($H_{0i,j}$) : $M_{i,j} <= 0$ or $M_{i,j} >= 0$, where $M_{i,j}$ is the estimated sample median of the difference in the MEMOS score and the other history mechanism being tested for question j of hypothesis i.

Alternate Hypothesis ($H_{ai,j}$) : either $M_{i,j} > 0$ or $M_{i,j} < 0$, depending on the direction of the question

b) p=significance level, sig. = ns (not significant), * (.05 level), ** (.01 level), *** (.001 level), Pref. = significant preference over the history mechanism pair tested (M=MEMOS, G=Go List, H=History Window, B=Bookmarks)

Results were also mixed for the intra-sessional MEMOS tool. MEMOS was more flexible ($p<0.001$) and less confusing ($p<0.05$) than Netscape's bookmarking mechanism, but saving session histories was generally more time consuming and required more mental and physical effort than typical bookmark saving. A strict comparison of the effort needed to establish bookmarks in a MEMOS format (all relevant pages bookmarked and organized in a separate hierarchy), would undoubtedly reveal more mental and physical effort for bookmark organization. However, the aggregate perceived ease of use measure indicated an overall significant preference (at a .05 level) for the MEMOS tool over bookmarking.

Usefulness was shown to be very significant among all intra- and inter-sessional dimensions ($p<0.01$). We could confidently conclude that MEMOS was perceived to be more useful than the corresponding Netscape history mechanisms for both intra- and inter-sessional support. At the intra-sessional level, comments made by subjects stressed the advantages of MEMOS recency stacking (eliminated duplications and no loss of information), alternative viewing options (recency and frequency lists), and most importantly, the opportunity to save navigation sessions for future use. At the inter-sessional level, subjects generally agreed that

Bookmarks were useful inter-session memory aids for sites that are frequently visited, such as favorite search engine or directory home pages. However, bookmarks failed to give proper support for less popular sites. Subjects agreed that it was virtually impossible to bookmark all potentially relevant pages, since the bookmark list would soon become unmanageable and often the relevance of a site was not evident until later. Bookmarking also allows duplicates, which may lead to confusion when using bookmarks for later retrieval. MEMOS allowed users to save entire navigation sessions under a session name, with user-defined hierarchies. Some subjects remarked that this new method of saving references to Web pages allowed for large numbers of references to be stored without becoming overwhelmed by volume. Specifically, these subjects stated that "bookmarks are only somewhat efficient since it is not likely that you will bookmark every page you see", "MEMOS has a great advantage of automatically recording all accessed pages", and "MEMOS is quicker and more effective than bookmarking for long term research in an area",

Hierarchical Organization Perceived Ease of Use and Usefulness (Hypotheses 7, 8)

Table 6 shows that all perceived ease of use and usefulness measures for the hierarchical organizational option of the MEMOS tool were shown to be very significant ($p<0.001$). The creation of a user-defined hierarchy can require some effort and time. However, once a logical hierarchy is set up, it is significantly easier to use, because it breaks lists into manageable chunks. Subjects commented that "hierarchies certainly make it easier to organize your sessions", the MEMOS hierarchy "makes it much easier to find desired pages" and "helps to alleviate frustration with finding information in a long list".

Table 6
Hierarchical Organization Perceived Ease of Use and Usefulness (H7, H8)

Question	Median	p	sig.
Perceived Ease of Use (PEOU):			
Confusing	2.5	.000	***
Easy to Use	5.5	.000	***
Aggregate PEOU	**4.5**	**.000**	***
Perceived Usefulness (PU):			
Easy to find desired page	6.0	.000	***
Fast at finding desired page	6.0	.000	***
Effective	6.0	.000	***
Useful	6.5	.000	***
Aggregate PU	**6.2**	**.000**	***

Notes :

a) 1-tailed Wilcoxon Signed Rank test used, with the following null and alternate hypotheses :
Null Hypothesis ($H_{0i,j}$) : $M_{i,j} <=4$ or $M_{i,j} >=4$, where $M_{i,j}$ is the estimated sample median of responses to question j of hypothesis i.
Alternate Hypothesis ($H_{ai,j}$) : either $M_{i,j}>4$ or $M_{i,j}<4$, depending on the direction of the question

b) Median = estimated sample median, p=significance level, sig. = ns (not significant), * (.05 level), ** (.01 level), *** (.001 level)

Intra-Sessional Usage (Hypothesis 9)

Hypothesis 9 examined the use of the MEMOS tool under different retrieval goals. Results from

a one-factor analysis of variance showed that MEMOS was used more ($F=4.34$, $p<0.05$) during general retrieval (average number of times MEMOS was accessed = 2.0) than specific retrieval (average number of times MEMOS was accessed = 0.9). During general retrieval, when no precise goals were given, subjects tended to delve more deeply into sites through internal link traversal. A typical general retrieval session would begin with a search engine query with general keywords, from which the search result page was quickly examined. A site located near the top of the search result page would be selected and, given that this page had links to other pages, the subjects would typically spend some time browsing through the site with internal navigation buttons/links. In order to return to a desired previous page, subjects had to click the "Back" button several times or jump directly to the page using a history list mechanism (Go List, History Window, or MEMOS). In most cases, the "Back" button was used instead of the more efficient history lists. When questioned about this behaviour, the common response among subjects who had previous experience with history list mechanisms was that these mechanisms were ignored/forgotten due to poor prior experience with Netscape's Go List and History Window. These subjects had found that it was easier to click the "Back" button several times, and wait for each page in the backtrack to display, than to look through a confusing list of duplicates and missing information to jump directly to a desired page. Subjects who had not used history list mechanisms previously tended to default to their usual "Back" button use. They commented that they "simply forgot history lists were there". Therefore backtracking with the "Back" button was the standard means of retrieving a previously accessed page. The lack of direct integration into the Netscape interface resulted in the relative low use of the intra-sessional MEMOS tool. However, the efficient and effective inter-sessional use of MEMOS also suggests the potential of this tool within navigation sessions. History information is gathered during the browsing stage and used during the rediscovery stage. Since we have shown the usefulness of our history collection method for rediscovery, it can be assumed that this information could also be useful for intra-sessional browsing.

Specific retrieval tended to be characterized by shorter trails than browsing. When the answer to a given question did not seem immediately obvious within a site, subjects tended to return to the search result page to examine another avenue. A one-factor analysis of variance was performed to analyze the proportion of re-visited pages (number of pages re-visited during a task / total number of pages visited during a task) for the three levels of general retrieval, specific retrieval with a time constraint, and specific retrieval without a time constraint. The proportion of re-visited pages was significantly higher ($F=33.15$ $p<0.001$) for the general retrieval session (proportion of re-visited pages = 0.35) than either specific retrieval sessions (proportion of re-visited pages for specific retrieval with a time constraint = 0.17; without a time constraint = 0.2). This result supports the observation of longer navigation trails during general retrieval, therefore requiring more backtracking to return to a desired previous page.

6. Findings and Conclusions

The contribution of this paper is to introduce a framework that outlines the major challenges facing the World Wide Web user, and the role of the Web browser to satisfy these challenges. This framework can help to direct research in this new and unique environment, and can help developers to explore and improve the Web browser interface. As the amount of decentralized and unstructured Web information continues to grow at a phenomenal rate, improved Web

interfaces (browsers) are needed to better satisfy our challenges. In this paper, we specifically illustrate an application of this framework by examining the use of user interaction histories to support the Web user to meet the challenges of browsing, organization and rediscovery.

In the Web environment, effective use of navigation histories can help users navigate the immense and complex Web environment. However, the history mechanisms available in current commercial browsers do not fulfill their potential for user support. Web users tend to waste much time on inefficient browser activities, such as successive backtracking with the Back button. We have successfully developed an advanced history mechanism, MEMOS, which overcomes many of the shortcomings of corresponding browser tools. Through our implementation of this tool, we have validated the Web browser history mechanism design guidelines proposed by Tauscher and Greenberg (1997). We have also extended these guidelines to include a vital link between short and long term memory by incorporating both intra- and inter-sessional support. The intra-sessional component of the MEMOS tool is more flexible and powerful than corresponding Go Lists or History Windows, and is meant to replace these mechanisms. The intra-sessional component of the MEMOS tool effectively allows the Web user to retrieve previously visited sites. It is meant to complement existing bookmarking tools, which are best suited to access sites that visited very frequently. The implication for the hypertext/hypermedia designer is that attention must not only be paid to supporting the user in finding new information, but also in retrieving previously accessed information. Navigation tools should allow users to quickly and easily locate information accessed during the current session, as well as information examined in previous sessions. History tools can be used to facilitate navigation, help prevent user disorientation, and encourage information organization for effective future rediscovery. Because browsers are used so frequently, a relatively simple tool, such as MEMOS, can provide significant benefits for the Web user.

Previously saved sessions are a small subset of Web pages that can be used for future information access. They are likely to be re-used, since the user has already shown an interest in them. In large information spaces, such as the Web, tools that create smaller, more manageable information subsets, can reduce the negative consequences associated with information overload. Reducing information overload can then result in more efficient (faster) and effective (accurate) information retrieval.

We have found that the application of information abstraction through user-defined hierarchies is a preferred means of saving navigation sessions for future use. In the highly cluttered, confusing, and unstructured environment of large hypermedia systems, such as the Web, designers must try to apply tools such as information abstraction to improve the retrieval and organization of information. A benefit of hierarchical directories is that they can add structure to a subset of information from an otherwise unstructured environment, through the application of information abstraction. This is becoming increasingly important as the Web and the number of its users continue to grow at a phenomenal rate. Researchers need to investigate other interface mechanism tools that will add structure to the unstructured Web environment and help to decompose its vast information space into manageable and useful sub-spaces.

We have introduced a framework for the Web navigation environment and primarily focused on the application of user histories within this framework. Our future work will extend our framework to a more sophisticated model of Web navigation, from which we can effectively explore Web usability issues and study other aspects to improve information retrieval. A

comprehensive model that explains the roles of primary participants in the Web information retrieval environment can help us to understand and facilitate user tasks in this exciting yet challenging domain.

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References

Adams, D.A., Nelson, R.R., Todd, P.A. (1992). Perceived Usefulness, Ease of Use, and Usage of Information Technology: A Replication. *MIS Quarterly*, June, 227-247.

Anderson, J.R. (1985). *Cognitive Psychology and Its Implications*, New York: W. H. Freeman and Company.

Appelbaum, M.I., Cramer, E.M. (1974). Some Problems in the Nonorthogonal Analysis of Variance. *Psychol. Bull.*, 81, 335-343.

Archer, N.P., Head, M.M., Yuan, Y. (1996). Patterns in Information Search for Decision Making: The Effects of Information Abstraction. *International Journal of Human Computer Studies*, 45, 599-616.

Balasubramanian, V. (1994). State of the art review on hypermedia issues and applications. <http://www.isg.sfu.ca/~duchier/misc/hypertext_review/index.html>.

Carmel, E., Crawford, S., Chen, H. (1992). Browsing in hypertext : a cognitive study. *IEEE Transactions on Systems, Man, and Cybernetics*, 22(5), September/October.

Cockburn, A., Greenberg, S. (1999). Issues of Page Representation and Organisation in Web Browser's Revisitation Tools. *Proceeding of the OZCHI'99 Australian Conference on Human Computer Interaction*, Wagga Wagga, Australia.

Cove, J.F., Walsh, B.C. (1988). Online Text Retrieval Via Browsing. *Information Processing and Management*, 24, 1, 31-37.

Davis, F.D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, September, 319-318.

December, J. (1994). Challenges for web information providers. *Computer-Mediated Communication Magazine*, 1(6), 8-14, <http://sunsite.unc.edu/cmc/mag/1994/oct/toc.html>

Greenberg, S., Cockburn, A. (1999). Getting Back to Back: Alternate Behaviors for a Web Browser's Back Button. *Proceedings of the 5th Annual Human Factors and the Web Conference*, Gaithersburg, Maryland, USA.

Head, M. (1997). *User Interface Features: Facilitating Information Access and Decision Making*. Ph.D Thesis, School of Business, McMaster University, Hamilton, Ontario, Canada.

Hendrickson, A.R., Massey, P.D., Cronan, T.P. (1993). On the Test-Retest Reliability of Perceived Usefulness and Perceived Ease of Use Scales. *MIS Quarterly*, June, 227-230.

Keyes, E., Sykes, D., Lewis, E. (1989). Technology + design + research = information design. *Text, Context, and Hypertext*, Cambridge, MA: The MIT Press, 251-264.

Liebscher, P., Marchionini, G. (1988). Browse and Analytical Search Strategies in a Full-Text

CD-ROM Encyclopedia. *School Library Media Quarterly*, 7, 223-233.
Marchionini, G. (1996). Resource search and discovery. In: *Getty Art History Information Program (1996) Research Agenda for Networked Cultural Heritage*. Santa Monica, CA: Getty AHIP, 35-40.
Marchionini, G. (1998). *Information Seeking in Electronic Environments (Cambridge Series on Human-Computer Interaction)*, Cambridge University Press.
Marchionini, G., Shneiderman, B. (1988). Finding Facts vs. Browsing Knowledge in Hypertext Systems. *IEEE Computer*, 21, 1, 70-80.
Miller, G.A. (1956). The magical number seven, plus or minus two: some limits of our capacity for information processing. *Psychological Review*, 63, 81-97.
Neter, J., Wasserman, W., Kutner, M.H. (1985). *Applied Linear Statistical Models (2nd ed.)*, Irwin.
Nielsen, J. (1990*a*). *Multimedia and Hypertext: The Internet and Beyond*, Boston, MA.: AP Professional.
Nielsen, J. (1990*b*). The Art of Navigating Through Hypertext. *Communications of the ACM*, 33, 3, 296-310.
Ossher, H.L. (1987). A Mechanism for Specifying the Structure of Large, Layered Systems. in Bruce Shriver & Peter Wegner (Eds.), *Research Directions In Object-Oriented Programming,* Cambridge, MA: MIT Press, 219-252.
Salomon, G., (1990). Designing Casual-Use Hypertext - The CHI 89 Information Booth. *CHI '90 Proceedings: Computer-Human Interface*, 451.
Shneiderman, B., Byrd, D., Croft, W.B. (1998). Sorting out Searching: A User-Interface Framework for Text Searches. *CACM*, 41, 4, 95-98.
Subramanian, G.H. (1995). A Replication of Perceived Usefulness and Perceived Ease of Use Measurement. *Decision Sciences*, 25, 5/6, 863-874.
Tauscher, L.M. (1996). *Evaluating History Mechanisms: An Empirical Study of Reuse Patterns in World Wide Web Navigation*, Masters Thesis, Department of Computer Science, University of Calgary, Alberta, Canada.
Tauscher, L., Greenberg, S. (1997). How People Revisit Web Pages: Empirical Findings and Implications for the Design of History Systems. *Int. J. Human-Computer Studies*, 47, 97-137.
Utting, K., Yankelovich, N. (1989). Context and orientation in hypermedia networks. *ACM Transactions on Information Systems*, 7(1), 58-84.

Appendix A
Perceived Usefulness and Ease of Use Measures Used in the MEMOS Study

This Appendix provides a brief description of our perceived usefulness and ease of use measures used in the MEMOS study. A complete description of their derivation is provided in Head (1997).

Questionnaires used during the experimental sessions were based on current literature. Davis (1989) developed and validated two scales, perceived usefulness and perceived ease of use, for assessing the acceptance of information technology. These scales, which have been shown to exhibit convergent and discriminant validity, internal consistency, replication reliability, and test-retest reliability (Davis 1989; Adams et al. 1992; Hendrickson et al. 1993; Subrmanian 1995), are shown below.

Perceived usefulness and ease of use items (Davis 1989) :

Usefulness	Ease of Use
1. Work More Quickly	1. Easy to Learn
2. Job Performance	2. Controllable
3. Increase Productivity	3. Clear and Understandable
4. Effectiveness	4. Flexible
5. Makes Job Easier	5. Easy to Become Skillful
6. Useful	6. Easy to Use

Researchers recognize that changes may be necessary to some of the variables, so they are applicable to the given situation (Subramanian 1995). In the Web browser history mechanism context, learning was not a relevant issue. These tools simply returned the user to a previously visited page. Since there was very little complexity involved, a beginner should have been, or quickly became, just as proficient with these tools as an expert user. Therefore the construct items "easy to learn" and "easy to become skillful" were not included in our questionnaires. Similarly, the "controllable" item was not included since the tools being evaluated were not complex, and the users did not need to control any aspect of the mechanisms. The Adams et al. (1992) study of electronic and voice mail also did not include this item. The remaining items of "flexibility", "clear & understandable", and "easy to use" were utilized to evaluate the ease of use construct. "Flexibility" was applicable since some history mechanisms gave the user flexibility in viewing options. For example, the History Window allowed users to view both URL addresses and page titles at the same time, and the MEMOS tool allowed users to view their history by recency and frequency. "Clear & understandable" was changed to "confusing" to reverse direction of the evaluation scale. A history list could have been confusing when a desired page was obscured by irrelevant information or duplication. Reversing the direction of an item on the evaluation scale was an effective means of ensuring respondents' attention to their scoring. The "ease of use" item was an overall measure for this construct.

In the Web browser history mechanism context, the perceived usefulness scales "work more quickly" and "increased productivity" are synonymous since productivity refers to a user's

ability to navigate Web pages without having to spend much time backtracking to a desired page. Therefore a history tool's ability to quickly find a desired page increases the productivity of navigation. A "fast at finding desired page" measure was used in the questionnaires to represent "work more quickly" and "increase productivity". Similarly, in the history tool context, "job performance" is closely linked to "makes job easier". The "job" of a history mechanism is to find a desired page, and the performance of this job depended on how easily the desired page can be found. Therefore, an "easy to find desired page" measure was used in the questionnaires to represent "job performance" and "makes job easier". The "useful" item was an overall measure for this construct. The measures adopted for usefulness and ease of use in our experiment are indicated below.

Perceived Usefulness and Ease of Use Measures Used in the MEMOS Study :

Usefulness	Ease of Use
1. Easy to find desired page	1. Flexible
2. Fast at finding desired page	2. Confusing
3. Effective	3. Ease to use
4. Useful	

For the perceived ease of use and perceived usefulness constructs used in this study, the Cronbach alphas were .804 and .829 respectively. This reliability defends the use of these literature-supported constructs.