# USER INTERFACE FEATURES : FACILITATING INFORMATION ACCESS AND DECISION MAKING

By

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# USER INTERFACE FEATURES

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# Abstract

The human computer interface is a vital component of the computer system. and is often seen as the entire system from the user's perspective. A properly designed interface should allow the user to effortlessly access information, which can also facilitate the decision making process. In this study, we develop a research framework to explore specific links between the decision making, information access and user interface domains. We examine three specific interface components (text and voice output modes, information abstraction, and World Wide Web history mechanisms) and their links within our research framework, which can then provide design implications for usable interfaces.

Voice and text output modes were investigated in a multiple alternative decision making task experiment. We were able to conduct a direct comparison between these output modes by presenting the same information for the same length of time for each mode (voice, text, and both voice and text). We found the text mode was the most efficient, resulting in shorter decision times. Both voice and text was preferred to voice alone, but there were no significant differences between text\voice and both\text output mode pairings.

A multiple alternative decision making task experiment was also used to investigate the effects of information abstraction in a hypermedia environment. Each alternative offered three levels of information abstraction, but the information structure was not imposed on the user. We found that a top-down search strategy was directly related to a tendency to use a

compensatory and alternative-wise decision making strategy. We also found that the propensity to use a top-down strategy became less as the search progressed in favour of a more opportunistic approach.

The final interface component investigated was a World Wide Web hypermedia history mechanism. A Memory Extender Mechanism for Online Searching (MEMOS) tool was developed to provide the Web user with intra- and inter-sessional navigation support in parallel with existing browser navigation mechanisms. This tool can be used to navigate among pages within a particular session, or save all or part of a navigation session for future inter-sessional use. Session sites may be saved in a three level user-defined hierarchy, thus making lists more manageable and understandable. We conducted experiments where subjects compared MEMOS with corresponding Netscape 3.0 Web browser history mechanisms. The results of the experiments indicated significant preferences for the MEMOS tool, and significant efficiency and effectiveness measures for MEMOS inter-sessional support. The application of information abstraction to the user-defined hierarchies was also shown to be effective.

From our examination of the above interface components we established specific interactive relationships among the decision making, information access and user interface domains. These relationships contribute to a better understanding of interface components that can be used to develop usable systems. Our framework also suggests possible directions for future research.

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I would like to thank my parents for their understanding and support. This thesis is dedicated to my mother, who unfortunately passed away before I could complete this dissertation, but whose kind encouragement and love will always be cherished.

Finally, I would like to thank my husband, Gord. His constant patience, support, and love gave me strength when I needed it most. This work could not have been possible without him.

**Table of Contents** **Page**

**List of Tables** **Page**

**List of Figures** **Page**

# Chapter One

# Introduction

Computers have become important tools in many disciplines. In the business environment, computers are being used to help decision makers to make operational, tactical, and strategic decisions. But, most notably in the last decade, advances in telecommunications have allowed us to access vast amounts of information from desktops at work or even at home. Regardless of its purpose, every computer must have an interface in order to allow for human computer interaction. This interface is a vital component of the computer system, and is often seen as the entire system from the user's perspective.

The human computer interface can make simple tasks more difficult, and difficult tasks more manageable. A poorly designed interface can hinder decision making or the general information acquisition process, by making it difficult and frustrating to access necessary information, because the focus is on the means (interface) rather than the mission (task). A properly designed interface should allow the user to access information seamlessly in a natural and effortless manner. The interface should be "transparent" to the user, focussing attention on the mission and not the means.

Our research is based on the framework outlined in Figure 1.1. Decision making, information access, and the user interface are three fields that have been examined (often in

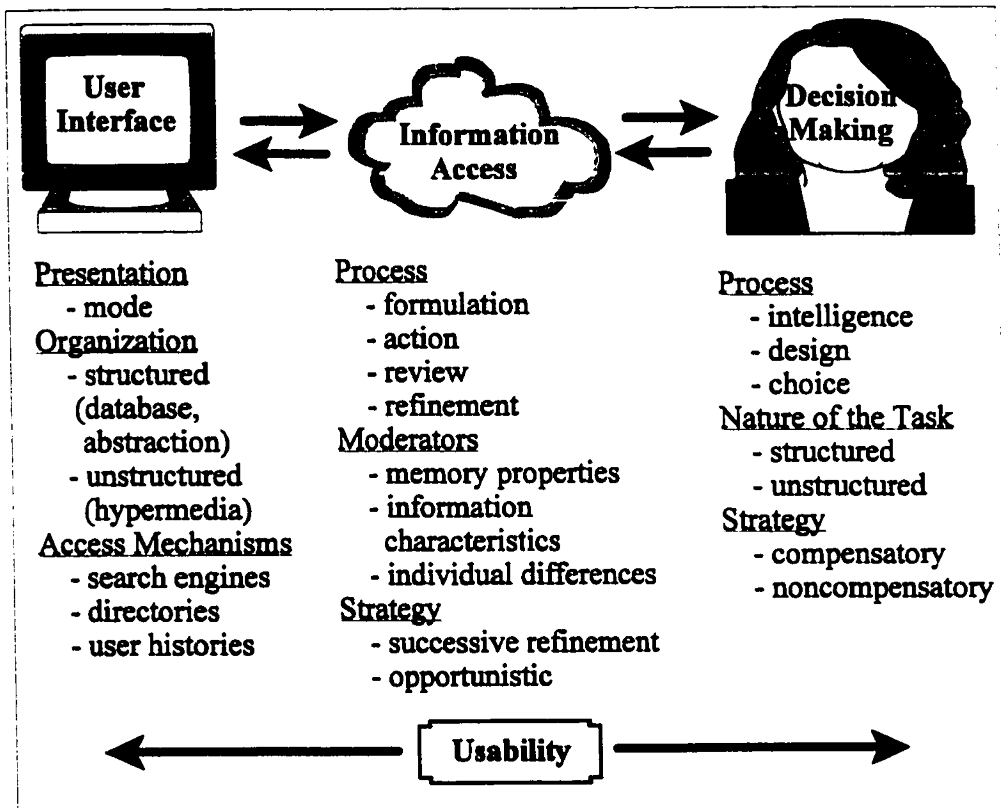


**Figure 1.1**
**Research framework**

isolation) by researchers. Few explicit links or connections have been made across these fields. Our general research objective is to explore some of the relationships among these domains. Such an investigation can help provide design guidelines that will aid the interface designer in developing usable systems that facilitate the information access and decision making process.

Our study begins in the next chapter with a literature review of the four main components outlined in our research framework. First, concepts and studies of decision making are reviewed. Decision making is a complex task that has generated extensive research, but relevant aspects of this field which apply to our research framework only examine very limited elements of this domain. Generally accepted models for the decision making process, nature of the decision task, and multiple-alternative decision strategies are presented. Second, we review information access through its process, moderators and strategy. Moderators, in this context, refers to factors that may influence the information access process and strategies employed (Montazemi and Wang 1989). For example, moderators such as human memory properties that limit the amount of information which can be absorbed at one time, act as a constraint on the information access process when the information space is vast. Third, we examine the user interface along the dimensions of presentation, organization, and mechanisms to support the user in accessing information. Information may be presented in several possible modes (text, voice, image, video, animation, graphical or tabular data) and arranged in a structured or unstructured organization. Traditional database systems and organization by information abstraction are two common structured formats. Hypermedia environments are a contemporary, unstructured approach to organizing information, which use mechanisms such as search engines, directories, and user histories to support the user during information access. The flexibility of hypermedia environments allows users to explore topics in multiple ways, and select the information structures they need. Last, we review interface usability, which determines how easy, efficient, memorable, error free and pleasant the system is to use. The more usable the interface is to the user, the more attractive the system, and the more likely that it will be used. Although usability is regarded as a user interface measure, it has an impact on information access and decision making dimensions. Usability can facilitate information access by presenting information in a manner that minimizes constraining moderators such as memory limitations and information overload, and can facilitate decision making by applying some information structure to an unstructured environment.

Our review found that the current literature does not tend to identify explicit links between related fields such as decision making, information access, and user interface. From a user interface perspective, the literature recognizes that characteristics of information presentation and organization can potentially impact the decision or information acquisition task, but empirical research needs to focus on the effects of specific components in this environment. Investigation of these components across our research framework helps to provide a better understanding of the relationships between the decision making, information access, and user interface domains.

In this research, we investigate the effect of three specific user interface components on information access and decision making processes and strategies. We first examine the interface presentation component of text and voice output mode. To study one aspect of output mode, we developed a multiple alternative experimental interface that presented information in text, voice, and both text and voice output modes. A direct comparison was possible since the same information was presented with each interface mode. This experimental interface also presented information at three different levels of abstraction: overall, general, and specific. Using this interface, we examined the effects of an interface organization component: information abstraction. We observed patterns in information search where an information structure was not imposed, thus displaying natural tendencies of users to use information abstraction.

The concept of information abstraction was then extended to the large, distributed, hypermedia system of the World Wide Web. Users navigate the Web information space by selecting hypermedia links that contain addresses to other Web pages. Web navigation is a recurrent task, since 58% of all accessed Web pages are revisits (Tauscher 1996a). Therefore, user histories can very helpful in supporting the Web user during the information navigation task. Web history mechanisms were the third interface component we investigated. Information abstraction can be used to automatically display a user's history of accessed Web pages through tools such as overview diagrams. Unfortunately, the vast, decentralized and unstructured nature of Web data makes the automatic hierarchical organization of relevant information available in Web pages very difficult. We developed and tested an advanced Web history mechanism that provides support during and between navigation sessions. Building on experience we gained with our interface organization component (information abstraction), users were given the option to save their navigation sessions in user-defined hierarchies. Effectiveness and efficiency of this tool was compared with standard Netscape 3.0 history mechanisms in a laboratory test environment.

This thesis is organized as follows. Chapter two reviews the related concepts and studies, organized by our research framework (Figure 1.1), leading to the questions and goals for this research. These research goals identify the links between the literature review and our research in the chapters that follow. Chapters three and four investigate the presentation and organization interface components of text and voice output modes and information abstraction. These chapters are based on our empirical findings from experiments conducted in a multiple alternative decision making task. This research has been published in Archer et al. (1996a) and Archer et al. (1996b) respectively[1].

Chapter five applies our investigation of interface components to the World Wide Web, where the history mechanism support tool is discussed. Existing history tools are examined, and the advanced history tool that we developed is presented. This tool incorporates an information abstraction component by allowing user-defined hierarchies of Web navigation pages. Empirical investigation of Web navigation and history mechanism support tools is presented in Chapter six. Chapter seven includes a final summary of findings and conclusions, and suggests directions for future research.

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# Chapter Two

# Review of Related Literature

This chapter examines some of the literature which relates to our research framework outlined in Chapter One. The four areas presented in the framework, and discussed in this chapter are : (i) decision making (process, nature of the task, and strategy components); (ii) information access (process, moderators, and strategy components); (iii) user interface (presentation, organization, and access mechanism components); and (iv) usability.

## 2.1 Decision Making

Decision making is a complex process which has generated an extensive field of research. This research has provided several insights into this fundamental human task, through the use of theoretical models and empirical investigation. From our research framework outlined in Chapter One, we are concerned with a limited segment of decision making research. The general decision making process, nature of the decision task, and decision strategies are components of our research framework and are outlined in this section. This is not meant to be a comprehensive investigation into decision making research, but rather an overview of generally accepted models in a very limited segment of research.

### 2.1.1 Decision Making Process

The most well known and generally accepted model of the decision making process was presented by Simon (1960). This is a simple model that has been the basis of most contemporary approaches. Simon (1960) conceptualized three major phases in the decision making process:

- *Intelligence Activity* : This phase consists of searching the environment for conditions calling for decision making.
- *Design Activity* : Inventing, developing, and analyzing possible courses of action takes place during this phase.
- *Choice Activity* : The final phase is the actual choice, where a particular course of action from among those available is selected.

The intelligence activity generally precedes design, and the design activity generally precedes choice. Each phase can be quite complex, consisting of iterative decision making sub-processes. For example, the design phase may call for its own intelligence activity. Problems at any given level can generate subproblems that, in turn, have their own intelligence, design and choice activities. In addition, at any phase the decision maker may return to a previous phase. For example, a decision maker in the choice phase may reject all alternatives and return to the design phase in order to generate additional alternatives (Davis and Olson 1985). A flowchart of the decision process is presented in Figure 2.1.

Some models of decision making go beyond Simon's (1960) choice phase by including a separate implementation and feedback component. Although Simon's (1960) third phase includes implementation, many authors feel it is significant enough to be shown

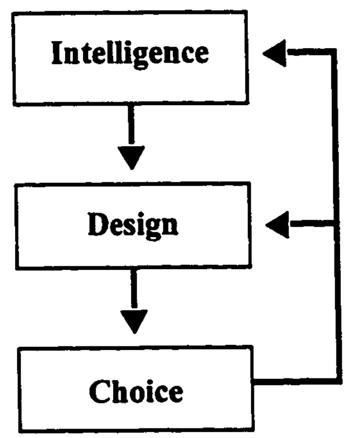


**Figure 2.1**
**The decision making process**

separately (Sprague 1989). For example, Rubenstein and Haberstroh (1965) proposed the following steps in the decision making process :

1. Recognition of problem or need for decision
2. Analysis and statement of alternatives
3. Choice among alternatives
4. Communication and implementation of decision
5. Follow-up and feedback of results of decisions

How people search through and combine information before reaching a final decision has become an important area of research, with implications for other domains, such as the human computer interface. Information systems can be and have been used in all three phases of the decision making process (Turban, 1995). Zmud (1983) stresses that a decision support system should capture and reflect the way decision makers think and support multiple decision processes and styles. To meet these guidelines, it is necessary to understand the nature of decision making tasks and the types of strategies employed during the decision making process.

### 2.1.2 Nature of the Decision Task

Simon's (1960) extensive work in the field of decision making has also introduced the distinction between programmed and nonprogrammed decisions. Programmed decisions are repetitive and routine, to the extent that a definite procedure can be applied to solve it. Nonprogrammed decisions are novel and unstructured. There are no definite procedures that can be applied to solve the problem, since it has not arisen before, its precise nature and structure are elusive or complex, or it is so important that it deserves a custom-tailored treatment (Simon 1960). Programmed and nonprogrammed decisions are two extremes on a spectrum or continuum of decision making tasks. Soelberg (1967) suggested that a decision maker in solving an nonprogrammed decision task tends to demonstrate the following characteristics:

- difficulty in specifying the nature of an ideal solution when starting the task
- few special-purpose rules applied when arriving at a choice
- a number of the decision criteria applied are not operational before starting the task
- many of the choice alternatives are unknown before starting the task
- information about the alternatives' consequences and relative worth is not immediately available from the task environment

Gorry and Scott Morton (1971) introduced the terms "structured" and "unstructured" for programmed and nonprogrammed decision tasks. These terms have been used most commonly in subsequent literature. As with the Simon (1960) model, decisions can be classified along a continuum where structured and unstructured tasks represent the end-points of this spectrum. A structured decision should have a fixed number of decision steps, all of which need to be taken in the right order which remains fixed across time and between decision makers. An unstructured decision has a variable number of decision steps, not all of which may be taken in arriving at a decision, and whose order may vary among decision instances and between decision makers. Gorry and Scott Morton (1971) stress that while highly structured decisions may be automated, unstructured tasks require individual judgement and evaluation as well as insights into problem definition.

Relating the nature of decision tasks back to Simon's (1960) model of the decision making process, Gorry and Scott Morton (1971) identify a fully structured problem as one in which all three phases (intelligence, design, and choice) are structured. Algorithms or decision rules can be designed that will allow the decision maker to find the problem, design the alternative solutions, and select the best solution. An unstructured problem task is one in which none of the three phases is structured. Semi-structured decisions, which fall between these two extremes on the nature of decision task continuum, have one or two of the intelligence, design, and choice phases unstructured.

### 2.1.3 Decision Making Strategy

Research in multiple alternative decision making involves the investigation of user retrieval and assimilation of data organized by attributes among alternatives. This can be referred to as an alternative × attribute matrix, where alternatives usually constitute the columns while attributes (or dimensions) constitute the rows of the matrix. Although the attribute × alternative decision matrix only represents a focussed subsection of decision making environments, our research framework, outlined in Chapter One, narrows this discussion to the multiple alternative decision context. An empirical method used to analyze decision making in this setting is process tracing. The following discussion first identifies decision making strategies used in multiple alternative environments. Process tracing techniques are presented, and then major determinants of decision strategy use are examined.

### *Decision Strategies*

In the evaluation of multiple alternatives, decision strategies are often classified as being either compensatory or noncompensatory. A compensatory strategy involves combining all available relevant information to form an overall evaluation, implying a complete examination of available information (Cook 1993). These models are called compensatory, since a high value on one dimension "compensates" or counteracts a low value on another dimension within the same alternative. Compensatory decision strategies refer to either of the following models (Ford et al. 1989, Sundström 1987) :

- ***Linear Model*** : This model assumes that each dimension for a decision alternative is given a value and the dimensions are combined additively to produce an overall value for each alternative. Comparisons among alternatives are based on this overall value, and the alternative with the highest value is selected. Application of this model is inferred when a decision maker displays a uniform pattern of inter-dimensional search. In other words, and equal number of dimensions are considered for each alternative and alternatives are evaluated sequentially.

- ***Additive Difference Model*** : This model assumes that alternatives are compared on each dimension by computing the difference between alternatives on each dimension and then summing these differences across dimensions. The sum of these differences results in a preference for a particular alternative. Application of this model is inferred when a decision maker considers an equal number of dimensions for each alternative and information is searched for intra-dimentionally.

In noncompensatory models, a low score in one dimension cannot be "compensated" for by a high score in another dimension which is within the same alternative. Noncompensatory decision strategies involve various simplifying heuristics or rules for evaluating and combining information. This reduces the complexity of the decision problem. If the number of different dimensions examined by the decision maker within alternatives differs, the use of a noncompensatory rule is inferred. Four major noncompensatory models are defined (Cook 1993; Einhorn 1970; Einhorn 1971; Ford et al. 1989, Sundström 1987):

- ***Conjunctive Model*** : Decision makers using this model establish a minimum criterion for each dimension and then reject alternatives which do not meet this minimum standard for each dimension. This implies a multiple cutoff procedure. The amount of information examined for different alternatives varies, and the search strategy is inter-dimensional.

- ***Disjunctive Model*** : A selected alternative must exceed the minimum criterion on at least one dimension, with the other alternatives being equal or less than the criterion on different dimensions. In other words, an alternative is judged on its best attribute(s) regardless of its other attributes. Therefore, the basic idea of the disjunctive strategy is to quickly find an acceptable alternative, rather than eliminating unacceptable alternatives.

- ***Lexicographic Model*** : This model involves the ordering of dimensions according to their importance. A decision is made on the basis of the more important dimension. If more than one alternative are equally as attractive based on this dimension, a comparison of these alternatives is made on the next most important dimension. Use of this strategy implies an intra-dimensional search. Since alternatives are successively eliminated, the proportion of information explored varies across alternatives.

- ***Elimination by Aspect Model*** : As with the lexicographic model, this model first involves the ordering of dimensions according to their importance. The most important dimension is examined first. Those alternatives that do not meet the predetermined criterion are eliminated from consideration. The

> remaining alternatives are then examined with respect to the next most important dimension. As with lexicographic models, use of this strategy implies intra-dimensional search, and the proportion of information examined varies across alternatives.

Noncompensatory strategies are less cognitively demanding and sophisticated than compensatory strategies. Noncompensatory strategies may also result in different decisions than when compensatory strategies are used. This may be due to order effects, available information that is not used, or inconsistencies in preferences (Einhorn 1971). Therefore, the decision maker is faced with a tradeoff between reduced cognitive effort and a potentially less than optimal decision.

### *Process Tracing Techniques*

It is generally believed that human decision making cannot be understood by only examining the final decision obtained through the process. Process tracing techniques are aimed at directly assessing what information is processed to form a decision and the order in which the information is accessed. The information obtained from process tracing is used to make inferences about the decision making strategies employed in arriving at a final decision.

Process tracing was first introduced as a critical evaluation tool to decision making with information boards (Payne 1976). Previous reviews of process modelling and process tracing techniques focussed on describing, rather than evaluating, the utility of research being conducted (Ford et al. 1989). Generally, information boards display information in an alternative × attribute matrix. Payne's (1976) information board consisted of a sheet of cardboard with attached envelopes that contained cards with the name of the dimension on one side and relevant information on the other. Therefore, in order to examine the information for a particular dimension, subjects had to first remove the card from the envelope and then turn the card around. Decision makers were instructed to use as much information as they need to make a decision. Common experimental manipulations are variation in the number of alternatives and attributes, and changes in the design of the information display board (Sundström 1987). A criticism of this approach is that there is considerable time and effort required to examine information, and therefore the information searched may not represent the true reactivity of the subject. Another problem with this approach is that the setting and presentation of information is artificial, and does not resemble the "real world" business decision making setting.

A second process tracing method is the use of verbal protocols. Verbal protocol analysis requires that the decision maker "think aloud" (describe what they are thinking or doing) while evaluating the information and making a decision. Experimenters then attempt to code the verbal statements. This "thinking aloud" may affect the performance of the decision maker, and coding of verbal statements may be difficult.

Recording of eye movements is a third process tracing technique. The problem with this approach is that for large number of data items, the recordings are too imprecise to interpret accurately (Cook 1993). Therefore, this method is restricted to a limited set of tasks and problem situations.

A fourth process tracing technique can be considered an extension of the information board. Due to the shortcoming of the above mentioned process tracing methods, researchers are beginning to use interactive microcomputer systems as experimental tools. This computerized approach involves the development of a program which can be used to display an alternative × attribute information matrix on a computer terminal or screen. This setting more closely resembles how information might be used in an actual computer supported environment.

A central aspect of analysis in most process tracing studies is the sequence in which information is examined during the decision making process. If the *n*th+1 item search is of the same alternative as the *n*th item searched, the transition is considered inter-dimensional (inter). However, if the *n*th+1 item searched is of the same dimension as the *n*th item searched the transition is considered intra-dimensional (intra). Figure 2.2 illustrates intra- and inter-dimensional transitions in a simple two-alternative example. A measure of the direction of search is defined as (inter-intra)/(inter+intra), where inter and intra are the number of inter-dimensional and intra-dimensional transitions respectively. A negative direction indicates the search is organized more by dimension, and a positive direction indicates the search is organized more by alternatives. Proportion of information searched, and variability in proportion of information searched across alternatives and across dimensions are also often measured. A low proportion of information searched and high variability indicates the use of a noncompensatory decision strategy, while a high proportion of information searched and a low variability indicates the use of a compensatory decision strategy.

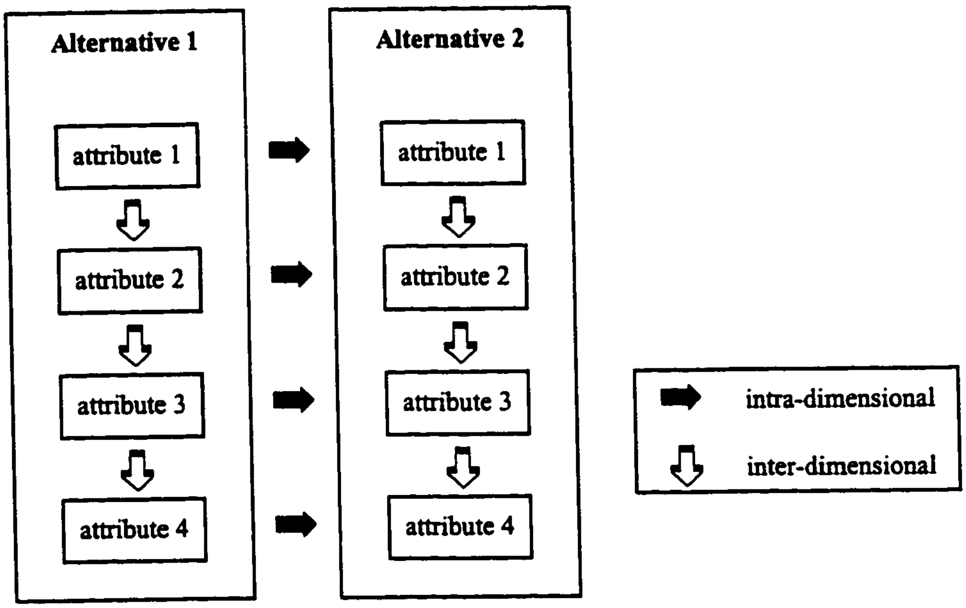


**Figure 2.2**
**Intra- and inter-dimensional search transitions**

## *Major Determinants of Decision Strategy Use*

Task complexity can be manipulated through information load or time constraints. Increasing task complexity through information load is performed by increasing the number of alternatives, dimensions, or both. Wright (1974) also suggests that complexity can be varied by changing the time available to make a decision. Task complexity is the major determinant of decision strategy use and is discussed below in terms of information load and time constraints. This sub-section concludes by examining the quality/effort trade-off made during the decision making process. This trade-off helps to explain why task complexity is a major determinant of decision strategy use. Other possible determinants, such as cognitive style and user experience, are discussed in Section 2.2.2.

## Information Load

Empirical studies have shown that decision strategies are sensitive to the number of alternatives presented (Payne 1976; Olshavsky 1979). Shifting from an inter-dimensional search strategy to an intra-dimensional search strategy or vice versa does not apparently help decision makers deal with an increased number of alternatives (Billings and Marcus 1983; Bockenhold et al 1991). Rosen and Rosenkotter (1976) found that alternative-wise and attribute-wise searching may occur as a function of the relationships that exist between attributes. In other words, independent attributes led to an attribute-wise processing, whereas dependent attributes led to an alternative-wise processing mode. Bockenhold et al (1991) also found that subjects tended to employ selective information processing, rather than examining all attributes of alternatives, and that decision makers did not always look at the same dimensions, implying a tendency to the less cognitively demanding noncompensatory search strategy. When a subject is faced with a moderate to a large number of alternatives, this noncompensatory search strategy is generally used to quickly eliminate alternatives until a most attractive alternative or more than one equally attractive alternatives remain. However, it appears that more information is needed when alternatives seem equally attractive, implying a shift to a more compensatory search strategy. Bettman and Park (1980) support this finding through their discovery that strategies changed from noncompensatory to compensatory as alternatives were eliminated from consideration.

Studies by Hendrick et al. (1968), Einhorn (1971), Jacoby et al. (1974), and Slovic and Lichtenstein (1971) have shown that increasing the number of attributes per alternative has the effect of a) increasing the variability of responses, b) decreasing the quality of choices, and c) increasing decision makers' confidence in their judgments. However, increasing the number of dimensions was not found to have a significant effect on underlying decision strategies in a study performed by Payne (1976).

Generally, increasing task complexity through information load leads to (1) decreases in the proportion of information searched, (2) increases in the variability of search patterns, and (3) decreases in mean search time (Ford et al. 1989). Since noncompensatory search strategies are characterized by a lower proportion of information searched and higher variability, empirical findings suggest that decision makers shift to a more noncompensatory search strategy as task complexity increases. This effect is more predominant when increasing the number of alternatives compared to increasing the number of attributes per alternative. This finding has been verified with different types of samples, different types of tasks, and different process tracing techniques (Ford et al. 1989).

## Time Constraints

Empirical studies on time pressure tend to incorporate two time pressure levels. Low time pressure groups are not given any time constraints or are given a time limit that is considered sufficient. High time pressure groups are generally given one-half or less of the amount of time considered sufficient (Benbasat and Dexter 1986).

Substantial research suggests that, when decision makers are under time pressure, they process information more selectively (Wright 1974, Ben Zur and Breznitz 1981, Svenson and Edland 1987, Verplanken and Weenig 1993) and use less complex decision strategies (Christensen-Szalanski 1980, Payne et al. 1988). Miller (1960) proposed that there are three major ways of coping with unavoidable and time pressured situations. The first method is *acceleration*, where the decision maker processes the same amount of information but at a faster rate. In this case the feeling of time pressure may lead to psychological and somatic (bodily) reactions in the individual. Errors may occur due to the temporary overload of memory or processing capacity. A second method of coping with time pressure is *avoidance*, where the decision maker examines information as he/she would in a non-pressured situation and simply stops the processing when time has run out. Response will be based on the state of the process when interrupted. This tactic may result in random choices or in choosing according to a momentary stand-out feature. Lastly, Miller (1960) suggested that a decision maker may cope with time pressure by *filtration*. Here, the decision maker chooses to examine only the subjectively important data for consideration. Therefore the cognitive process is altered as a result of the time pressure.

Wright (1974) found that a decision maker under time constraints would try to simplify the task by placing greater weight on negative attribute information. Results from Ben Zur and Breznitz (1981) also suggest that under high time pressure decision makers made less risky choices and spent more time examining negative dimensions. They suggest that time pressure is a stressful condition, and the threat of a negative consequence induces further apprehension and stress. By making less risky choices, the decision maker is lowering feelings of apprehension, thereby establishing feelings of safely under time stress. Svenson and Edland (1987) confirmed that under high time pressure: a) decision makers became more influenced by negative aspects on the most important attribute; b) initially less important attributes were given even smaller importance; c) increased importance was given to the already initially most important attribute.

Studies outlined in Ford et al. (1989) suggest that time pressures influence subjects to examine fewer pieces of information, and to process information faster with processing becoming more attribute based. However, Verplanken and Weenig (1993) found that there was no difference between time pressure conditions in the amount of information inspected. Subjects under time pressures simply worked faster. Most studies tend to agree that variability of amount of information searched across alternatives is larger under time pressure than without time pressure. Verplanken and Weenig (1993) imply that, although time pressured subjects inspected the same amount of information as unpressured subjects, under time pressure attention was more unequally distributed across the alternatives. Since noncompensatory decision strategies are characterized by higher variability in the number of dimensions examined within alternatives, imposing a time constraint leads to a more noncompensatory search strategy.

## Quality/Effort Trade-Off

An important aspect of the human mind is its limited capacity to process information. In treating information like any other commodity, the economic theory suggests that rational decision makers will gather/examine information up to the point where marginal cost exceeds the marginal benefit derived from additional information (Maute and Forrester Jr. 1991). According to the cost-benefit framework, decision makers try to satisfy the joint objectives of maximum accuracy and minimum effort. Since these objectives often conflict, trade-offs must be made. Payne (1982) proposed that decision makers focus on trade-offs between quality and effort in decision making, and this trade-off is a factor affecting the selection of decision strategy. This notion was supported through subsequent empirical studies (Johnson & Payne 1985, Jarvenpaa 1989). As task complexity increases, the required effort also increases. Decision makers then trade-off the accuracy of compensatory strategies, for the less demanding noncompensatory strategies.

Simulation and conceptual literature also indicate that cognitive effort is an important determinant to decision strategy selection. Monte-Carlo simulations of decision strategies have shown that heuristic strategies, which substantially reduce effort compared to normative procedures, can also be highly accurate (Johnson and Payne 1985). Conceptual models of Beach and Mitchell (1978) and Shugan (1979) agree that decision makers try to minimize effort. However, Einhorn and Hogarth (1978) suggest that effort may be a more important factor than accuracy, since feedback on effort is relatively immediate whereas feedback on accuracy is subject to delay and ambiguity. In a study performed by Todd and Benbasat (1993), it was found that the amount of information processed did not increase with the use of a decision aid. The aid was used to reduce the amount of effort required to complete the task, not necessarily to improve decision making quality. Since decision makers tend to prefer decision making strategies that require a lower expenditure of effort, Todd and Benbasat (1993) suggest system design approaches should be used that provide tools to minimize the effort required to use more desirable strategies.

### *Summary*

Decision making is a very complex task that has generated extensive research. Our research framework, outlined in Chapter One, addresses only a narrow aspect within decision making research: the decision making process, nature of the decision task, and multiple-alternative decision strategies.

The decision making process consists of three major phases: intelligence, design and choice activities. This model, conceptualized by Simon (1960) is generally accepted and has been the basis for most contemporary approaches. A structured decision task can follow a definite procedure and may be automated, whereas an unstructured decision task requires individual judgement and evaluation. The nature of many decision tasks is a combination of these two extremes, where one or two of the intelligence, design and choice phases are unstructured.

Next, we examined a limited area of decision making where a choice must be made among multiple given alternatives. Here we distinguished between compensatory and noncompensatory search strategies. Each of these general search strategies can be further divided into specific models. Compensatory search strategies refer to the linear or additive difference models, and noncompensatory search strategies refer to the conjunctive, disjunctive, lexicographic, and elimination by aspect models. The majority of process tracing studies are aimed at identifying the search strategy employed, through manipulation of various independent variables. Task complexity has been found to be the major determinant of decision strategy use. As task complexity increases, decision makers tend to shift from a compensatory search strategy to a less cognitively demanding noncompensatory search strategy. Decision maker trade-offs between effort and accuracy help to explain these results. Although some accuracy may be sacrificed by employing a noncompensatory search strategy in a more complex task, decision makers tend to seek strategies requiring lower expenditure of effort.

The following section examines information access, by investigating the process, moderators, and strategies of accessing information.

## 2.2 Information Access

Key concepts in information retrieval literature include relevance, recall, and precision. Relevance of retrieved documents is a very subjective notion. It may be explained in a variety of ways by different inquirers, and even by the same inquirer at different times (Blair 1990). With most information retrieval systems, after any given search the documents can be classified in four categories: a) retrieved and relevant (useful); b) retrieved and not relevant (useless); c) not retrieved and relevant; and d) not retrieved and not relevant. The ideal retrieval situation would be where all relevant and no non-relevant documents are retrieved. Realistically, this rarely occurs (Blair 1990).

Recall and precision are two criteria frequently used to judge the performance of a search in an information retrieval system (Lancaster 1978). Recall, which is a completeness measure, is the extent to which the retrieval of wanted items occurs. For example, a recall ratio of 0.7 implies that 7/10 of the relevant documents in the database were found. Precision is the proportion of retrieved pages that are relevant. For example, if 100 pages are retrieved from a search and 20 are judged relevant by the person requesting the search, the precision ratio is 0.2. Therefore, recall refers to the ability of a system to retrieve relevant documents, and precision relates its ability not to retrieve irrelevant documents (Lancaster 1978). There tends to be an inverse relationship between these two measures. When a search is broadened to achieve better recall, precision tends to degrade, and when a search is narrowed to improve precision, recall tends to degrade.

This section examines the information access component of our research framework, outlined in Chapter One. First, the information access process is investigated, where browsing and searching tasks are discussed. Next, moderators which can act as constraints or influences on the information access process are presented. Lastly, general access strategies are discussed and compared.

### 2.2.1 Information Access Process

Shneiderman et al. (1997) proposed a four-phase framework for text searches: formulation, action, review of results, and refinement. Although this framework is specific to textual database searching, we have applied these concepts and terms to a more generalized model of information access. The framework phases and their interconnections are discussed below.

#### *Formulation*

Before accessing information, users must consider their information needs and clarify their goals, at least at a general level. Goals of information access behaviour fall into two broad categories: general browsing and more focussed searching. Information access goals depend on the type of task involved. A *closed* task has a specific objective that is often decomposed into sub-goals. The user passes control to sub-goals by stacking or popping them from a mental push-down stack, thereby moving towards a goal state (Carmel et al 1992). On the other hand, an *open* task has a general objective, and is considered more exploratory, vague, and non-specific than closed tasks. Searching is considered a closed task, whereas browsing is an open task.

Several researchers have further divided navigation goals into three main categories. Three classification models are summarized in Table 2.1. Vora et al (1994) comment that readers following the scan-browse goal tend not to read the text, but focus on the highlighted links. By doing this, readers are not able to capture the relation between the source and the target, and are unable to understand the organization of the information itself. A closed task would be expected to produce tactics which require the first category of browsing models, whereas an open task would be expected to require the second and third categories.

**Table 2.1**
**Navigation goal classification**

| Cove and Walsh (1988) | Salomon (1990) | Carmel et al. (1992) |
|---|---|---|
| ***(1) search browsing*** : directed search where a specific goal is known | ***(1) goal-directed search*** | ***(1) search-oriented browse*** : search goal planning, scanning to find, and reviewing to integrate information |
| ***(2) general purpose browsing*** : a general goal governs a consulting of sources that have a high likelihood of items of interest | ***(2) goal-directed browsing*** : the user discovers or reformulates a goal in the course of browsing | ***(2) review-browse*** : review to integrate information into user's mental model |
| ***(3) serendipity browsing*** : purely random with no goal | ***(3) casual browsing*** | ***(3) scan-browse*** : scans for information of interest, but does not review to integrate the information found |

## *Action*

Formal Boolean search, consisting of query formulation and execution, is applied to closed tasks. On the World Wide Web (or just Web), for example, this Boolean search would typically involve a user supplying a list of key words or phrases coupled by Boolean operators to one of the Web search engines. A Web search engine, such as Alta Vista, HotBot, and WebCrawler, responds to the user's request with a list of possibly relevant Uniform Resource Locator (URL) links. The user would then proceed to examine the resulting URL links to locate the desired information. On the Web, an open task, which implies a general browsing goal, is characterized by link traversal, where users browse from one URL to another by following "hyper-links". A search strategy that uses an Internet search engine has the advantage that it will return URL links that have at least some relationship to the topic of interest. On the other hand, browsing strategies have the advantage of potentially finding information which might not otherwise have been found, since the page in question may not have been indexed by the search engine. But the more general browsing strategies can result in the "art museum problem" (Foss 1989), where the user may spend a great deal of time in unrelated directions while learning very little.

Marchionini (1987) proposes that browsing strategies are used as alternatives to formal (Boolean) searching for one or more of three reasons. First, browsing is used when the users cannot or have not defined their search objectives. Without defining information needs, people often proceed iteratively, beginning with broad, general information, and looking for more specific and relevant links. Second, browsing is used when it takes less cognitive load to browse than it does to plan and conduct a formal search. This "cognitive laziness" may be the result of a poor understanding of the structure of the information. Third, browsing is used when the information system supports and encourages this strategy. Although the Web has a number of search engines to choose from, many Web pages encourage browsing by offering outside links to both related and unrelated material.

Bates (1989) suggests a fourth, and more general, reason for the use of browsing over searching : the user hopes to gain incidental learning on a topic that is of interest. This incidental learning describes the notion of "Web surfing", where users generally browse the Web for entertainment. However, people also browse to learn, where learning is the central focus rather than "incidental" (Carmel et al. 1992). For example, specialists may browse to keep their expertise current.

### *Review*

The review phase in the information access process is the act of examining the retrieved information and determining its relevance under the navigation goal. For general browsing, relevant information can fall in a broad spectrum that evolves continuously during the browsing task. For example, a user following general-purpose browsing may initially wish to gather information about tourism in British Columbia. During this session, the user may encounter information about the Commonwealth games held in Victoria, British Columbia in 1994. Exploring this information, the user may become interested in the musical groups that performed during the ceremonies and proceed to investigate information about music. Therefore the relevance of information during browsing tends to evolve over the information access session. For more focussed searching, this evolution of relevance is not as obvious but still present. Even when we are trying to find the answer to a specific question, the relevance of information which may lead us to a solution may evolve as we learn more about the topic or area of interest.

Since relevance is an evolving concept, intuitively, browsing and searching should not be mutually exclusive tasks. Bates (1989) suggests that a user's search strategy is constantly evolving through browsing. Marchionini (1997) also illustrates the linkage between search and discovery (browsing) by outlining that a search query serves to "identify an intellectual neighbourhood for the information to be examined by browsing". Therefore a general-purpose browsing session will be characterised by episodes of searching, and a focussed searching session will be characterised by episodes of browsing or discovery.

### *Refinement*

The results of the review phase in the information access process are used to refine the "intellectual neighbourhood" (Marchionini 1997). General concepts such as decomposition, coupling and cohesion (Davis and Olson 1985; Powers et al. 1990) can be applied to the refinement phase of the information access process. When information is vast and difficult to comprehend as a whole, it can be decomposed or factored into sub-components. Relevant sub-components can be further divided or decomposed until the information is of manageable size. Coupling refers to the interrelatedness between sub-components, while cohesion refers to the interrelatedness within sub-components. For effective refinement, relevant sub-components should be loosely coupled and tightly cohesive. For example, if an individual was interested in finding information about hockey, typing "hockey" as a keyword in the Web Alta Vista search engine would generate over 670,000 results. Decomposition is needed to refine the information space into a relevant and manageable size. Sub-components of hockey may include ice hockey and field hockey. These sub-components are rather loosely coupled and tightly cohesive since most information retrieved for each of these types of hockey pertains to that type and is not shared or coupled with the other type. Further decomposition of ice hockey may include players and teams. This division is strongly coupled since these sub-components are strongly interrelated (players play on teams, and teams consist of players). On the other hand, a decomposition such as "league" would be loosely cohesive since it would result in many different types of leagues (adult, amateur, minor, national, etc. ) as well as many different facets of hockey (players, teams, rules, tournaments, etc.). Effective search refinement requires decomposition into small, manageable, loosely coupled, and tightly cohesive chunks.

It is important to note that the information access process is highly iterative. The information seeker may return to a previous phase at any point during the information access process. For example, refining the information space may result in several returns to the action phase to generate new search queries. A flowchart of the information access process is presented in Figure 2.3.

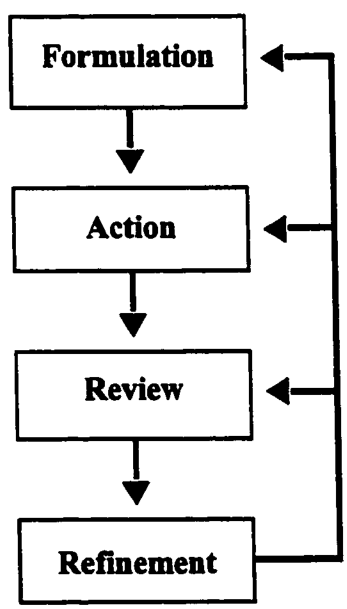


**Figure 2.3**
**Information access process**

## 2.2.2 Information Access Moderators

The moderators discussed in this subsection can constrain or influence the information access process. Humans are limited by the amount of information they can absorb or process at one time, therefore our memory acts as a constraint to accessing large amounts of information. Besides data volume, which can result in information overload, other characteristics of information may also hinder or facilitate the information access process. Individual differences such as cognitive style and user experience are also presented as possible moderators to accessing information.

### *Memory Properties*

There are several theories of human memory performance. In this discussion, we do not subscribe to any one theory, but use the findings of researchers as descriptive tools to explain the relationship of memory to our research.

Every day humans are bombarded with massive amounts of information. This information must be organized in some way to properly interpret it. We organize information in order to make it manageable through classification and categorization. For example, the human eye is capable of discriminating between several million colour differences. However, we use only a very limited number of colour concepts. By automatically categorizing whole ranges of the subtly different colours under the concept "blue" we greatly reduce the amount of learning in which we would otherwise have to engage (Lovell 1980).

When detected information becomes categorized, a representation of this category enters the short-term store (Barsalou 1992). If the information remains in short-term memory (STM) long enough, it may be transferred to a long-term store. The STM system is generally believed not to be autonomous (Barsalou 1992), since it has been shown that long-term memory (LTM) interferes/influences STM. It is useful to think of STM as a working memory holding knowledge that is currently active or in use. A mental process cannot function properly unless the knowledge required by the process can be kept in working 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 emphasizes that people are extremely limited in how much information they can recall. Information can be kept active in working memory with rehearsal, but when distracted from rehearsing, people tend to lose information from STM very rapidly. In addition, increasing the number of items that a subject must keep in short term memory increases the amount of time required to access any item (Anderson 1985).

LTM information can remain stored for indefinite periods of time without using continuous rehearsal (Murphy 1992). In general, the more information is processed, the better it is remembered. Some factors that determine more processing done on information include (Barsalou 1992):

- *Presentation Duration* : Information is encoded better with longer presentations.
- *Rehearsal* : Different types of rehearsal include a) elaborative rehearsal (strategic processing is devoted to elaborating the information), b) maintenance rehearsal (allocate just enough

processing to keep the information from being lost). Maintenance rehearsal improves recognition but not recall.

- *Number and Distribution of Presentations* : The more times a stimulus is presented, the better it is remembered.

## Retrieval

Information in LTM is in an inactive state, and must be retrieved or activated in order to be used. Once activated, the information becomes part of STM (Anderson 1985). The key to retrieving information is retrieval cues. The effectiveness of a retrieval cue is determined by the extent to which the cue overlaps with the information to be retrieved (target). The effectiveness of the cue increases as it : a) shares increasing properties with the target, and b) contains decreasing properties not in the target (Barsalou 1992). Three common retrieval cues which differ in their overlap with targets are

- *Free Recall* : must recall an item/list in any order.
- *Cued Recall* : given a cue such as a category name, must recall a category member/list in any order
- *Recognition* : must pick out a relevant item/sub-list from a larger list.

The overlap between cues and targets increases from free recall to cued recall to recognition, and subsequently memory is generally poorest for free recall, better for cued recall, and best for recognition (Barsalou 1992). Wolford (1971) and Anderson (1985) agree that recognition performance is better than recall. Since humans have a greater capacity for recognition than for recall, Murphy (1992) proposes that the human-computer interface should be designed for recognition rather than forcing recall. However, there have been cases of recognition failure where subjects fail to recognize previously presented items which are subsequently produced in cued recall (Horton and Mills 1984).

Free recall is difficult due to the lack of cue information. The foremost factor in overcoming this challenge is organization (Barsalou 1992). The use of taxonomic (category clustering) and thematic (generating associations to form a familiar frame) relations to organize information can improve free recall. Reinstating the original context also produces better memory, presumably because it maximizes the overlap between cues and targets (Barsalou 1992). In contrast, recognition cues direct search to the appropriate target location in memory. Two strategies are generally employed during recognition (Horton and Mills 1984, Barsalou 1992) :

- *familiarity strategy* : if an item is initially perceived as highly familiar, it may be inferred as a target
- *contextual search strategy* : when familiarity is not conclusive or there is a need to ensure accurate selection, people search for contextual information evidence

It is interesting to note that familiarity of high-frequency material may make it difficult to recognize. It may be difficult to determine if the high-frequency material is familiar because it is the desired target or because it has occurred so often in the past. In contrast, when low-frequency material appears familiar, there is increased confidence of the item being the desired target, otherwise it would not seem familiar (Mandler 1980, Barsalou 1992).

### *Information Characteristics*

Information characteristics can hinder or facilitate the information access process and influence the access strategies employed. For example, large amounts of irrelevant, out of date and inaccurate data can unnecessarily lengthen the information acquisition process and obscure the information which has value and quality. O'Brien (1996) presents information characteristics along three dimensions as show in Table 2.2.

**Table 2.2**
**Information characteristics (O'Brien 1996)**

| | |
|---|---|
| **Time Dimension** | |
| Timeliness | Provided when it is needed |
| Currency | Up-to-date when it is provided |
| Frequency | Provided as often as needed |
| Time Period | Provided about past, present, or future time periods |
| **Content Dimension** | |
| Accuracy | Free from errors |
| Relevance | Related to the information needs of a specific recipient for a specific situation |
| Completeness | All that is needed is provided |
| Conciseness | Only what is needed is provided |
| Scope | Broad or narrow focus, internal or external focus |
| Performance | Measuring activities accomplished, progress made, or resources accumulated |
| **Form Dimension** | |
| Clarity | Provided in a form that is easy to understand |
| Detail | Provided in detail or summary form |
| Order | Arranged in a predetermined sequence |
| Presentation | Narrative, numeric, graphic, or other forms |
| Media | Video display, printed paper, or other media |

The Internet is a unique environment that presents massive amounts of information on a large number of unrelated topics. Easy access to Internet information can be hampered by some basic characteristics of Internet data. Four of these characteristics are :

1. *Decentralized Data* : Internet data is spread across many Web sites all over the world, which can make locating information difficult. Although software "robots", that update Web search engines, traverse the Web to keep track of this 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.

2. *Unstructured Data* : Internet data is largely unstructured and fragmented since standards do not exist for its form, identification, and classification (Tauscher 1996a). Although the data can exist in a variety of formats, fortunately the increased sophistication of Web browsers and evolving HTML standards have made these data formats transparent to the user.

3. *Unreliable Data Quality* : Data quality is affected by the nature and maintenance of information. Much Web information is opinion rather than fact, and data maintenance is often not considered a high priority. The designer only has control over the pages located on the designer's server. Links to remote servers may become disabled or out-of-date, while new relevant sites may become available. Proper maintenance of Web sites should include updating local information, checking the quality of outside links, and scanning the Web for new relevant links.

4. *Data Volume* : The volume of data on the Internet has grown at a phenomenal rate. This pushes the limits of search result usefulness (Tauscher 1996a).

In addition to these information characteristics, access to Web information is constrained by resource limitations. Since Web traffic has been increasing dramatically, bandwidth has become a limited resource. Not only is there more demand for Web pages, but user expectations for aesthetically appealing pages (which may include "bandwidth-hungry" images, video and audio) are increasing. The escalation in the number of users and amount of data being transferred places heavy burdens on available bandwidth, and results in longer Web page retrieval times. Retrieval delays are also impacted by the proximity of Web servers, and the inability of servers to effectively handle high incoming traffic. Although the use of mirror sites (duplication of Web servers and their contents at different geographical locations) can help the proximity and server access problems, few sites offer this option. Excessive delays in Web page retrieval will affect natural navigation behaviour when frustrated users interrupt downloading of pages.

## Information Overload

Information overload is a consequence of large amounts of information and limited human memory capabilities. As more and more information is becoming easily accessible through developments in telecommunications, information overload is becoming a central information characteristic issue. This issue and its possible effects of disorientation and cognitive overhead are presented below. This discussion focusses on the Web, which is the largest hypermedia environment in the world.

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. Many surface cues, such as paper and print quality, that may indicate the quality or value of information are not evident since browsers tend to present Web information in the same way, by interpreting HTML code. There is no effective screening mechanism, such as peer review, to guarantee the accuracy and quality of Web information. Peer reviews and other measures of value and "correctness" gained from traditional media are difficult to apply to a medium that is highly dynamic and, by its nature, always incomplete. December (1994) suggests that "like cheap, suburban land, Webspace can fill with banalities" since Web information providers do not face scarcities in presentation media.

**Disorientation and Cognitive Overhead**

The Web has the ability to present vast amounts of diverse, complex, multimedia information that is richly interconnected and cross-referenced through URL links. Unfortunately, this environment can also result in user 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 (1990b) 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 making 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 1996b). Users taking long sidetracks may not being 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.

Physical effort is also necessary to navigate back to a previously visited page. This can become a burden when the user must repeatedly navigate back through a set of pages, or visit pages that are of no interest in order to reach a desired location (Tauscher 1996b). Disoriented users will likely perform additional navigational actions requiring more physical effort.

### *Individual Characteristics*

There is considerable variability among individuals in decision making and information access tasks, sometimes in the final level of performance, and sometimes in the manner in which the task is mastered. The most common distinctions between individual characteristics in empirical research are cognitive style and user experience. These dimensions are discussed below.

## Cognitive Style

Learning style is defined as the composite of characteristic cognitive, affective, and physiological factors that serve as relatively stable indicators of how a learner perceives, interacts with, and responds to the learning environment (Keefe, 1979). Included in this comprehensive definition are cognitive styles, which are intrinsic information-processing patterns that represent a person's typical mode of perceiving, thinking, remembering, and problem- solving. Some common cognitive styles include :

- *field independence/dependence* - Field independent people rely on their internal sensory processes, and are not swayed by contradictory external evidence. Field dependent people rely on external cues, and are influenced by information from the outside world.

- *extravert/introvert* - Extraverts are more outgoing, whereas introverts are more within themselves.

- *impulsive/reflective* - A reflective individual has a strong desire to be right the first time, while an impulsive individual does not take the necessary time to evaluate his/her own solution and often relies on some external source for solution evaluation.

- *heuristic/analytic* - Heuristics tend to look at the broad view of a problem, whereas analytics prefer to go through all the data before making a decision.

- *intelligence* - Intelligence significantly affects the potential ability to learn, reason, and solve problems.

Personality dimensions assess the influences of basic personality on preferred approaches to acquiring and integrating information. Models stressing personality include Witkin's (1954) construct of field dependence/field independence, and the Myers-Briggs Type Indicator (MBTI) (Myers, 1978). The MBTI provides dichotomous scales for measuring extroversion versus introversion, sensing versus intuition, thinking versus feeling, and judging versus perception. Taggart and Robery (1981) suggest that a decision maker's thinking mode can be measured by using the MBTI scales for thinking/feeling and sensing/intuition. Using these two scales, there are four possible outcomes of dominant scores : sensing-thinking, intuition-thinking, intuition-feeling, and sensing-feeling. Taggart and Robery (1981) classify analytic and heuristic decision making style with decision makers that exhibit the sensing-thinking and intuition-feeling scoring respectively. Decision makers who exhibit intuition-thinking and sensing-feeling are classified as intermediate or neutral between the analytic and heuristic decision making styles. Zmud (1978) found that in an environment where decision aids were not available, analytics prefer to examine more information, and on average take more time to make decisions than heuristics. DeHaemer and Wallace (1992) confirm that in a decision making environment, the heuristic/analytic dimensions have a small but significant effect on how and in what form individuals prefer to gather and use information. However, there is no consensus on the value of cognitive style research for MIS and DSS design. Huber (1983) states that the impact of decision style on performance is considerably less than the impact of task type or decision situation. He claims that the literature on cognitive style is an unsatisfactory basis for deriving operational guidelines for MIS and DSS designs. Robey (1983) agrees that decision support systems (DSS) "are likely to be ready sooner than will an empirically-tested contingency theory involving user styles". However, Umanath et al. (1990) point out that although only about 10 percent of variance in decision making performance or behaviour can be attributed to cognitive styles, we cannot afford to ignore a variable that accounts for 10 percent of explainable variance.

## User Experience

Research on expert-novice differences in problem solving typically examines users in recall tasks, protocol analysis tasks and sorting tasks. Chase and Simon (1973) examined differences in the recall abilities between beginner and master chess players for chess board configurations. They found that experts did not possess overall better memory than novices, but were able to organize individual chess pieces into meaningful chunks where each chunk contained several pieces.

A protocol analysis study was performed by Larkin et al. (1980) where simple physics problems were presented to novice students and expert professors. Experts were quicker in solving problems since they organized information in larger units containing several equations. Experts also tended to display a top-down approach, whereas novices tended to use a bottom-up procedure that lacked comprehensive planning. Batra and Davis (1989) found similar results where experts focussed on generating an overall (top-level) understanding of the problem before progressing to the details of solving the problem. However, the employment of a comprehensive plan does not necessarily result in complete information examination. Bettman and Park (1980) found that subjects which had a moderate level of prior knowledge or experience tended to examine more information than those with low or high levels of prior knowledge or experience. This finding is reasonable since the subjects with moderate levels of prior knowledge or experience have the ability to process the new information and the motivation to perform the processing. Subjects with low levels of prior knowledge or experience may not possess the ability to process the information in the given task, whereas subjects with high levels of prior knowledge or experience have enough ability but do not necessarily need to, or feel they need to examine all available information. Experienced subjects also demonstrated information searching which is more alternative-wise, meaning that attributes for a particular alternative tended to be examined together before moving to the next alternative. Inexperienced subjects tended to employ noncompensatory decision strategies such as elimination by aspects (outlined in section 2.1.2). Generally, experts searched information more actively than novices, who searched information in the order presented to them.

Chi et al. (1981) employed a physics problem setting, where users were asked to sort physics problems into similarity groups. Novices were influenced by surface characteristics of the problem, but experts were able to relate problems to higher level categories of underlying principles. Archer and Kao (1993) also found that users with domain expertise were more likely to use high level abstractions in problem solving.

The studies outlined above are representative of the research methods and findings concerning expert-novice differences in a problem solving setting. In a problem solving environment, experts and novices differ in their tendency to: a) use chunking in free-recall; b) use comprehensive plans (but not necessarily comprehensive searching); and c) utilize higher levels of abstraction to obtain an overall or underlying understanding of the problem.

### 2.2.3 Information Access Strategies

Two general strategies to problem solving are the successive refinement and opportunistic strategies. Information access strategies mirror the information requirement for problem solving strategies, therefore we use these models as the basis for our information access strategy classification. These models are discussed below as well as a third integrated model which combines aspects of both strategies.

#### *Successive Refinement Model*

Early insight from cognitive psychology suggested that problem solving could be considered a top-down, goal-driven, and hierarchically structured process (Miller et al. 1960). From this perspective, a successive refinement approach was introduced to explain the information access strategy. The use of this strategy entails examining problems in terms of high-level goals that are successively decomposed and refined into achievable actions. This model representation has been used in the context of artificial intelligence (Ernst and Newell 1969, Newell & Simon 1972, Sacerdoti 1974, Sacerdoti 1977, Sussman 1973), and structured programming (Dahl, Dykstra, & Hoare 1972). In successive refinement, goals and sub-goals are fully expanded or refined at the same level of abstraction or detail before moving to a lower level in the goal hierarchy. Complete plans will eventually exist at all levels of abstraction. Abstracted information will be accessed before its successive detail.

Thorndyke (1978) argues that this top-down process of successive refinement can help to minimize memory load. The problem solver and information seeker can focus on one coherent area of the hierarchy, rather than trying to consider several diverse areas at once. Jeffries et al. (1981) found that computer programming, which is a structured task by nature, was decomposed in a top-down successive refinement fashion. Although novice programmers tended to exhibit a depth-first strategy (expanding one area of the hierarchy at one time) and experts displayed a breadth-first approach (simultaneously expanding multiple sub-goals at one time), both levels of expertise emphasized top-down problem decomposition. Hayes-Roth (1979) observed that the imposition of severe time constraints tended to result in top-down approaches, whereas a bottom-up approach was more common in a minimal time constraint setting. Under the successive refinement model, both depth-first and breadth-first strategies will eventually result in complete plans at all levels of abstraction. Therefore, successive refinement strategies can be characterized by either top-down or bottom-up information access strategies.

### *Opportunistic Model*

Hayes-Roth and Hayes-Roth (1979) introduced an alternate view to problem solving strategies. They assumed that planning and problem solving are opportunistic, heterarchical processes. That is, at each point in the process, the problem solver's current decisions and observations suggest various opportunities for plan development. Subsequent decisions follow up on selected opportunities (Hayes-Roth and Hayes-Roth 1979). This process "violates the assumptions of the top-down successive refinement model, since it suggests that plans or solution steps may be executed before plan or problem solution sequences are complete" (Davies 1991). Interim decisions can lead to subsequent decisions at any point, or hierarchy level, in the problem space. Planning is assumed to be incremental, and thus this strategy rarely produces a complete plan in the systematic fashion of the successive refinement model. Hayes-Roth and Hayes-Roth (1979) suggest that in complex and uncertain environments, the opportunistic problem solver would benefit from less of the discipline imposed by a top-down strategy. This problem solver could formulate and pursue promising partial plans instead of being burdened by the maintenance of a structurally integrated plan at each decision point. Therefore the information access behaviour under the opportunistic model is much less structured than the top-down or bottom-up approach of successive refinement.

Guindon (1990) found that software designers mixed high and low-level decisions during a design session in an unsystematic fashion. Ullman et al. (1986) and Visser (1987) found similar deviations from the hierarchical problem solving process in the context of engineering design and machine installation respectively. Hayes-Roth and Hayes-Roth (1979) did not claim that one model is more correct than the other, but suggest that the decision and information environments are the major determinants of model appropriateness.

### *Integrated Model*

Davis (1991) proposed that the problem solving process is more likely to be a combination of the successive refinement and opportunistic models. This integrated model suggests that problem solvers may follow a broad top down strategy with episodes of opportunistically directed activities. In the computer program design environment, Davis (1991) found that opportunistic episodes may occur at any point during the problem solving process. Successive refinement and opportunistic strategies can co-exist in a single task, where one model may take precedence over the other at any particular point. Interestingly, Davis (1991) also found that task expertise had an effect on model preference. Novice programmers tended to display more opportunistic behaviour than experts who adopted a more top-down strategy.

### *Summary*

In this section we examined the information access component of our research framework, outlined in Chapter One. First, the information access process was examined along a four-phase model: formulation, action, review and refinement. Browsing and searching goals were contrasted and were shown not to be mutually exclusive. As with the decision making process outlined in section 2.1.1, the information access process is iterative, where one may return to a previous phase at any point.

Next, we examined various moderators that could constrain or influence the information access process and the strategy employed. The first moderator was human memory properties. When information is transferred to long term memory (LTM), it can remain stored in an inactive state for an indefinite period of time. The key to activating, or retrieving, information stored in LTM is retrieval cues. Recognition is the easiest retrieval cue since the overlap between cue and targets is greatest. Free recall, where the overlap is smallest, is the most difficult. The memory capacity for recall is much more limited than for recognition.

Characteristics of information also influence information access. For example, users may encounter several problems when navigating through large hypermedia structures, such as the Web. Users can easily become entangled in a large and complex web of decentralized, unstructured, and potentially unreliable information. It is easy to become disoriented when overloaded with massive amounts of information, much of which may be irrelevant.

The last moderator examined was individual differences. Individuals differ among information access and decision making tasks. Individual characteristics such as cognitive style and user experience can result in differences in task procedure and performance. Although there is debate over the value of cognitive style research, it may be detrimental to ignore a variable that accounts for 10 percent of explained variance in decision making performance or behaviour. Research on user experience generally finds that domain experts chunk more information and use higher level information than novices to obtain overall understanding in a problem solving setting.

Moderators such as human memory, information characteristics and individual differences can affect the information access strategy employed by the information seeker. Information access strategies mirror the information requirements for problem solving strategies. Successive refinement, where goals and sub-goals are fully expanded or refined at the same level of abstraction before moving to another level, is characterized by either top-down or bottom-up information access strategies. In contrast, the opportunistic model suggest that current decisions and observations lead to various opportunities for plan development, resulting in a much less structured information access strategy. A third approach was introduced which integrates the previous two models: following a broad top-down strategy with opportunistically directed activities.

The next section examines the user interface component of our research framework, outlined in Chapter One. Presentation, organization and access mechanism aspects are discussed.

## 2.3 User Interface

To the decision maker using a computer system to support the decision making task, the human-computer (user) interface is probably the most important component of the entire system. Since the majority of decision support system users are not computer-trained personnel, the type of interface that is used plays an important role in the success of these systems (Bidgoli 1990). A user may often consider the human computer interface as the entire system. In other words, in the eyes of the user, the interface is the system. The decision maker is often not concerned with the underlying operations of the system. Aspects such as system design, data gathering, model and database structure, storage and retrieval techniques, etc. are generally not the chief concerns to the user, whereas flexibility and ease of use of the system are. The easier and friendlier the interface appears to the decision maker, the more attractive the system. Dos Santos and Holsapple (1989) argue that the interface can determine the impact a decision support system has on decision making.

This section examines the user interface in terms of presentation, organization, and access mechanisms, as outlined in the research framework presented in Chapter One.

### 2.3.1 Information Presentation

Various characteristics of information presentation can have an influence on the information access and decision environment. This section examines interface presentation characteristics along the dimension of presentation mode (text, voice, image, video, animation, graphical or tabular data). Although text is the traditional mode of presentation, Streeter (1988) presents the following advantages and disadvantages to voice output in comparison to traditional text output:

*Advantages*

- universality : almost everyone understands spoken language
- voice operates over distance : do not have to be positioned at a terminal
- user is free to other modularities : can incorporate visual modes simultaneously
- attention grabbing : written instructions are easier to ignore

| | | |
|---|---|---|
| *Disadvantages* | • | bandwidth : speech transmission and storage require higher bandwidth |
| | • | speed : slower to receive and comprehend voice |
| | • | voice is transitory : difficult to review or preview |
| | • | potentially annoying : a poor voice interface can be more annoying |

In general, audio effects are useful tools for drawing a user's attention. Audio effects can be used to complement video effects such as colour, blinking, flashing, and brightness contrast, or reveal information difficult to represent with video. Both video and auditory cues may have an effect on the motivation of users to explore unknown system features, thereby potentially impacting user learning and satisfaction (Gerlach and Kuo 1991).

There has been much debate over the effectiveness of graphs versus tables for presenting information. Some researchers agree that when large amounts of data are required, graphs may be more effective than tables for allowing the user to summarize the data. Graphs may also be more effective for tasks that require identification of patterns from large volumes of data. However, if the task requires pinpointing data with precision, tables may be more effective (Gerlach and Kuo 1991). Superiority of table or graph presentation is highly dependent on the given decision task. In some cases, a combination of these two presentation methods may prove to be most effective.

The use of graphics and images is becoming increasingly popular in computer systems. It is a common current belief that the use of visual interaction techniques has advantages over more traditional techniques such as textual languages. Implementation of such visual techniques is becoming easier due to hardware and software technology developments (Tauber 1993). However it is important that designers' judgement not be clouded by the obvious advantages of visual techniques. Visual notations are not universally the best. For any given problem or task, it is important to analyze the appropriateness of visual representation. The success of representation, graphical or not, depends on whether it makes accessible the particular information needs of the user, and how well it copes with different user information requirements (Petre and Green 1993).

Petre and Green (1993) argue that reading a graphic is an acquired skill . The user learns to approach the graphical representation as an active reader and, while taking advantage of available perceptual cues, to apply acquired rules of interpretation. They introduce the notion of "secondary notation" which is the use of layout and perceptual cues that are not formally part of the graphic representation. Examples of secondary notations include elements of adjacency, clustering, white space, labelling, etc. Secondary notation can clarify information (such as structure, function or relationships) or give the user hints. The mere presence of graphical features does not guarantee clarity in representation. Good use of secondary notation is also required. Poor use of secondary notation can confuse and mislead the user. Unlike text, which involves serial reading, graphics require the reader to identify some appropriate inspection strategy. Inspection cues may be given in graphical representations as well as secondary notation. Petre and Green (1993) found that novice users had difficulty in determining what is important or relevant. Novice users were apparently unable to recognize the available secondary notational cues, whereas experts were able to recognize and take advantage of these cues. These finding indicate that experience determines the strategy of how to view a well-structured visual representation.

Some researchers have attempted to link the use of graphical representation in problem solving to performance. Schwartz (1971) found that graphical representation in solving well-structured deduction problems may improve subjects' performance. Carroll et al (1980) generalized this finding to more ill-structured problem domains such as design.

## 2.3.2 Information Organization

The previous section examined how information may be presented, while this section investigates the underlying organization of information. Information may be organized in a structured (database, abstraction) or unstructured (hypermedia) manner.

### *Structured Information*

Traditional information retrieval concentrated on the development of information management systems to support user retrieval from large collections of homogeneous textual material. With this approach, textual material is grouped into collections which are then grouped into a textual document library. Descriptive attributes allow for the retrieval of documents. This concept has been extended to automated database systems. In database systems, search is by attribute, attributes tend to be well defined, and searches are deterministic in nature. For example, a relational database stores information in the form of two-dimensional tables where columns of the tables represent the attributes that describe the table entity. These entities and attributes should be well defined through a structured data modelling process that also defines the logical relationships between entities. Extracting data from a traditional database to satisfy information requests can usually be performed with little difficulty using a query language, such as SQL (Structured Query Language) or QBE (Query by Example), or a report generator.

Information may also be organized by levels of detail. This structured organization is called information abstraction and is discussed below.

## Information Abstraction

Abstraction is the process by which details of an object are left unspecified in favour of a less cluttered appreciation of its structure (Zeigler and Rada 1984). Therefore the method of abstraction involves the mapping of objects of one class into a second, presumably less complex class. Zeigler and Rada (1984) propose that this abstraction mapping is a many-to-one mapping, where the complexity of the "abstract" class is smaller than the original "concrete" class. The many-to-one mapping implies that many source objects can be represented by the same target abstraction, but when given this abstraction we cannot uniquely recover a concrete object it represents.

Zeigler and Rada (1984) also state that the usefulness of abstraction depends on three factors :

- *applicability* : it must make sense to apply abstraction to the particular question or problem
- *validity* : abstracted information should give the same result as the original more detailed information
- *computational advantage* : it should be computationally easier on the problem solver to use the abstracted information rather than the original more detailed information

Ossher (1987) considers abstraction to be a powerful tool to reduce complexity in information acquisition and problem solving. Information abstraction allows the decision maker to focus on more important facets of the decision task without being buried in details. Some complexity management techniques outlined by Ossher (1987) include clustering entities with common properties; highlighting to draw attention; analogies and deviations between familiar and unfamiliar problems; approximation by omitting some details; convergent approximation through a sequence of approximations; localization of closely related information; and graphic/diagram use.

Abstraction can be viewed as being either horizontal or vertical (Kao 1992). A horizontal abstraction of a problem may include many problem facets at a particular level of detail. Vertical abstraction may include several levels of detail along a particular problem dimension. Therefore horizontal abstraction tends to deal with breadth of a problem, whereas vertical abstraction tends to deal with depth. A combination of both horizontal and vertical abstractions is often included in a problem abstraction.

Abstraction has been extensively applied to the problem solving environment, in areas such as human memory (Rosch 1978), conceptual model design (Archer and Kao 1993), problem diagnosis (Rasmussen 1985), and computer program design (Davies 1991). An hierarchy is a natural way to represent information and corresponding relationships. But effective representation of abstraction may be difficult on a computer screen of limited size. Presenting too much information at one time will only overwhelm the user and counteract any possible positive effects of abstraction. Hierarchies can be represented through tree-structures (Furnas and Zacks 1994), or through enforced top-down structures such as menus

(Norman et al. 1986). In more complex structures, displaying relationships between child and parent information is likely to be useful.

### Abstraction in Decision Making

Under the premise that changes in information load will lead to changes in information search strategies, and changes in information search strategies may affect decision quality, designers can encourage a particular decision process through the manipulation of information load. For example, an organization may wish to encourage a compensatory search strategy since it is thought to be more logically justifiable or defensible. On the other hand, an organization may wish to encourage a noncompensatory strategy since it is thought to be less costly or faster. Encouraging a certain search strategy is especially important for those decisions that may be made by several people in the organization. For example, capital budgeting and commercial loan decisions are often made by several different people in an organization. An organization may find it preferable to encourage a consistent approach across these decision makers rather than to allow each decision maker to individually decide on the approach to be used.

Compensatory strategies tend to require a higher level of cognitive effort (Cook 1993). To encourage this type of strategy, the decision support system should aim at reducing the level of cognitive effort required. For compensatory strategies, information abstraction can provide an aggregation or summarization purpose to help decrease this cognitive effort.

Noncompensatory strategies are often viewed as being biased due to order effects, available information that is not used, or inconsistencies in preferences (Einhorn 1971). Therefore a decision support system that aims at supporting noncompensatory strategies should present information in such a way as to minimize these inherent biases. Cook (1993) suggests that systems could be designed to support qualitative inquiries based on fuzzy logic. In other words, terms such as "few", "many", "high", and "low", can be used to represent inexact data. The use of fuzzy logic may help to reduce the possible arbitrariness of cutoff levels to eliminate alternatives. Therefore, for noncompensatory strategies, information abstraction can provide a classification purpose to help reduce this possible arbitrariness of cutoff levels.

Other uses of information abstraction that may be helpful in the decision making process include :

- initial overview : Abstracted information is used before its corresponding detail.
- identifier : If alternatives are not identified in a meaningful manner (i.e. represented by numbers or letters), high level information abstraction may serve an identification purpose.
- direct search : Abstracted information may direct the search strategy of the decision maker.
- replace detailed information : This can be seen as a subset of "direct search". However in this case abstracted information replaces all its corresponding detail.

Progressive abstraction has also been found to stimulate creativity in problem solving (Couger et al 1993). This technique involves moving through progressively higher levels of problem abstraction. When a problem statement is systematically enlarged in this way, new concepts and definitions arise that can be analyzed for usefulness and feasibility. Once an appropriate level of abstraction is reached, it becomes easier to identify possible solutions. Figure 2.4 shows an example of the progressive abstraction technique used to increase the solution set for a problem of shortage of entry level employees. This example illustrates that moving up one level of abstraction (plus-one level) expands the solution set from three to eight. Moving up one more level (plus-two level) resulted in identification of seven additional areas for analysis. Therefore, by moving to higher levels of abstraction, the solution space was increased from three to 15 sub-areas. Zeigler and Rada (1984) also agree that abstraction may stimulate the formation of new questions that were inconceivable prior to its introduction.

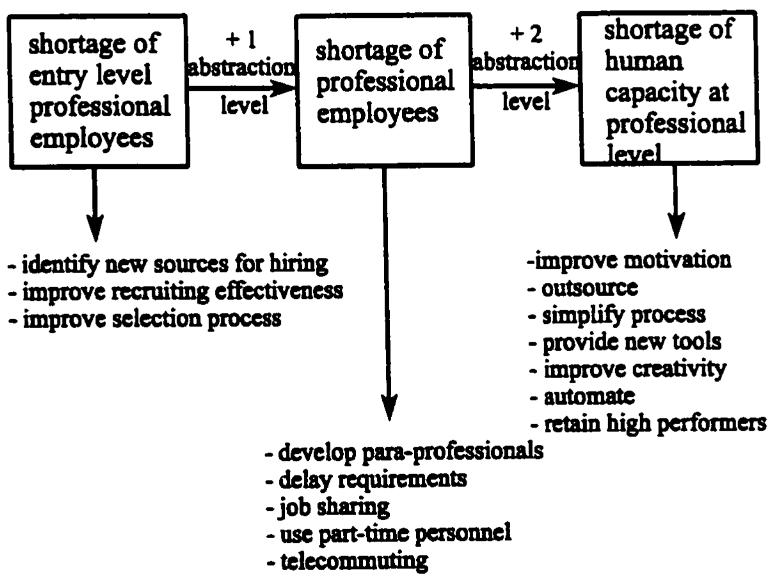


**Figure 2.4**
**Progressive abstraction technique (Couger et al 1993)**

### *Unstructured Information*

In the last decade, we have witnessed a dramatic change in information access. Traditionally, librarians had to serve as intermediaries between end-users and their particular information needs. With the recent explosive public interest in information access and communication technologies, end-users now have access to vast amounts of information from their desktops at work and home. Much of this information is in the form of hypermedia. Searching for information in electronic systems has truly changed from an intermediary, third-party operation to one that is user-driven (Toms 1997).

Hypertext is nonlinear text, whereas hypermedia is an extension to include a variety of symbolic expressions (e.g. diagrams, voice, pictures, icons, videos, etc.) beyond text (Kozma 1991). A network representation of information is one of the defining characteristics of hypermedia. This network representation can be much more complex than linear or hierarchical representation. Readers are active participants in the information accessing process, and assume part of the author's role by selecting the structure they need (Begoray 1990). The hypermedia environment promotes self-regulated learning. Corno and Mandinach (1983) identify self-regulating learning as "the highest form of cognitive engagement". Salomon (1988) points out that this environment may prompt learners not only to think about ideas, but also to think about how they are interrelated and structured. However, McCombs (1988) points out that many individuals may have trouble adjusting to self-directed learning. These individuals may lack effective skills and motivation necessary for self-management.

Hypertext and hypermedia systems offer great flexibility over traditional linear documents. But this flexibility can often be at the cost of high cognitive overhead and a disorienting lack of contextual cues (Girill and Luk 1992). A general problem of hypermedia outlined by Heylighen (1991) stems from the open support form of such systems. An open support system allows the user to use individual intelligence and creativity in order to solve a problem, with the system merely functioning as a medium which enables the use to express his or her ideas. A closed support system, on the other hand, places the user into a passive role while the system performs the "thinking". The open support system of hypermedia offers much flexibility with little "intelligence" in helping the user solve complex problems. Heylighen (1991) argues that nothing in the hypertext concept "helps one to decide which chunks and links to introduce, or what meaning to attribute to a specific link". Kozma (1991) agrees that a nonlinear environment requires readers to decide what information to examine and in what order, therefore building such sequences is likely to be more difficult for users new to the domain. One way to avoid this problem is to permit only particular types of links (such as fixed meanings of "is an instance of", "implies", or "causes"), but this creates a more closed support system.

The hypermedia environment may also benefit decision making. Spiro and Jehng (1990) believe that this environment facilitates cognitive flexibility since it allows a topic to be explored in multiple ways using many different concepts or themes. This highly flexible knowledge structure facilitates the use of information to solve a wide range of problems. Kozma (1991) suggests that "each concept can be subsequently used in many different ways and the same concept can apply to a variety of kinds of situations".

The Web is a large, distributed system on the Internet through which users equipped with graphical browsers can examine hypermedia Web "pages" from around the world. Web pages are normally in hypertext markup language (HTML) form (Aronson 1994), which includes text and references to media forms such as images, sound, video, on host computers connected to networks throughout the world. Pages referenced elsewhere, on the page being viewed, may be retrieved by clicking on a highlighted text, icon, or image, thus generating an access request to that page's Internet address, resulting in its retrieval (Archer 1996). Without a doubt, the Web is the largest, most complex, most rapidly expanding, and most commonly used hypermedia system.

### 2.3.3 Access Mechanisms

Interface mechanisms that can be used to support the user in accessing information include search engines, directories and user history tools. This section focusses on interface mechanisms that assist the user in accessing information on the Web.

#### *Search Engines*

Search engines allow the user to enter key words or phases which are checked against the associated database. If one or more matches are found, most search engines will display summaries of the retrieved information, location of the information, and a relevance ranking or ordering of the query results. In large hypermedia environments, such as the Web, search engine databases are created automatically through software programs, called robots or spiders, which roam the Web information space collecting titles, text, and links from Web pages. While no search engine covers the entire Web, many have indexed millions of Web pages.

The large size of Web search engines' indexes are both their strengths and weaknesses. When searching for a narrow, specific topic, a search engine may be the best (or only) way to locate information resources. When searching for a broad topic that uses common, frequently-occurring words, search engine results will list sites that, while containing a mention of the search term, have little or nothing to do with the desired topic. The user must often weed through thousands of sites in order to sort out the few useful resources. Unfortunately most Web search engines perform poorly along recall and precision dimensions (Archer 1996). Only a small fraction of the URL results from a search engine query may be relevant, and the most valuable information may not even be accessed if an excessively large number of links is retrieved.

Web search indexes vary in many ways, such as the number of sites included in the database, the types of information collected by the robot, the search options provided for users, etc. Therefore, performing the same query across various search engines will often produce very different results. For this reason, it may be necessary to employ several search engines for any particular query. Using synonyms for key words may also yield dramatically different results. This explains why different users may obtain different results when searching along the same topic. Searching for exact key words or phrases is difficult since people tend to use a tremendous variety of words to express the same concept, and the same word can be used in an unpredictable variety of contexts.

### *Directories*

Directories are collections of information organized by subject. Most directories are organized hierarchically and allow the user to "drill down" to lower and more detailed levels (Archer 1996). Hypermedia directories allow users to click on a topic of interest, and then browse through the list of resources in that category.

Web directories are constructed and maintained by human beings, rather than by the automated robots or spiders used to create search engines. This human involvement makes directories quite different from search engines. Directory databases are much smaller than search engine databases, but tend to provide more relevant results. In some cases, the resources may also be rated and reviewed. Specialized directories are oriented to particular topics and are more likely to be devoted entirely to those topics. Generally, directories provide a more focussed and organized approach to locating resources than search engines.

Most directories include an option to search by key word or phrase. This feature is intended to help users jump quickly to the appropriate section of the directory, not as a means of searching a large portion of the Web. Search engines are more useful for users that wish to search millions of sites for key words or phrases.

### *User Histories*

A user history is a log of the user's past interactions. Lee (1992) outlines several important benefits of support tools that allow users to refer to and incorporate their history in their current interactions :

- *user support capabilities rely on history information* : includes descriptive information (preferences, interaction style, skill level, etc.), interpretive information (errors, feedback, etc.), and functional information (about system interaction and adaption).

- *humans draw heavily from past experience* : users can avoid past errors, forego previous fruitless approaches, etc.

- *history-cued problem solving facilitates learning* : using actions from previous problem-solving episodes to generate actions for the current problem-solving episode

- *history information helps users cope with improvisation* : user histories can help users figure out how they dealt with uncertainties in the past

- *history tools relieve cognitive and physical burdens* : by reusing past approaches, users can rapidly repeat actions

The benefits outlined above justify the use of user histories along several dimensions (Lee 1992). User histories can be used for reuse (saving keystrokes and/or mouse strokes), error recovery (utilizing command/functions such as UNDO and REDO), reminding (deliberate or spontaneous activation of past knowledge or experience), user modelling (adapting system behaviour to the individual), user interface adaptation (adapting system appearance to the individual), and information navigation. In Section 2.2.2 we pointed out that users can easily become lost when navigating through large information spaces. Nielsen (1990b) suggests that user interaction histories can be used to help them understand and recognize their present location. Tauscher (1996a) agrees that improved history mechanisms can help to minimize navigation problems experienced in large hypermedia systems. For example, effective use of navigation history can help reduce some of these 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.

### *Summary*

The human-computer interface is probably the most important computer component to the decision maker or information seeker. It has the power to facilitate information access and decision making. According to our research framework, outlined in Chapter One, this section examined the user interface along the dimensions of presentation, organization, and access mechanisms.

Information may be presented in several possible modes, such as text, voice, image, video, animation, graphical or tabular data. Although there are many possible modes to chose from, interface designers should only use those modes that best convey the information to facilitate access and decision making behaviour.

Information may also be arranged in a structured or unstructured organization. Traditional database systems and organization by information abstraction are two common structured formats. Information abstraction has the power to reduce complexity, thus allowing the user to focus on more important facets of the decision making or information acquisition task. To reduce the cognitive effort of compensatory strategies, information abstraction can provide an aggregation or summarization purpose. For noncompensatory strategies, information abstraction can provide a classification purpose to help reduce possible arbitrariness of cutoff levels of eliminate alternatives. Among other benefits, abstraction can also help to stimulate creativity or formulate new questions.

Due to recent advances in telecommunications, a vast amount of information is now available through desktop computers at work, or even at home. This widespread access to information has driven the development of new powerful unstructured information organization such as hypertext and hypermedia. Although these systems provide great flexibility over traditional linear documents, this flexibility can often be at the cost of high cognitive overhead and a disorienting lack of contextual cues (Girill and Luk 1992).

Lastly, this section examined interface mechanisms that can be used to support the user in accessing information, such as search engines, directories and user history tools. Search engines are most useful for users that wish to search millions of sites for exact key words or phrases, while directories provide a more organized approach allowing users to "drill down" through a subject hierarchy. A user's past interactions (history) can also provide several benefits and can be used along several interface dimensions, such as support for information navigation. Navigation histories can help users to understand and recognize their present location in the information space, and reduce some of the problems inherent with large hypermedia environments.

## 2.4 Usability

Usability is the fourth and final component of the research framework, outlined in Chapter One. Although usability is a user interface measure, it also spans information access and decision making dimensions because these are affected by the user interface. A usable system will facilitate interaction with the system by making the interface "transparent" to the user, focussing attention on the mission and not the means. Usability can facilitate information access by presenting information in a manner that minimizes hindering moderators such as memory limitations and information overload. Usability can also facilitate decision making by applying some information structure to an unstructured information environment.

Researchers in this field agree that usability is not a single one-dimensional property, but has many aspects or components. Nielsen (1993) defines usability as having the following components: a) learnability ; b) efficiency; c) memorability; d) errors; e) satisfaction. Learnability is central to usability. This is the first experience users have with a new system, and most systems need to be easy to learn in order to allow users to start using the system within a minimal amount of time. Highly learnable systems allow the novice user to obtain usage proficiency within a short period of time. However, ease of learning may sacrifice interface efficiency. Ideally, systems should provide an interface with multiple interaction styles, where the user can learn the system through one interactive style, and later switch to another more efficient style for frequently used operations. Time necessary to reach this level of efficiency varies across system and user differences. In addition, some users may not reach a final state level of performance because they continue to learn indefinitely. For example, most popular wordprocessors offer both menu and function key based interactive styles. Working with a menu bar is ideal for the novice user. Menus and submenus are more time consuming than using function keys to perform the same tasks, and are therefore less efficient. However, function keys are much harder to learn initially. Ideally, users should learn the system quickly through the menu based interactive style, and once comfortable with the system, incorporate function keys to increase usage efficiency.

Memorability is concerned with having an interface that is easy to remember. This is an important aspect for casual users who use the system infrequently or intermittently.

Casual users have used the system before. Therefore they are not considered novices, and do not need to re-learn the system from "scratch". However the amount of re-learning may still be extensive if the system has poor memorability. Memorability can also be expanded to include aspects of interface presentation and organization of information. Properties of human memory limit how much information can be absorbed at one time. The user interface can present and organize information to help minimize the hindering effects of memory limitation. An interface that posses high memorability should ease memory burdens by being easy to remember and providing an information structure that can be easily absorbed.

The fourth aspect of usability concerns system errors. Errors are time consuming, frustrating and may have drastic results in lost/destroyed work. Errors should be minimized, and recovery assistance should be provided when errors do occur.

The final aspect outlined by Nielsen (1993) is satisfaction. Satisfaction is subjective to the user, and refers to how pleasant it is to use the particular system. While some systems rely more on this factor than others (i.e. entertainment systems), if the user likes interacting with the system he/she will be more likely to use the system. It may be difficult to accurately measure satisfaction levels toward a particular system, since users may be influenced by their attitudes towards computers in general.

Gould (1992) presents an eleven category classification of usability components, where information organization is considered a separate sub-component. The user interface can organize and present information to help add structure to an otherwise unstructured environment. Therefore, usability is a user interface measure than spans information access and decision making by facilitating these processes through interface presentation and organization of information. No matter how usability is defined, researchers agree that usability is made up of many important factors which are often mutually dependent. Designers must be careful not to be myopic and only concentrate their efforts on one aspect of usability.

### *Measuring Usability*

Several methods for measuring and evaluating usability have been developed by researchers and practitioners. This section is limited to the usability measuring methods most applicable to our research.

Usability testing refers to testing with real users. Users should be as representative as possible of the target end users of the system. In most cases, interfaces need to be tested with novice users as well as expert users. But before any subjects are used to test a system, it is important to define the purpose of the test since it has a significant impact on the type of testing to be done. If the purpose of the test is a formative evaluation, then the designers wish to learn the specific good and bad aspects of the interface, and how the design can be improved. A typical method for this type of evaluation is verbal protocol, in which the subjects "think-aloud". However if the purpose of the test is a summative evaluation, the designers wish to assess the overall quality of the interface. A typical method for this type of evaluation is a measurement test. Measurement tests require users to perform a predefined set of test tasks while experimenters collect time and error data. Some typical quantifiable usability measurements include (Nielsen 1993) :

- time to complete given task
- number of tasks completed within given time period
- number of user errors
- time to recover from user errors
- number of commands/feature used
- number of commands/features not used
- frequency of use of online help and documentation
- number of times the user displayed frustration, joy, or was sidetracked from the task

When conducting usability testing it is important to consider reliability and validity of the test. Reliability can be a problem due to individual differences that exist between users. In some cases these differences can be quite extreme, but these issues can be addressed through statistical tests. On the other hand, validity measures question whether the usability test gives meaningful results for real world applications of the system. Users may be influenced by the test laboratory setting. Other validity problems include using the wrong users, giving the users the wrong task, or not including appropriate time constraints and social influences. Validity issues can be addressed through methodological understanding of the test method employed as well as some common sense.

Other usability evaluators that can be used to supplement the above mentioned methods include observation, questionnaires and interviews, logging actual use, and user feedback. These methods are briefly discussed below.

- Observation : reveals the users' real tasks, and may suggest needed functions and features.
- Questionnaires and interviews : questionnaires give users' subjective satisfaction level with the system, but interviews give "richer" information since they are the most adaptive data collection process (Northcraft and Neale 1990).
- Logging actual use : collect statistics about the detailed use of the system.
- User feedback : initiated by the user in follow-up studies, but may not always be representative of the majority of the users or the majority opinion of the system.

### *Summary*

A usable system should be easy to use, efficient to use, easy to remember, error free, and pleasant to use. Usability can also be expanded to span across information access and decision making dimensions. A usable system can facilitate information access by presenting information in a manner that minimizes hindering moderators such as memory limitations and information overload. A usable system can also facilitate decision making by adding information structure to an otherwise unstructured environment. The more usable the interface is to the decision maker, the more attractive the system, and the more likely it will be used in practice. Usability can be measured through usability testing with real users, or by other evaluators such as questionnaires, interviews, user feedback, etc.

The next section will conclude our literature review by summarizing the research questions identified and the research goals of this study.

## 2.5 Research Questions and Goals

This section summarizes some research problems identified from the literature review. Our research goals are derived directly from these problems. We wish to address these issues, and further our knowledge and understanding in these areas.

In general, we have found that current literature tends to examine fields such as decision making, information access, and user interface in isolation. Few specific links or connections have been made across these fields. Beyond this general problem, our literature review has identified the following specific research problems :

(1) **Empirical studies have not investigated the potential relationship between decision making strategies and information access strategies**

(2) **The effects of individual characteristics such as cognitive style are rather inconclusive. Further studies in various problem settings need to be performed.**

(3) **Direct comparison between interface modes of presentation is difficult. However, text and voice can be directly compared when presenting the same information in the same context. Research in this area is lacking.**

(4) **Most studies examining the use of information abstraction focus on model and program design. In decision making tasks, the interface often forces an information structure. Research is needed to examine the natural tendencies of users to use information abstraction in a multiple alternative decision task where a structure is not imposed.**

(5) **The World Wide Web is a new and unique environment that lacks empirical research on navigation behaviour. Research is needed to investigate Web information access strategies under browsing and searching tasks.**

(6) **Web navigation support through history mechanisms is undervalued, and research into new tools is necessary.**

(7) **The application of abstraction in a Web navigation setting needs to be investigated.**

Our general research objective is to explore the interactive relationship among the components identified in our research framework : decision making, information access, and user interface. This investigation can provide design guidelines that will help the interface designer to develop usable systems that facilitate the information access and decision making process. Our specific research goals that address the specific issues listed above are :

(1) **To develop a further understanding of information access and decision making strategies through empirical research.**

(2) **To examine the effects of individual characteristics on the use of information abstraction in a multiple alternative decision making task.**

(3) **To make a direct comparison of voice and text output mode efficiency, effectiveness and preference.**

(4) **To examine how decision makers search an hierarchical information space when a structure is not imposed.**

(5) **To examine patterns in Web navigation.**

(6) **To develop a Web history navigation tool that allows hierarchical organization of information.**

(7) **To conduct an experimental study which evaluates the efficiency and perceived effectiveness of the proposed Web history navigation tool.**

Essentially, we wish to investigate decision making and information access behaviour (goals 1, 2, 5) and examine interface components that facilitate this behaviour.

Specific interface components that we examined in this research were voice and text output presentation mode (goal 3), information abstraction organization (goals 4, 7), and Web history mechanisms (goals 6, 7).

Chapters Three and Four investigate the interface presentation and organization components of output mode and information abstraction. These chapters are based on earlier experiments we conducted with a multiple alternative decision making task, and published in Archer et al. (1996a) and Archer et al. (1996b) respectively[2].

Chapter Five examines history mechanisms for supporting Web navigation. Existing history tools are examined and an advanced history tool that we developed is presented. Chapter Six reviews the experimental studies conducted using this tool, and Chapter Seven concludes our study by summarizing our findings, conclusions, and areas of future research.

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# Chapter Three

# User Interface Presentation : Text and Voice Output Modes[3]

This chapter examines the user interface presentation component of our research framework, outlined in Chapter One, by exploring the effects of text and voice output modes. We examined preferences and information access performance under voice, text, and both voice and text output modes. The individual characteristic moderator of cognitive style was also investigated in this context.

Multimedia computer systems are defined as those that transact or interact in more than one medium, i.e. which carry information in two or more formats of text, audio, graphics, animation, or video (Fox 1989). Although advances in multimedia computer equipment and software (Bly et al. 1993; Hodges & Sasnet 1993) have created many opportunities for developing more usable systems to support the decision-making process, the challenge remains to design good interfaces which take advantage of these additional communication modes. Previous studies into how such systems can most effectively support the decision process or how they may impact decision outcomes have been limited primarily

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[3] Based on Archer et al. (1996a). Copyright permission has been granted from the journal publisher to reprint portions of this material in this thesis. This author's contribution to this work included : design of the experimental interface, conducting experiments, and analysis.

to comparisons of graphical and tabular data presentation modes (summarized in a meta-analysis by Montazemi & Wang 1989). The multimedia computer interface designer must often consider multiple objectives, which can include minimizing information accessing effort, maximizing communication efficiency, matching user preference to presentation mode, and providing information in such a manner that it does not result in a mismatch with the user's individual characteristics, such as experience and cognitive style. As one would expect, it is not possible to meet all of these objectives simultaneously, but research is needed to determine how balance can be achieved in this variety of decision-making situations.

Traditionally, text had been the major input/output mode for human-computer communication, but voice communication between human and computer is now feasible through speech synthesis and voice recognition (Streeter, 1988). Since oral and written communication are the most widely used mode for verbal information exchange, it is natural to expect that people should be able to converse with machines as effortlessly as they converse with one another over the telephone. However, voice input/output technology is still not mature and requires more computing resources, including storage space and processing power, in comparison with text. In this study, text and voice output modes were compared, to investigate how either mode or their combination can affect user preferences and task performance in a decision-making situation. This type of study is essential to help point the way to more usable interface designs for the more powerful multimedia systems now available.

## 3.1 Dimensions of the Study

This study considered the dimensions of interface and user characteristics. The interface characteristics were represented by output mode (text, voice, or a combination of both) and levels of information abstraction. The user characteristics dimensions were represented by user experience level and cognitive style. This chapter only discusses output mode as a support tool. Information abstraction is examined in Chapter Four. The impact of user experience on the use and effectiveness of information abstraction, is also discussed in Chapter Four.

### Voice and Text Output Modes

With the current wide availability of multi-media computing, voice is often used in conjunction with visual information because it provides a complementary channel to assist users in assimilating information, information can be received without direct attention to the source, and the user can simultaneously attend to other tasks (Streeter 1988). Voice and text combinations provide a useful experimental platform because exactly the same information can be provided through each channel, giving an effective means of comparison.

There has been some research into the effects of using either voice or text or combined voice and text. Streeter (1988) stated that the major advantage of using speech in an interface is its universality; almost everyone understands spoken language. But one notable disadvantage is that voice delivers information at less than half the rate that text can be scanned usefully. A combination of voice and text output modes would also likely slow the information acquisition process. However, Nugent (1982) found that a dual modality output presentation tended to give subjects better comprehension and retention than single modality outputs. Sipior and Garrity (1992) found that presentations with a mix of audio and visual accompaniments improved receptiveness attributes such as perception, attention, comprehension, and retention. DeHaemer and Wallace (1992) suggest that, based on existing research results, the visual and aural modes of receiving information appear to be non-interfering and may enhance performance for certain tasks. They observed the effect of voice output on computer-supported decision making, where voice instructions were used to solve a visual decision problem, and found an interactive effect between user decision style and the use of computer synthetic voice. Chalfonte et al (1991) compared voice and text annotation in co-authored documents in terms of interactivity and expressiveness, and found that voice was preferred for addressing higher level issues in suggesting document modifications, but text was preferred for more detailed and lower level comments. Most previous studies either make intuitive comparisons between voice and text, based on their own characteristics, or compare them when they are used to represent different information or in different contexts. In our study, we singled out the effects of the voice and text modes and used more precise performance measurements.

## 3.2 Experimental Design

The objective of this study was to investigate how voice and text output modes affect user preferences and information access performance in a decision making setting. The effects of cognitive style on decision making were also examined.

## Hypotheses

### *Hypothesis 1 (Output Mode Preference)*

When representing the same information, a voice and text combination will be preferred by users over either voice only or text only, and text will be preferred over voice only.

### *Hypothesis 2 (Task Efficiency with Output Modes)*

Information access will be faster with an interface that uses text output, compared to one with voice output or with a combination of voice and text output.

### *Hypothesis 3 (Task Effectiveness with Output Modes)*

Decisions will not be affected by the voice or text output mode used in the interface when these modes contain the same information.

### *Hypothesis 4 (Task Efficiency with Cognitive Styles)*

Analytic individuals will take more time to make decisions than will heuristic individuals.

Hypotheses were based on the current literature discussed in section 3.1.

## Experimental Interface

During this study, we did not attempt to measure the quality of decisions made by users, but concentrated on the information access behaviour. To evaluate this behaviour and determine user interface preferences, a computer interface was developed to support a simple decision-making task. The decision task was similar to, but implemented differently from, the apartment selection task introduced by Payne (1976). In our experiment, the apartment selection task was designed so that each apartment choice had the same set of attributes organized in three levels of information abstraction. Information attributes were both qualitative and quantitative, of the type normally used in making apartment choices. Table 3.1 shows the attributes and their values for one of the apartments used in the study. The information was presented in small chunks in each attribute. The sequential nature of voice makes it necessary to present voice information in small and manageable chunks in order to reduce the disadvantages that it otherwise has in relation to text, which can be accessed randomly and at a viewer-controlled pace.

**Table 3.1**
**Example data for one apartment**

| Attribute* | Data |
|---|---|
| Overall | One bedroom, basement apartment, rather low price, good condition |
| Environment | Moderately quiet and well maintained |
| Landlord | Visits frequently |
| Noise | Near an elementary school |
| Cleanliness | Virtually spotless |
| Brightness | Dark, with one medium and two small windows |
| Rental | Rather low priced with a long term lease |
| Rate | $265 per month plus $65 for utilities |
| Lease | Twelve month lease |
| Location | Downtown Hamilton |
| Campus | 20-minute drive to campus |
| Shopping | Large shopping centre is two blocks away |
| Bus | Stop for buses going to campus is one block away |
| Parking | Outdoor parking |
| Interior | Small one bedroom apartment; living room, kitchen, full bath, two closets |
| Size | 8 x 10 foot bedroom, 12 x 12 foot living room |
| Closet | One closet in the bedroom, and one in the hallway |
| Kitchen | Dishwasher and dishes available |
| Features | Coin operated laundry available |

* Amount of indentation is related to abstraction level, with "Overall" at the highest level

The apartment selection interface, shown in Figure 3.1, was designed with Asymetrix Toolbook® software. A recorded female voice output was used instead of a synthesized voice to avoid potential problems associated with low quality synthesized voice. Information about a chosen apartment was not displayed unless selected by the subject, and then only for a limited time.

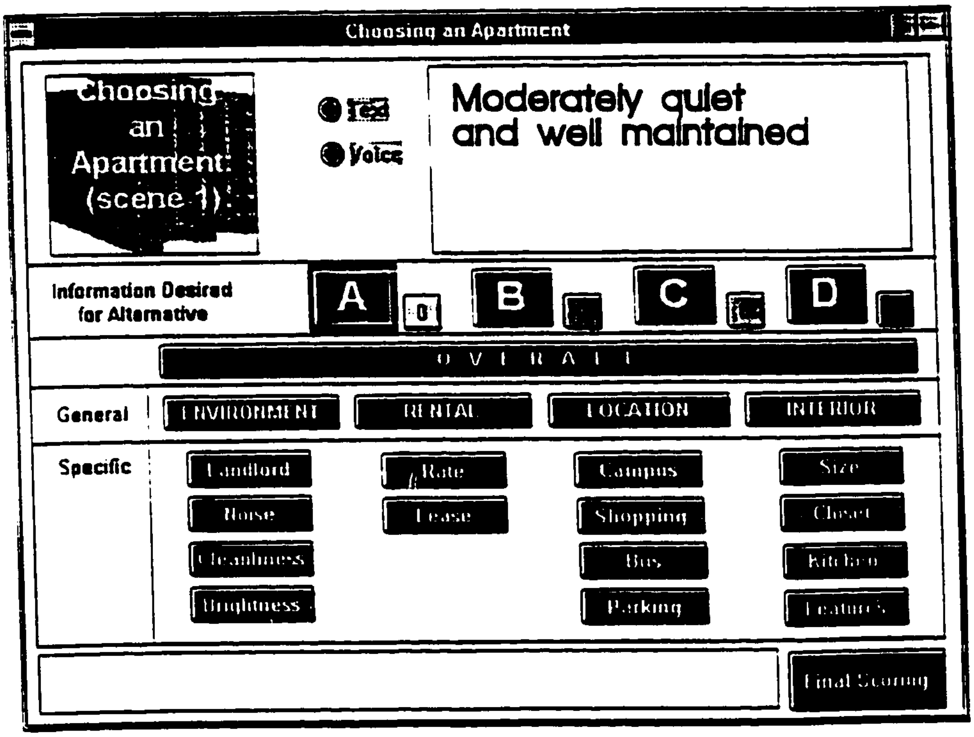


**Figure 3.1**
**Apartment ranking interface**

In our experiments, we used a constant number of four alternative apartments in each decision situation, which were referred to as a "scene". A scoring button shown beside each of the four Apartments (A, B, C, or D) in Figure 3.1 could be clicked at any time by the subject, to increment or decrement the score of any apartment between the values of 0 and 10, as a memory aid and as a means of "zeroing in" on a rating for that apartment. The final score assigned to each apartment was used to indicate the ranking of the apartment, with a higher score indicating a more desirable apartment. An additional memory aid was the black background colour for the data attribute buttons. This background colour changed to grey when the button had been selected by the subject, serving as a reminder of which information had been selected, but did not restrict the subject from returning to that information at any future time. No other memory aids were supplied.

Three output modes could be selected in advance by the experimenter for each scene. These modes allowed output either entirely by voice only (Voice), by text only (Text), or by both voice and text output of identical information (Both). The time taken to play back information from any of the buttons when in Voice mode was used as a standard, so if Text or Both (Voice and Text) modes were used, exactly the same time was used to display Text information as the equivalent voice output. However, the user could terminate an output and go on to another attribute at any time simply by clicking on the next attribute of interest. Text information was shown in a small pane at the upper right of the screen (see Figure 3.1). When voice was used, it duplicated the same information as the text output. When the subject completed analyzing data and scoring the apartments, the Final Scoring button could be clicked to leave the apartment selection process, and make any final score adjustments.

## Experimental Design

The experiment was a partial repeated within-subject unbalanced factorial design. The two factors were: Output Mode (Voice, Text, or Both (voice and text)), and cognitive Style (Heuristic, Neutral, or Analytic), blocked on Order (whether a scene was analyzed First or Second in order by the subject, to account for differences due to task or interface learning effects). The design was unbalanced because there were unequal numbers of subjects in the three cognitive style classifications, and it was a partial repeated design because each subject carried out a task with only two of the three possible interface types. Sixteen subjects were assigned randomly to each of the three groups. Randomization of subjects occurred along the following dimensions, and is summarized in Table 3.2 (numbers in parentheses indicate the number of subjects assigned per cell):

- Scene Assignment : two grouping (Scenes A&B, and C&D) of four scenes were randomly assigned
- Scene Order : the order of scene grouping was reversed for half the subjects

**Table 3.2**
**Apartment selection experiments: Subject assignment according to randomization elements**

| Voice vs. Text | | | | Voice vs. Both | | | | Text vs. Both | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Scene A&B | | Scene C&D | | Scene A&B | | Scene C&D | | Scene A&B | | Scene C&D | |
| A first (4) | B first (4) | C first (4) | D first (4) | A first (4) | B first (4) | C first (4) | D first (4) | A first (4) | B first (4) | C first (4) | D first (4) |

Each subject's task was to evaluate his or her apartment preferences in a scene on a numerical scale from 1 to 10 for the four apartments in a scene. This task was repeated with a different scene of apartments and a different output mode. An interface comparison questionnaire was then completed, where subjects entered their output mode preferences along usability dimensions.

Prior to the task, all subjects were given a short automated demonstration (using both Text and Voice) on how to use the system to search for information and to adjust scoring preferences for the apartments. They were then given a simplified problem with two apartments where they could learn directly how to use the interface, before moving on to the first of the two apartment ranking tasks. The total time required by a subject to train and to complete the entire apartment ranking process varied from about 20 minutes to 45 minutes.

### *Subjects*

Subjects were 48 MBA students (21 female, 27 male), and the median number of times they estimated they had conducted such an apartment search was 6.5. Almost all said they had searched for living quarters at some time in the previous year. MBTI results revealed that, in this group, there were twelve Analytics, five Heuristics, and thirty-one Neutrals, according to the Taggart and Robey (1981) classification structure. From these subjects, 92% had extensive computer experience, but only 55% had experience with computer-based voice output systems.

## 3.3 Findings and Conclusions

Specifics of the data analysis are not presented here. This section presents the major findings and conclusions for each of the hypotheses outlined in section 3.2. More detailed information on the data analysis is available in Archer et al. (1996a). Hypothesis 1 was analyzed with responses to questionnaires that compared the Voice, Text, and Both (Voice and Text) output modes. Hypotheses 2, 3, and 4 were tested by analyzing data collected during the experiments.

<u>Hypothesis 1</u> **When representing the same information, a voice and text combination will be preferred by users over either voice only or text only, and text will be preferred over voice only.**

This hypothesis was not fully supported by the apartment selection experiments. Users did have a preference for Both (text and voice) over Voice output modes, but there was no significant preference between Text and Voice, and there was no significant preference between Both (text and voice) and Text. These results imply that adding Voice to Text did not significantly alter the perceived utility of Text, but adding Text to Voice significantly improved its utility. A number of subjects commented that the combination of both modes helped them to remember the information better. This is in agreement with other published results (Nugent 1982; Baggett & Ehrenfeucht 1986).

During the experiment, when Voice alone was compared to Text alone, exactly the same information was presented to the subjects. The messages were short, with no opportunity for confusion, and the female voice used was clear. The only real difference would be due to the slowness of the voice interface, but this would not be directly apparent to users, who performed the apartment selection tasks separately with the two interfaces. Hence the two interfaces would appear to be roughly equivalent to users except for individual tastes or preferences. On the other hand, when voice is added to text in the Both interface, the additional voice output could have both a positive effect (assists remembering) and negative effect (slows the reading rate) on the text output. But adding text to voice in the Both interface brings only positive effects to voice output (assists remembering and increases communication rate). This advantage was evident to the subjects that compared Both to Voice, and hence the significant preference of Both over Voice. This finding has important implications. For example, we can expect that adding a small text display to a telephone interface could improve the usability of a telephone answering system, but adding voice to a computer interface which already displayed text would not improve the interface significantly.

<u>Hypothesis 2</u> **Information access will be faster with an interface that uses text output, compared to one with voice output or with a combination of voice and text output.**

Efficiency, measured by average scene length, of the Text interface was significantly better than with either of the other two interfaces. There was no significant difference between Both and Voice interfaces. Therefore, hypothesis 2 was supported. The Voice and Text combination has the effect of lengthening the average time taken before the user goes on to access another attribute (as compared to Text alone). This may be because the subjects' reading of the information was being disrupted (and therefore slowed) by speech, or it could indicate that some subjects were ignoring the text output and listening to voice output instead. However, the Both interface has an important universality characteristic: it is usable by people with either hearing or visual disabilities.

**Hypothesis 3** **Decisions will not be affected by the voice or text output mode used in the interface when these modes contain the same information.**

The interface design of the apartment selection experiment allowed us to measure performance dependency on output mode, because information content did not differ among the modes. Our results indicated that output mode did not have a significant impact on user ratings for the apartments. Therefore, this hypothesis was supported. We believe this is due to the fact that exactly the same information was available through each of the three interfaces. This result cannot be generalized to other interfaces which involve graphics, images, etc., since the information presented through these media is not the same. For example, although images and video are often used to present information in a pleasing manner, these modes frequently need to be augmented by text or voice to ensure that users receive all the information necessary to make a rational decision. To carry out fair comparisons between such interfaces is more difficult.

**Hypothesis 4** **Analytic individuals will take more time to make decisions than will heuristic individuals.**

Cognitive style was not a significant factor for output mode preference, but it was significant in measuring relative time taken per attribute. Heuristics moved on to the next attribute on average when less than 90% of the presentation time was completed, while Analytics stayed on for an average of 120% of the available presentation time. Hypothesis 4 was supported for relative presentation time per attribute reference, but, in terms of scene length, cognitive style was not significant. It appears that, although Heuristics spent less time on each attribute, they looked at more attributes before reaching the final decision. In contrast, Analytics spent more time on each attribute, made a more careful evaluation and looked at fewer but more relevant (to them) attributes in order to reach the final decision. Thus, the overall time spent for information gathering for different cognitive styles was roughly the same. The lesson for multimedia interface designers is that the interface should not, inadvertently or otherwise, favour one style over another because cognitive style may affect how the interface will be used. For example, putting pressure on the user to assimilate information as fast as possible may degrade user performance if the user's personality is not suited to that style of information gathering.

### *Summary*

In this chapter, we examined the effects of user interface presentation output modes of voice and text on information access in a decision making environment. It was shown that current literature lacks precise performance measurements for voice and text output. A study performed by Archer et al. (1996a) was reviewed, that investigates the effect of voice and text output modes on user preferences and task performance in a decision making setting.

A computer interface was developed to support an apartment selection decision-making task. Subjects performed two selection tasks using two of the three available output modes : voice only (Voice), text only (Text) and a combination of voice and text (Both). The information provided by the Voice and Text modes was identical, thereby allowing us to analyze efficiency and performance dependency measures.

It was found that Both was preferred over Voice, but there was no significant different between Text and Voice and Both and Text output modes. It seemed that by adding

Voice to Text, a positive effect (assisting remembering) as well as a possible negative effect (slowing reading rate) were added. By adding Text to Voice, only positive effects (assisting remembering and increasing communication rates) were added.

For information access performance, Text was more efficient (shorter decision time) than Voice or Both. We suggested that Voice may disrupt or replace the reading of information. However, scoring decisions were not affected by the output mode. The Both interface has an important universality characteristic: it is usable by people with either hearing or visual disabilities. Since it compares well with Text in all aspects except efficiency, this makes it a promising approach for such users.

Finally, the effects of cognitive style on the efficiency of decision making task were examined. It was found that Heuristics spent less time on each attribute, but looked at more attributes before reaching a decision than Analytics. Multimedia computer interface designers should be careful not to favour any one style over another, since decision makers' cognitive style may determine how the interface is used. Ideally, output mode and data display speed should be under the control of the user as much as possible.

This chapter investigated the user interface presentation component of our research framework, outlined in Chapter One, by exploring the effects of text and voice output modes. The next chapter examines the interface organization component of information abstraction in a decision making environment. The study performed by Archer et al. (1996b) is extended to this discussion.

# Chapter Four

# User Interface Organization : Information Abstraction[4]

This chapter examines the user interface organization component of our research framework, outlined in Chapter One, by exploring the effects of information abstraction on information access and decision making. The individual characteristic moderator of user experience was also investigated in this context.

The use of computers to support decision making continues to expand rapidly, encouraged by the much more widespread availability of advanced technology in the form of inexpensive hardware, flexible software, user-oriented interfaces, and network and multimedia capabilities. These allow decision support systems (DSSs) to provide information to decision makers in a wide variety of formats and output modes. Recent advances in communications technology have also made available to users large amounts of information on diverse topics, accessible at many sites and in a number of forms. But these new technologies currently outpace an understanding of how the information they provide can be accessed, selected, organized, and presented through suitable interfaces in supporting and/or influencing decision making (Benbasat & Nault, 1990).

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[4] Based on Archer et al. (1996b). Copyright permission has been granted from the journal publisher to reprint portions of this material in this thesis. This author's contribution to this work included : design of the experimental interface, conducting experiments, and analysis.

Research on the use of decision making strategies for alternative choice/ranking problems, where available information is accessed at will by the decision maker, has not evaluated the impact of hierarchical data structures. Since many computer-based decision making applications involve information retrieval through constrained structures such as hypermedia and menu systems, it is of great interest to understand how the decision maker's information access and decision strategy preferences would be manifest with hierarchical data structures in the absence of such constraints. We believe that a great deal may be learned by studying such strategies, since this could be helpful in the provision of decision support in a more natural fashion which suits the user's importance structures, rather than forcing the user to adapt to a system's particular data display structures. In our study, we examined the cognitive behaviour of users accessing information at will at different abstraction levels without any system-imposed constraints. The effect of user experience on information abstraction access was examined, and an exploratory study was undertaken to develop an understanding of the information access strategy and the decision strategy used, and whether these strategies were related.

## 4.1 Dimensions of the Study

The experimental interface discussed in this chapter is the same as the one presented in Chapter Three. An apartment selection decision task setting was used to examine the effects of organization (information abstraction) and moderator (individual differences) components on information access and decision making strategies. The particular individual difference examined in this Chapter is user experience.

## Information Abstraction

At different phases of the information access process, a decision maker may need information to be represented at different levels of abstraction, from the higher levels containing less and more generalized information, to the lower levels containing more detailed and specific information. Information abstraction is widely used in many forms to reduce complexity in information acquisition and problem solving (Ossher 1987). It can help users to focus on certain facets of the problem, to deal with the problem at a desired level of complexity, and to think about the problem rather than being occupied with unnecessary details.

Levels of abstraction are often predetermined by system designers and are organized in a top-down hierarchical structure. Among the most commonly used techniques are menu selection and the use of windows in a user interface (Norman et al 1986). With these interfaces, users are forced to access information in a top-down manner. To assess the true preference and usage of information abstraction in interface design, it is important to ensure that users do not need to use different amounts of effort to access information at different abstraction levels, since Todd and Benbasat (1993) have shown that decision makers tend to access information in a manner which minimizes effort. In our experimental interface design, we attempted to minimize any difference in effort required to access information at different abstraction levels.

In this exploratory study, information access patterns were examined according to search direction, information access strategies, and decision strategies. Search Direction indicates the subject's preference for search by alternative or by attribute, as defined by

Payne (1976), and refined by Todd and Benbasat (1991). This is essentially a measure of "horizontal" or "among alternative" search strategy preference, which has been found to correlate with decision strategy (Payne 1976, Cook 1993).

A pure top-down information access strategy strictly follows a hierarchical tree menu structure. Any transitions that violate this strategy are opportunistic transitions, where a transition is defined as movement between two successive attribute accesses from the same alternative (whether or not these retrievals are interrupted by retrievals from other alternatives). A transition is opportunistic if a) it does not enter the structure at the highest abstraction level of a given alternative, b) it moves downward to lower level attributes in a different category, or c) it moves directly from one category of attributes to another.

## User Experience

Nielsen (1993) indicates that user experience has three main dimensions: experience with the system, with computers in general, and with the task domain. All of these types of experience may have an impact on how users utilize data presented through a computer interface. For example, Archer and Kao (1993) found that users with domain experience were much more likely to make use of high level abstractions in problem solving. Batra and Davis (1989) also found that users experienced in the task domain focussed on generating an holistic understanding of a problem before solving the problem, but novices tended to have an inability to map parts of the problem description into appropriate knowledge structures. The ability to reason about a problem depends upon previous experience in that domain, since this provides a framework or schema with which to structure known information (Staggers and Norcio 1993).

## 4.2 Experimental Design

The objectives of this study were a) to determine whether users use top-down information access strategies when they are not forced by the interface design to do so, b) to classify the patterns of information access strategies that users prefer to use, c) to determine whether a propensity for top-down search is related to the decision strategy used, d) to determine whether the use of a top-down strategy will change over the duration of the information access process, and e) to determine whether user task experience has an effect of information abstraction use. Since this was largely an exploratory study, no hypotheses were stated.

### Experimental Interface

The experimental system was the same as the one presented in section 3.2. Subjects were asked to score four alternative apartments, referred to as a "scene", followed by the evaluation of another scene of four apartments. There were a total of nineteen attributes including fourteen attributes at the Specific (most detailed) level of abstraction, four attributes at the General (intermediate) level of abstraction, and one attribute "Overall" at the highest level of abstraction. The intermediate level attributes were generalizations of the most important information from their subsidiary low level attributes, and the top level attribute highlighted certain overall information. Table 3.1 in Chapter Three shows the attributes and their values for one of the apartments used in the study. The same attributes and relationship structures were available for all the alternatives, and users could easily switch among alternatives at will, with simple mouse button pointing and clicking. This allowed users to evolve their own individualized search strategies, giving them the choice of either using or not using the explicit hierarchical structures displayed in the data. At the same time, there was nothing to inhibit them from changing their search strategies during the problem-solving process.

The particular interface design we chose was oriented towards alternative processing because information abstraction tends to be useful mainly in this context. Information search by alternative was the least-effort search strategy since attributes were organized by alternative, and attributes for a particular alternative at any level of abstraction could be accessed by one mouse click . If the subject chose to use an attribute search strategy, the selection of a series of the same attribute across multiple alternatives would require two mouse clicks for each attribute accessed; one to select the alternative and another for the attribute. According to Jarvenpaa (1989), the natural desire to minimize effort and errors helps to explain why researchers (Huber, 1980; Russo & Dosher, 1983) have found that individuals tend to choose less attribute processing when using text data than when using numerical data. In our case, the data format was predominantly text. We believe that such an interface was congruent with the tendency of most users to prefer alternative processing for such a task, and would lead to a higher likelihood of information abstraction use.

## Experimental Design

The main experiment consisted of 48 task domain experts. This experimental design is outlined in section 3.2, and not re-iterated here. Since we wished to examine the effect of domain experience on abstraction use, a subsidiary experiment was conducted on 22 non-task domain experts. The non-experts used the same interface in the same manner as the experts of the main study. Although the subsidiary study did not allow a complete evaluation of the three interface pairings described in Chapter Three (Text, Voice, and Both), it was sufficient to investigate information abstraction use.

### *Subjects*

In our experiment, we drew upon two different levels of students for subjects: MBA students who were experienced in apartment search, and high school students who had no experience in ranking and selecting alternative living accommodations. A total of 76 subjects participated in the experiment. 48 were MBA students, all of whom had experience in searching for and selecting living accommodation (an average of 6.5 times per student). The remaining 26 subjects were students at a nearby high school, 6 of whom had some experience in searching for living accommodation, while the remainder had no such experience. Of the 76 subjects, 38 were male and 38 were female. Subjects were relatively familiar with computers and graphical user interface interactions.

## 4.3 Findings and Conclusions

The exploratory analysis was performed to investigate user information access patterns and user experience effects on information abstraction use. Specifics of this analysis are not presented here. This section presents our major findings and conclusions. More detailed information on the data analysis is available in Archer et al. (1996b).

### Search Patterns

A relatively large number of the subjects (57%) used a pure alternative search, which is to be expected from an interface which favours this approach. Subjects were also classified into the following groups :

- primarily top-down behaviour (29%)
- primarily opportunistic behaviour (17%)
- combined top-down/opportunistic behaviour (54%)

Our findings indicate that the majority of the subjects used the higher abstraction levels to some extent in retrieving and evaluating information, and that most of these subjects used top-down information access strategies at least part of the time. Davies (1991) observed that the top-down strategies adopted by computer program designers tended to vary over time in the degree of opportunism exhibited. Our study also revealed that there was a consistent difference among the three subject groups throughout the information access process. The degree of top-downness did not affect the tendency to become more opportunistic as the end of the process was approached. Even the basically opportunistic subjects became significantly more opportunistic as they moved through the search process. A possible explanation for this observed tendency was that users tended to retrieve and analyze data in a more organized and top-down manner during the early stages of the search, but become increasingly opportunistic as the search progressed, in order to selectively pick out certain attributes, to repeat retrievals of data which may have been forgotten, or to evaluate specific attributes against the user's current and evolving opinions of the relative value of the alternatives being considered.

It was also discovered that search direction and decision strategy were related to top-down information access. A more top-down strategy was related to a more alternative-oriented search, and pursuing a compensatory decision strategy was congruent with a top-down information access strategy. An implication of this in interface design is that, while decision strategy used (compensatory versus non-compensatory) may depend upon the number of alternatives presented to the user (Payne 1976), with a consequent effect on between-alternative (or attribute) search strategy, this may also carry over into a corresponding effect on the within-alternative (top-down) information access strategy. Although further studies are required to confirm this, we can anticipate that, since a larger number of alternatives tends to lead (Payne 1976) to more non-compensatory decision strategies, this will also lead to more opportunistic within-alternative searches.

## User Experience

We found that being an expert or non-expert in the domain did not affect the information access strategy. The implication of this result is that the individual user's needs for information determine the access strategy used and we cannot assume, for example, that expert users should be supplied with an interface which forces a top-down or any other approach. On the other hand, we note that user experience was found to be important in an analysis of top-down strategy in computer program design (Davies 1991). It is possible that the difference in our findings may be partly due to fundamental differences between problem solving through information search and problem solving by creating a computer program or model.

In this study, we have observed that when data are structured hierarchically, most users tend to access the data part of the time in an hierarchically top-down manner, punctuated by opportunistic episodes where attributes are accessed as the need arises, rather than in a completely organized hierarchical manner. On the other hand, we found that domain experience did not significantly affect the information access strategy. These findings have implications in terms of the design of decision support systems. The first is that hierarchical data structures can be helpful in decision-making based on data retrieval. The second is that users should not be constrained to access the data hierarchically, since this would tend to interfere with their tendencies towards branching into opportunistic episodes. This could affect the decisions made, since users prefer a least effort approach (Todd & Benbasat 1993) and would be less likely to access as much information in a constraining environment.

### *Summary*

In this chapter, a study performed by Archer et al. (1996b) was reviewed, that examined the effects of information abstraction on information access and decision strategies. Search patterns were studies in a three-level hierarchy of information abstraction, according to search direction, information access strategies, and decision strategies. The effects of user domain task experience on the use of information abstraction were also investigated.

A total of 76 subjects were asked to perform a multiple attribute alternative ranking tasks, with an interface that allowed equal access to detailed data and two higher levels of data abstraction. We found that, when users were not constrained by any built-in structure in their choice of information, there was a spectrum of use which combined various proportions of top-down search with opportunistic episodes. Our most important findings were that the propensity to use top-down information access strategies a) was directly related to a tendency to use compensatory decision strategies, b) became less over the time of the search in favour of a more opportunistic approach, c) was related to the likelihood of using an alternative search strategy, and d) was independent of domain experience. An implication of these findings is that, in order for a data retrieval interface to be implemented successfully, users should not be constrained by the system to follow a built-in search strategy, but should be allowed to develop their own information access strategies through the use of a flexible interface.

This chapter investigated the user interface organization component of our research framework, outlined in Chapter One, by exploring the effects of information abstraction on information access and decision making strategies. The next chapter examines the interface access mechanism of user histories applied to the World Wide Web environment. Existing history mechanisms for intra- and inter-sessional support are outlined, and a new tool that we developed for both intra- and inter-sessional support is presented.

# Chapter Five

# User Interface Access Mechanisms : World Wide Web History Tools

This chapter examines the user interface access mechanism component of our research framework, outlined in Chapter One. We apply our discussion of user histories to the World Wide Web environment, presenting existing Web browser history mechanisms and introducing a new tool that we developed for providing both intra- and inter-sessional support.

Nielsen (1990b) suggests that interaction histories can be used to help users understand and recognize their present location within a complex database. Tauscher (1996a) agrees that improved history mechanisms can help to minimize Web navigation problems. For example, effective use of navigation history can help reduce some of the Web navigation problems outlined in Chapter 2 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.

History mechanisms used by Web browsers include backtracking, already-visited cues, bookmarking, and history lists. Backtracking and history lists are intra-sessional memory aids that allow the user to navigate back to previous sites visited within the current session. Already-visited cues and bookmarking are inter-sessional memory aids that allow the user to examine pages visited during a previous session. Two studies have examined the use of standard history mechanisms used by most Web browsers. Table 5.1 provides some summary statistics, where Study 1 results are taken from Catledge and Pitkow (1995), and Study 2 results are from Tauscher (1996b).

**Table 5.1**
**Percentage use of navigation actions in published studies**

| Navigation Action | Study 1 | Study 2 |
|---|---|---|
| Backtracking | 42.6% | 31% |
| Bookmarking | 2% | 3% |
| History Lists | 0.1% | 0.7% |

Browsers use memory and disk caches to save Web pages and images that have been examined. For example, Netscape Navigator 3.0 allows the user to specify the amount of memory (RAM) and disk (storage) cache to keep local copies of Web documents and thus reducing subsequent display times. The user can also specify how often current Web pages should be compared to the version saved in cache. Netscape can compare the cached version with the server: a) each time the page is browsed, b) only the first time the page is accessed during a navigation session, or c) never. History mechanisms are supported by the browser caching system, but the speed of page retrieval is affected by cache preference settings.

## 5.1 Intra-sessional History Mechanisms

Web browser intra-sessional history mechanisms of backtracking and history lists are discussed in this section. Overview diagrams are not standard tools incorporated within Web browsers, but such devices have been developed as add-ons by independent institutions.

### Backtracking

A backtrack is a simple concept where a user clicks on a button and returns to the previous page. Web browsers allow for backtracking by supplying a "Back" button to press or a menu item to select. A "Forward" option is also available on most browsers, which undoes the effect of Back. Nielsen (1990a) points out that a problem arises when the user backtracks more than once and when the user visits certain pages more than once. Current Web browsers interpret Back and Forward actions as downward and upward movement on a history list that operates as a push-down stack. The most recently visited page is usually pushed onto the top of the stack (Tauscher and Greenberg 1996). Recalling a previously visited page by using the Back button or history list selection moves the stack pointer to the currently displayed page in the stack. Loading a new page adds the page to the top of the current stack pointer position. This might result in losing all pages above the current stack pointer position. For example, Table 5.2 shows a simple navigation trace using the stacking routine of Netscape Navigator 3.0, where pages are accessed by pressing URL (Uniform Resource Locator, a Web page's Internet address) hypertext links or using the Back button. After the third page is visited (Hamilton Air Show - Schedule), the back button is pressed twice to return to the Q778 Internet Mall. The current stack pointer is now positioned on the original Q778 Internet Mall that was accessed as a start-up document. When Bio-Soft is viewed by selecting a URL link, it is pushed on top of the current stack pointer, thereby popping off all sites above it (Table 5.3(a)). However, if a page is revisited through a URL link, it gets pushed onto the top of the stack once again (Table 5.3(b)).

Therefore, the history stack is not a true trace of the user's navigational pattern. Depending on how the page is loaded, it may pop several pages from the stack or add duplicate information to the stack. Since Back and Forward actions move the pointer down and up the stack, users may be surprised when the pages that are loaded 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.

**Table 5.2**
**Navigation trace**

| Order | Title of Visited URL | User Action |
|---|---|---|
| 7** | Q778 Internet Mall | URL Link |
| 6* | Bio-Soft | URL Link |
| 5 | Q778 Internet Mall | Back |
| 4 | Hamilton Air Show - Introduction | Back |
| 3 | Hamilton Air Show - Schedule | URL Link |
| 2 | Hamilton Air Show - Introduction | URL Link |
| 1 | Q778 Internet Mall | Start-up Document |

**Table 5.3**
**Browser history stack**

(a) at point *

| Position | Title of Visited URL |
|---|---|
| 0 | Bio-Soft |
| 1 | Q778 Internet Mall |

(b) at point **

| Position | Title of Visited URL |
|---|---|
| 0 | Q778 Internet Mall |
| 1 | Bio-Soft |
| 2 | Q778 Internet Mall |

## History Lists

Most browsers provide a history list feature that can be shown in a drop down menu or a separate window. These lists are not true navigation lists, but operate as a stack. As with backtracking, users may be surprised and confused when the list does not follow their conceptual navigation model.

Browsers differ in the ordering of history items. For example, Microsoft Internet Explorer and NCSA Mosaic display the most recent pages at the bottom of the list, while Netscape shows the recent pages at the top. Netscape 3.0 offers two options for viewing the history stack : the Go List which is found under the Go menu (Figure 5.1), and the History Window which is opened through the Window menu (Figure 5.3). The History Window displays both the page titles and URLs but requires horizontal scrolling. Page titles must be of limited length, or they are truncated. Several slots in the history list may display the same duplicate information due to the nature of the history stack. The Go List provides the same information, but only shows page titles. Internet Explorer 3.0's Go List (Figure 5.2) is similar to the Netscape version, but the stacking routine used by Internet Explorer is somewhat different. The Go Lists shown in Figures 5.1 and 5.2 are the result of identical navigation sessions. Internet Explorer's Go List has fewer duplications, but more pages have been "popped" from the history stack. In general, the intra-sessional history lists provided by commercial Web browsers are rather inflexible and unfriendly.

Although most history lists provided by Web browsers are intra-sessional, Microsoft's Internet Explorer offers an inter-sessional History Folder (Figure 5.4), which is a sorted list of all pages visited in past sessions. The user may decide how long (in terms of

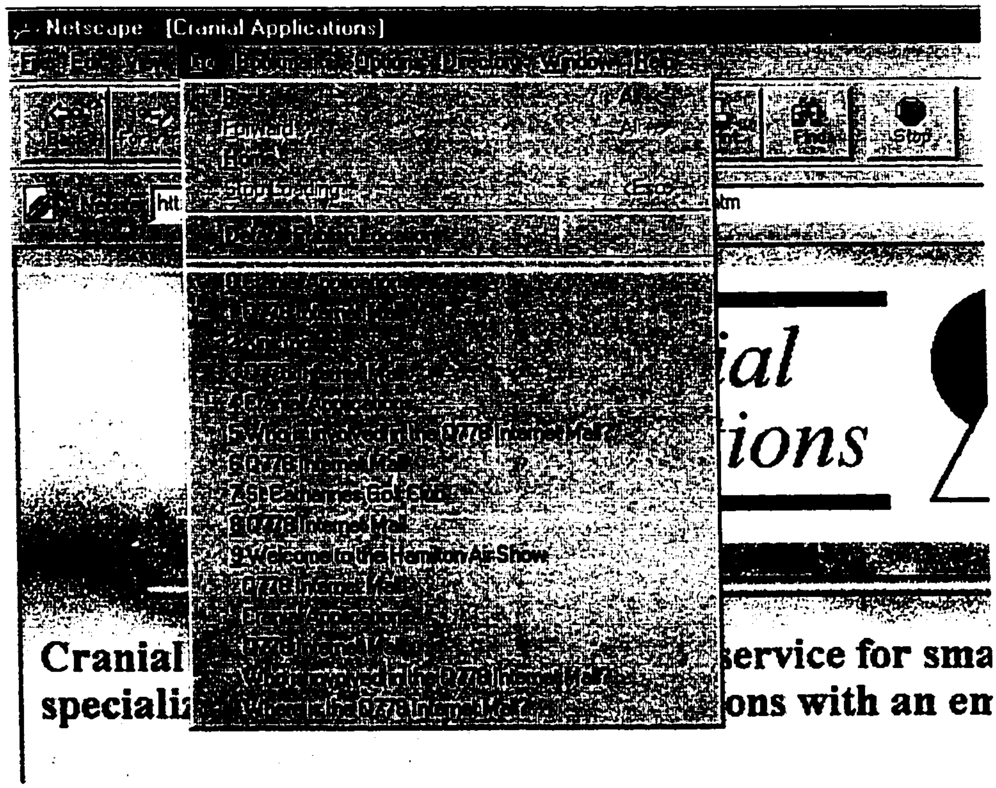


**Figure 5.1**
**Netscape 3.0's Go List**

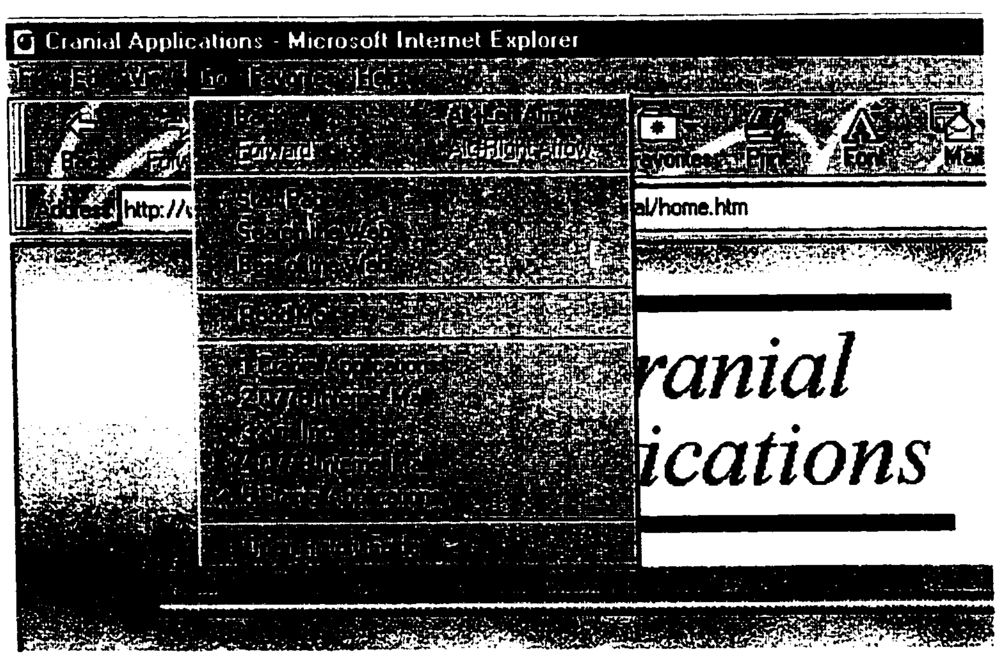


**Figure 5.2**
**Internet Explorer 3.0's Go List**

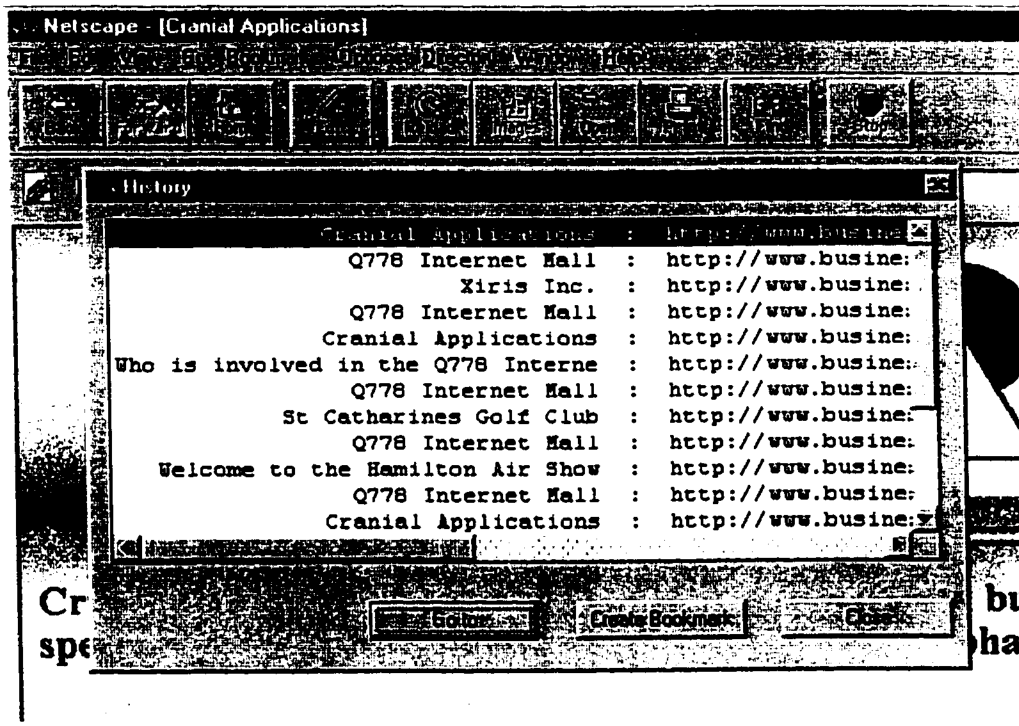


**Figure 5.3**
**Netscape 3.0's History List**

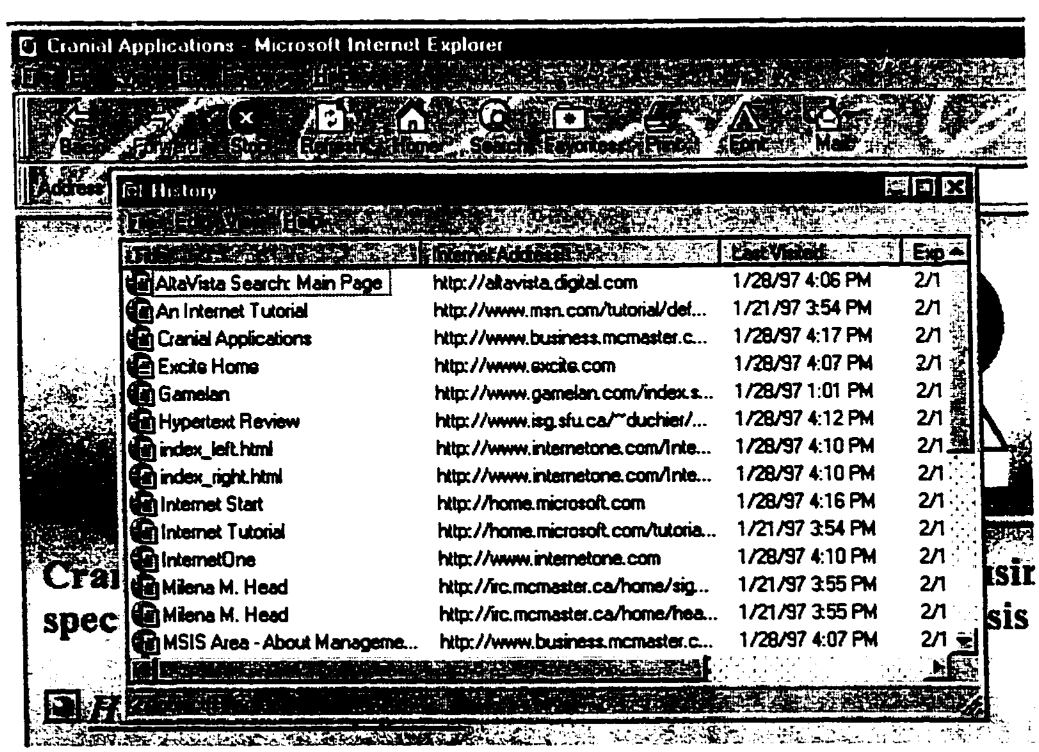


**Figure 5.4**
**Internet Explorer 3.0's History Folder**

days) pages should be kept in the History Folder, and may choose to view a small or large icon display, or a short or detailed list. The detailed list allows the user to view a Web page's title, address, date of last visit, date of expiration from the folder, and the last updated date. The user has the option to view the history list sorted according to any of the above fields in increasing or decreasing order. Items may be deleted from the History Folder, but the user may not edit or modify any of the information. Web page titles are assigned by the page creator and may not have a meaningful representation for the user, and prepositions such as "a" and "the" will place the page in an unnatural alphabetical position when sorted by title. In addition, the user cannot rearrange sites or group them according to meaningful topics.

During the time of our study, Microsoft Explorer 3.0 and Netscape 3.0 were the latest versions of these browsers. However, since then Microsoft and Netscape Communications released their 4.0 version. Explorer 4.0 organizes user histories in folders for previous days and weeks, but does not allow rearrangement or regrouping of sites. The stacking routines and Go Lists for these new versions have not been modified from previous 3.0 versions. The Netscape 4.0 History Window is similar to the Internet Explorer 3.0 History Folder, which is a list of pages visited during the last specified number of days. A history expiration of 9 days is the default for Netscape 4.0. Users may view, sort, and search the list by title, location (URL), first visited, last visited, expiration, and visit count fields. However, like the History Folder, users may not edit or modify any of the information, and sites cannot be rearranged or grouped according to meaningful topics. Although these mechanisms attempt to provide some inter-sessional support, the lists can quickly become very long and unmanageable. List length can be kept under control by decreasing the history expiration, but users may find themselves searching for information that was accessed weeks before, not days before. In addition, these mechanisms do not differentiate between different users. One computer and browser, may be shared by many users, such as a typical household. These history lists keep track of all pages visited by the browser, and the lists can quickly become very long and complicated by excessive irrelevant sites for any particular user.

## Overview Diagrams

An overview diagram gives a two-dimensional representation of hyperspace. The main advantage of this type of graphical representation compared to a flat linear list is that it provides information about the hyperspace structure. In large hypermedia structures overview diagrams can only give information about the local neighbourhood of pages, and must usually provide at least two levels of detail.

Smith and Wilson (1993) argue that the most appropriate types of navigation devices are those that are spatially based. Cognitive spatial maps not only help users regain their bearing after a sidetrack, but also enable short cuts to desired locations. Overview diagrams should provide an answer to the question : "how did I get here?", and might also answer "where do I go from here?". These two-dimensional representations help give users a conceptual model of the local hyperspace. A model promotes information organization and system understanding, and thus may help to minimize confusion and errors (Staggers and Norcio 1993).

Although overview diagrams can serve as excellent navigational aids, for large systems they become complex and introduce navigational problems of their own (Nielsen 1990a). Within the context of the Web, Smith and Wilson (1993) identify some problems with graphical browsing: large number of nodes; large number of links; frequent changes to the network; insufficient visual differentiation among nodes and/or links; and users who are not visually oriented. With limited screen space, graphical navigational tools can only show a very small portion of the hyperspace structure at one time. Nielsen (1990a) refers to this inability to view large amount of information at any one time due to the small size of computer displays as a context-in-the-small problem. Readability becomes a central concern. Creating an aesthetic layout of a complex structure is extremely difficult. If the size of the diagram is reduced to fit a monitor screen, the details become too small to be seen. However, just displaying the structure without corresponding details is inadequate. Details must be available so the user may navigate to a specific page. The user should be able to get able to get an idea of not only the structure but the actual contents of the nodes and links just by looking at the navigational views (Mukherjea and Foley 1995).

An alternative to multilevel overviews is a fisheye view algorithm which is similar to looking at a scene with a wide angle lens - things of greater interest will be at the center, while items of lesser interest will be on the periphery (Balasubramanian 1994). Lamping et al. (1995) incorporated this fisheye technique by mapping a large hierarchy into a circular display region. This display initially shows a tree with its root at the center, but can be transformed to bring other nodes into focus. The node in focus always includes several generations of parents and children in its display. The implementation of fisheye views requires two properties of the information space (Nielsen 1990a) : it must be possible to estimate the distance between a given location and the current focus of interest, and it must be possible to display information at several levels of detail. Unfortunately, it is very difficult to meet these conditions in unstructured hypermedia systems such as the Web.

Some overview diagrams have been developed as add-ons to graphical browsers. These projects can be categorized as "exploratory" or "reflective". In the exploratory approach, the user may visualize the local space without having to visit any of its pages. A server, or set of servers, must be queried by the client as a batch job to determine the structure of documents and to generate a display when user browses the space (Ayers and Stasko 1995). These queries are time-consuming and resource-intensive for the server(s) involved, and this approach is largely infeasible in the highly unstructured Web environment. On the other hand, a reflective approach builds a representation of the hyperspace during user navigation. Only those pages that have been visited by the user are visualized. Although the exploratory approach is not a true history mechanism since it incorporates pages that are not part of the user's history, both methods are discussed below.

### *Exploratory Tools*

Navigational View Builder is a tool that provides the user with different hierarchies, each giving a different perspective to the underlying information space (Mukherjea et al. 1995). It uses four strategies to form effective views (Mukherjea and Foley 1995):

- *binding* : Visual properties (such as colours and shapes) can be used to represent information from the underlying information space. Users can specify the bindings between the information attributes and the visual attributes of the nodes and links.

- *clustering* : Abstractions may be formed that cluster files (in the same directory, or sharing a certain attribute) into a single node.
- *filtering* : The user may remove unwanted information.
- *hierarchization* : An algorithm that forms hierarchies from hypermedia graphs.

Figure 5.5 shows a portion of a Navigation View Builder overview diagram (Mukherjea 1995) for the research activities at the Graphics Visualization and Usability (GVU) Center at Georgia Tech (URL: http://www.gatech.edu/gvu/gvutop.html). This figure clearly indicates why large scale overview diagrams are useless in a real-world hypermedia systems (Mukherjea et al. 1995). Using the strategies outlined above, Figure 5.6 shows only those pages that are linked to both images and movies. Currently this system only runs on the GVU research Web pages (approximately 400 nodes and 800 links), and takes about 7 seconds to run the hierarchization algorithm. The Navigation View Builder requires semantic information to create meaningful hierarchies. This information, such as distinctions between research and personal pages, was manually inserted into the GVU pages. Unfortunately, Web pages offer few useful semantic attributes, but efforts are underway to extract meaningful information from these pages automatically.

WebMap is another exploratory tool that can be added onto the NCSA Mosaic browser (Dömel 1994). Nodes are displayed without URLs or titles to conserve screen space. As a mouse cursor is moved over a node, the page title and URL are displayed in the bottom portion of the WebMap window. Several graphic layouts (Figure 5.7) may be presented to the user alternatively or simultaneously. Another useful feature of WebMap is the possibility to store the whole map and load it during another session.

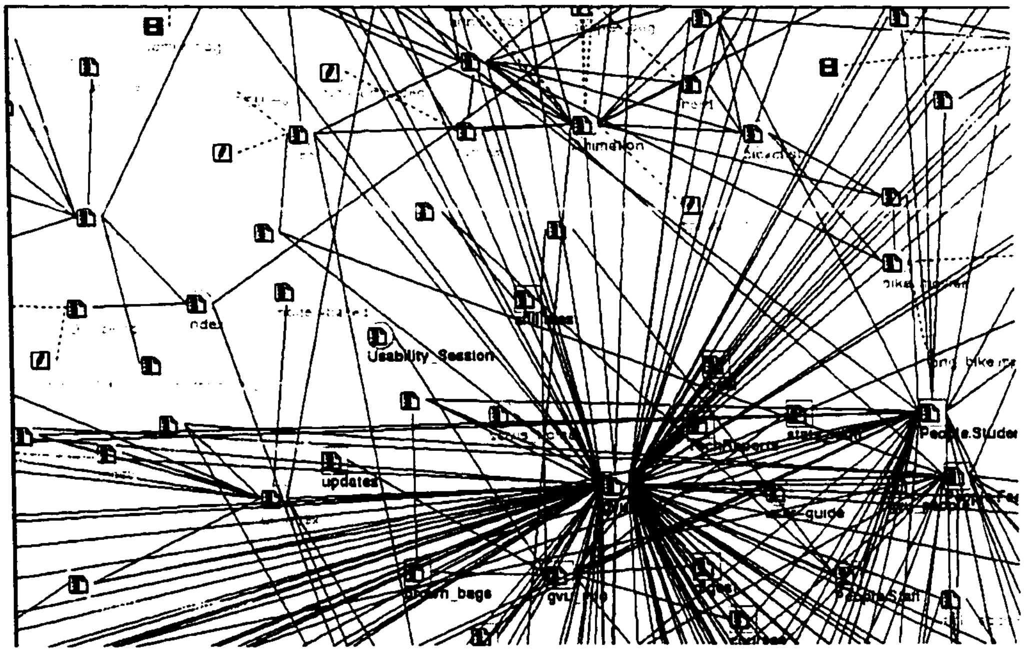


**Figure 5.5**
**Navigation View Builder : Portion of an overview diagram for the Web pages about research activities at GVU (Mukherjea 1995)**

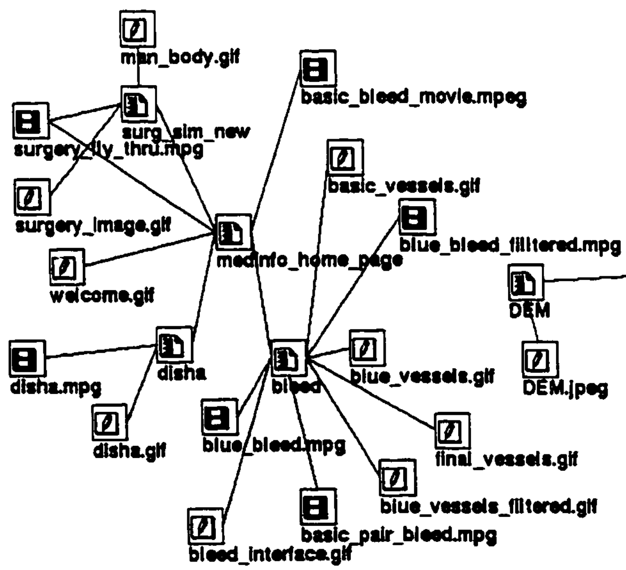


**Figure 5.6**
**Navigation View Builder : Filtered pages that link to images and movies (Mukherjea 1995)**

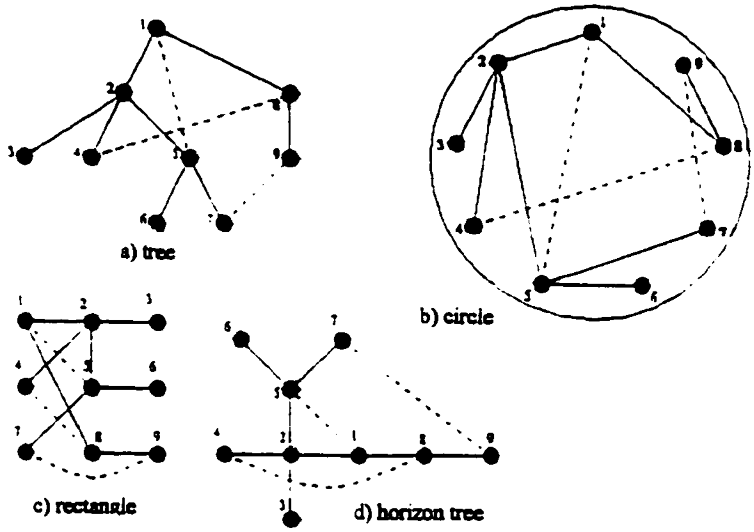


**Figure 5.7**
**WebMap's layout strategies for the same topology (Dömel 1994)**

### *Reflective Tools*

MosaicG is an add-on tool for NCSA Mosaic version 2.5 that provides a two-dimension view of pages visited by a user in a navigation session. History is displayed as a two-dimensional tree built from left to right. The way a tree is built depends on the way documents are accessed. If a page is accessed by selecting a URL link, it is added as a child node. If a page is opened by manually entering the URL or selecting an entry from a bookmark list, it becomes the root of a new tree. Thumbnail (small-scale) images of documents are shown in the nodes of the tree to allow the user to quickly recognize a page or set of pages (Figure 5.8). These images attempt to lessen the burden on the user to recall titles of pages by facilitating quick recognition (Ayers and Stasko 1995). Page titles and URLs are displayed in the bottom portion of the MosaicG window when the mouse cursor moves over the nodes in the tree. The user can also selectively display page titles or URLs for each node, using a title-shortening algorithm.

To eliminate visual clutter, users may condense branches of the tree that are no longer of interest (Figure 5.9). This saves valuable screen space and allows the user to

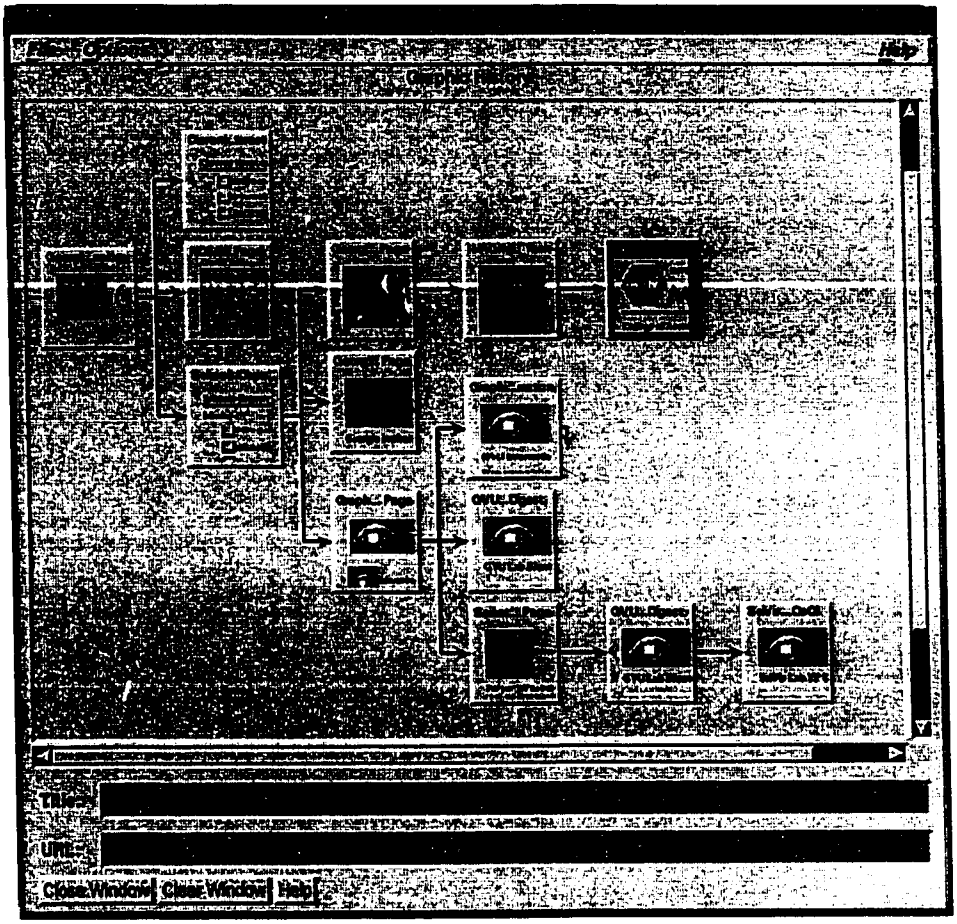

**Figure 5.8**
**Graphic history view of MosaicG (Ayers and Stasko 1995)**

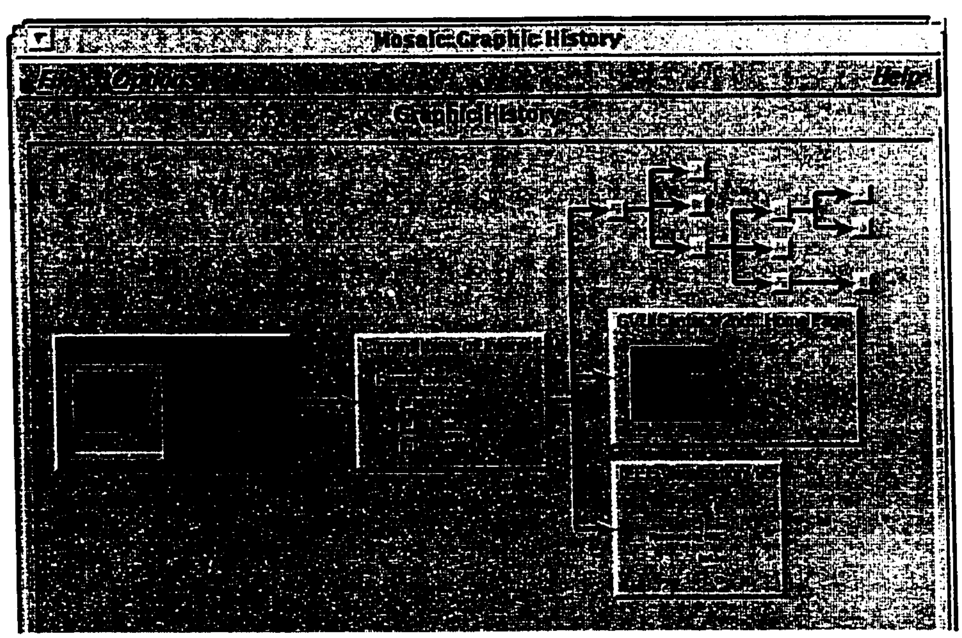

**Figure 5.9**
**MosaicG with a portion of the tree collapsed (Ayers and Stasko 1995)**

formulate a mental model of the information structure. A Zoom Out feature permits the user to collapse every node in the tree to a small square. A user may also save a browsing session generated by MosaicG. Thumbnail images are not preserved but will be updated if the nodes are revisited.

## 5.2 Inter-Sessional History Mechanisms

Web browser inter-sessional history mechanisms of already-visited cues and Bookmarking are discussed in this section. As mentioned in section 5.1, recent versions of browsers may also offer some inter-sessional support with their history lists. These are not re-iterated here.

### Already-visited Cues

Web browsers differentiate hypertext links from regular text by using colour and underlining. Links that have been accessed are displayed in a different colour then those that have not been viewed. Most browsers allow users to set a history expiration date that determines how long (in days) before already-visited cues are expired. Depending on this history expiration date setting, these cues can provide intra and inter-sessional history information. Unfortunately, the user must be able to remember which relevant pages provided these cues.

### Bookmarking

Most browsers allow users to define bookmarks at pages they may wish to return to later. Bookmarks differ from history lists in that the user must explicitly specify that a page is to the bookmarked, whereas history lists are updated automatically. Although bookmarking can be a very useful tool, people may not recognize the relevance or importance of a particular site until later, when its connection with something else suddenly becomes apparent (Nielsen, 1990a). At this point the relevant URL may already be lost from the history stack.

Bookmark lists tend to be smaller and more manageable than history lists. However, users tend to place more and more URLs in their bookmarks due to the difficulty of finding locations on the Web (Nielsen, 1990a). Netscape was the first browser to allow a hierarchical bookmark list through the use of user-defined nested folders. This hierarchical organization enables users to browse through their personal site repositories more easily. However, as the number of bookmarks increases, this manual URL classification and organization can become difficult and tedious. 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 uninformative page titles or URL addresses.

Some add-on tools have been developed to improve the effectiveness of standard browser bookmark lists. Maarek and Shaul's (1996) Bookmark Organizer provides automatic classification together with user adaption. Pages can be automatically classified with a mechanism that uses cluster analysis based on conceptual similarity. However, the user has the power to select when, and on what part of the hierarchy the automatic classification should be applied.

Netscape SmartMarks (Netscape Communications Inc 1997) provides an advanced bookmark and Web monitoring service. Users can automatically receive notification of changes that have occurred on bookmarked sites. This tool also allows custom bookmark descriptions and comments with the ability to sort, rename, show and hide bookmark folders.

Netscape also provides an inter-sessional list of URLs that have been explicitly entered. The last ten locations that have been typed into the location field are stored in a pop-up menu to the field's right. Pages that are accessed through bookmarks or hyperlinks are not stored in this list. This inter-sessional list provides a limited benefit due to the infrequency of explicit entering of URL addresses. Most pages are accessed through URL hyperlinks given in search engine results or other Web pages.

## 5.3 MEMOS: An Intra- and Inter-Sessional Tool

Greenberg (1993) identifies the term "recurrence rate", as the percentage of any activity which is a repeat of a previous one. Tauscher (1996a) found that 58% of all accessed Web pages are re-visits. This classifies Web browsing as a recurrent system, since such systems exhibit a recurrence rate of 40-85% (Greenberg, 1993). History mechanisms can be powerful navigational aids in recurrent systems, but Web browsers have not taken full advantage of their potential. History lists are particularly undervalued. Users might be encouraged to benefit from a history list tool if it were properly designed.

Tauscher (1996a) presents some design guidelines for Web browser history lists derived from Greenberg's (1993) fundamental design requirements for reuse facilities.

Based on these guidelines, we developed a history tool called the Memory Extender Mechanism for Online Searching (MEMOS) for Netscape Navigator 3.0, using a combination of JavaScript (Netscape Communication 1997) and Java (Sun Microsystems Inc 1997). JavaScript is an interpreted object oriented language that was developed, and is continuing to be developed, by the Netscape Communications Corporation. Java is a robust, object-oriented, platform-independent multi-threaded, dynamic general-purpose programming environment. The MEMOS tool developed with JavaScript and Java is able to show much more information than the corresponding browser History and Go Lists. MEMOS maintains a recency history list, showing the most recently accessed sites at the top of the list, and a frequency history list, showing the most frequently accessed sites at the top of the list. 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 all or part of a navigation session for future inter-sessional use. MEMOS was not truly integrated with the Netscape 3.0 interface, since we were unable to obtain the browser source code from Netscape Communications Corporation. Some of the main features of the MEMOS tool are outlined below, followed by a snapshot of MEMOS during a navigation session in Figure 5.10. These features are organized by Tauscher's (1996a) guidelines, which are paraphrased in bold.

**MEMOS maintains a record of URLs visited, and allows users to recall previous URLs from this record.** 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 history. MEMOS history items appear in descending order of recency since users have a natural tendency to scan lists from the top down.

**It is more efficient and less demanding, in terms of physical and cognitive activity, for users to recall URLs from MEMOS 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. The MEMOS window occupies approximately half the screen, thereby allowing the user to view page changes in the main Netscape window. The user can employ a "trial-and-error" approach if he/she is unsure of the desired page's title or URL. This reduces the cognitive burdens of recall and recognition.

**Pruning duplicates increases the probability that MEMOS will contain the required 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, it does not increase the difficulty of locating an item on the list.

**Alternative strategies are supported by MEMOS.** Current Web browsers employ a stacking method to collect history information. A recency ordered list with no duplicates will fare better since it does not lose information as the stacking-based approach does, and it more closely resembles the user's navigation mental model. When pruning duplicates in a recency ordered list, the URLs may be saved in the original position of the history list or in its last position. The "last position" approach performs better, since just revisited URLs will stay at the top of the list and local context is maintained. MEMOS saves URLs in their last positions.

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 these alternative 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).

**History items 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 choose to view either of these page descriptors.

**MEMOS allows end-user customization of history data.** Users may 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.

**Saving and clearing of history data.** Recency and frequency lists may be cleared at any time by selecting the "Clear" button. This is useful when users change or modify searching topics. 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. A sample session save is shown in Figure 5.11. Unwanted Web subspaces may be removed from the list by unchecking the appropriate check boxes, and pages may be organized into a three level user-defined hierarchy. When selecting a second or third level hierarchy, users are prompted to choose the appropriate parent page from a list of possible choices. 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 5.12. This interface follows the familiar Windows "File Manager" format with folders and indentation indicating a grouping of lower level sites or hierarchies. Hierarchical abstraction is used in this history tool to extend previous research by Archer et al. (1996).

### *Summary*

In this chapter, we examined the interface access mechanisms of user histories applied to the World Wide Web environment. Current history mechanisms were discussed, some possible independent add-ons were presented, and a new intra- and inter-sessional support tool was introduced.

Traditional intra-sessional history mechanisms include Backtracking and History Lists. A major problem with these mechanisms is the browser's interpretation of a user's

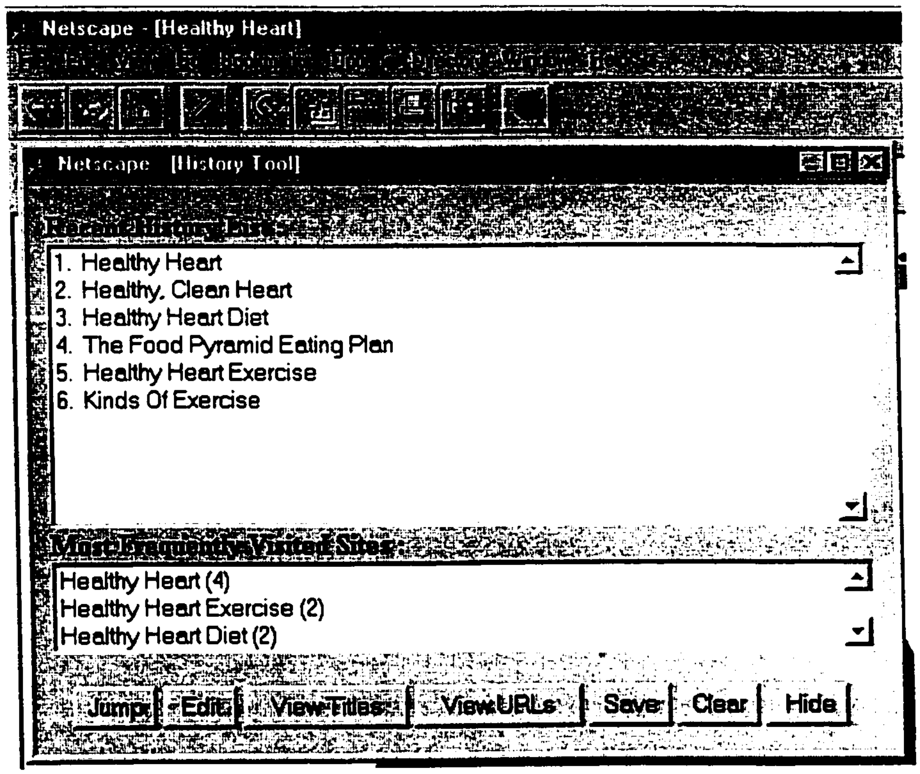


**Figure 5.10**
**The MEMOS intra-sessional history tool**

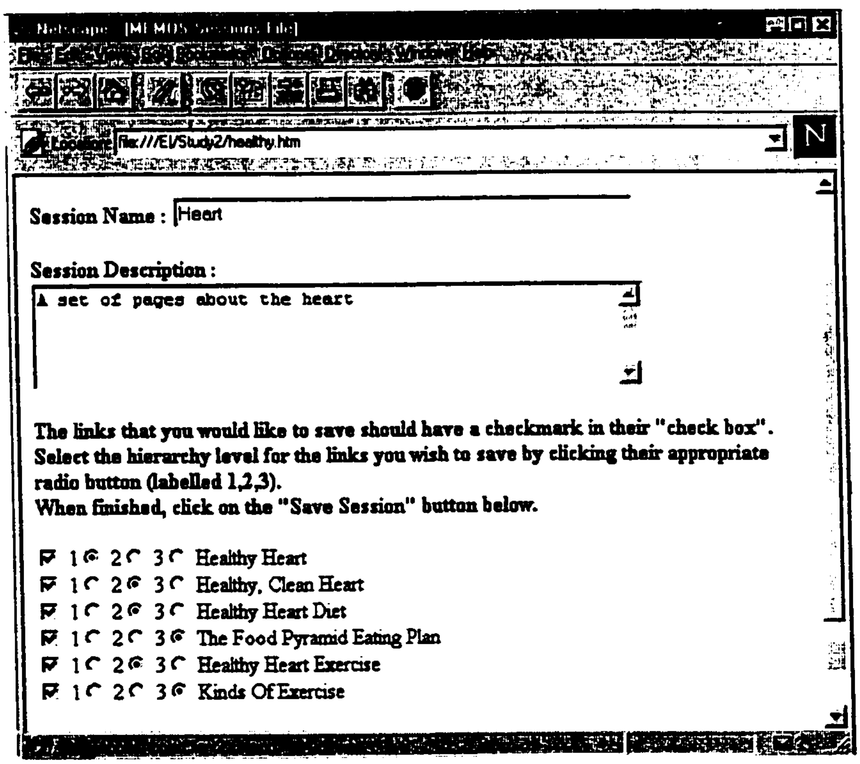


**Figure 5.11**
**Saving a session with the MEMOS tool**

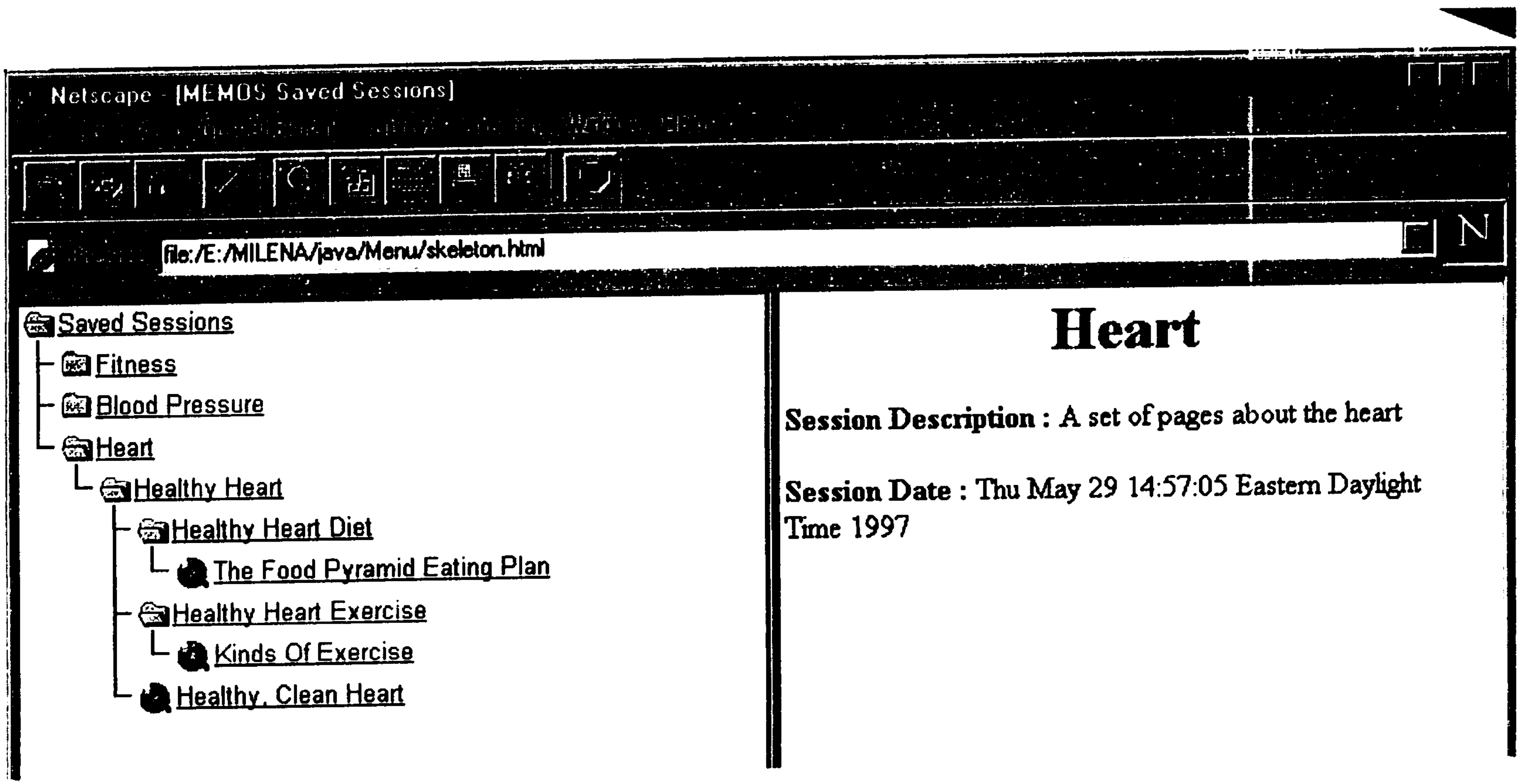


**Figure 5.12**
**MEMOS saved session file**

history as a stack. Depending on how pages are accessed, stacks may lose important information or contain unnecessary duplication. Intra-sessional overview diagrams were also presented as possible browser extensions. Overview diagrams are an effective means of conveying information about the structure of the information space. However, the Web is a vast unstructured system that makes the application of overview diagrams very difficult.

Inter-session mechanisms used by most Web browsers include already-visited cues and bookmarking. Already-visited cues are only helpful when the relevant page containing these cues is located. Bookmarks can be very useful, but the user must explicitly specify a page is to be bookmarked when it is the current document displayed within the browser. The importance of a page may not become evident until later, when it may be too late to return to it from the history stack. Most browsers offer hierarchical organization options with their bookmarks. Unless this organization is performed on a regular and frequent basis, classifying bookmarks may prove to be difficult due to list length and uninformative page titles.

A Memory Extender Mechanism for Online Searching (MEMOS) tool was developed to provide both intra- and inter-sessional support. This tool was developed in accordance with design guidelines for a Web browser history list (Tauscher 1996a). Users can utilize the intra-sessional history tool to navigate among pages within a particular session, or save all or part of a navigation session for future inter-sessional use. Session sites may be saved in a three level user-defined hierarchy, thus making lists more manageable and understandable. Users do not have to worry about bookmarking every possibly relevant site, since the MEMOS tool automatically tracks all visited pages and allows saving entire sessions in one step.

In the following chapter, an experimental study is outlined that examines the efficiency and perceived effectiveness of the MEMOS tool compared to standard Netscape Navigator 3.0 history mechanisms.

# Chapter Six

# Experimental Studies

This chapter continues our investigation of user history interface access mechanisms, as outlined in our research framework. The studies in this chapter were designed to achieve our seventh research goal, i.e., to conduct an experimental study which evaluates the efficiency and perceived effectiveness of the proposed MEMOS Web navigation tool for intra- and inter-sessional support. A pilot study was performed on a limited sample to support proposed hypotheses, justify the need for a full study, and obtain feedback on the design of the experiments and MEMOS tool. Minor modifications were made to the MEMOS interface and aspects of the experimental design were altered before the full study, which is reported in detail.

Web pages on two general 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 Personal® 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 Search® (http://altavista.digital.com), and a sufficient number of pages (approximately 6,000) were downloaded to give the experimental setting a real "online feel".

## 6.1 Pilot Study

Four subjects, all with substantial previous Web experience, were observed in the pilot study. Subjects were asked to perform three Web navigation tasks : browsing (on a given general topic), searching (for the answer to a specific question), and searching with a time constraint. These navigation tasks were performed twice by each subject, once with the availability of the MEMOS tool and standard Netscape 3.0 history mechanisms, and once with the availability of only the Netscape history mechanisms. A three-by-two analysis of variance design was used, as shown in Table 6.1. This was a balanced repeated measures design, since all of the pilot subjects performed every factor level task. However, the completion of every factor level task was time consuming (averaging 2 hours). Subjects were also asked to return for a second session, approximately one week after the first, to perform four specific search tasks. Two questions were based on previously saved sessions, and two were based on Web pages accessed during the first session, but not saved with the MEMOS tool. The average time for the second session was only thirty minutes.

**Table 6.1**
**Pilot study experimental design for the efficiency and effectiveness of the MEMOS tool in comparison to standard Netscape 3.0 history mechanisms**

| | **Factor B (MEMOS availability) :** | |
|---|---|---|
| **Factor A (user strategy) :** | With MEMOS | Without MEMOS |
| Browsing | group 1 | group 1 |
| Searching | group 1 | group 1 |
| Searching with Time Constraint | group 1 | group 1 |

Since the sample size of this pilot study was very small, it was difficult to apply standard statistical tests to the results. However, a purpose of this study was to obtain an indication of efficiency and perceived effectiveness used to support the proposed hypotheses and justify the need for a full study. The pilot study met this purpose and sufficient data were gathered to indicate an advantage of the MEMOS tool over standard Netscape 3.0 history mechanisms and a need for further research, as demonstrated in the remainder of this chapter. Pilot study questionnaires are provided in Appendix I.

## Intra-Sessional Results

Table 6.2 summarizes the perceived effectiveness measures (completed at the end of each browsing or searching task) on a five point Likert scale, ranging from 1 (not at all effective) to 5 (very effective), for the first session. Averages are given with standard deviations in parentheses.

**Table 6.2**
**Pilot study first session perceived effectiveness of navigation mechanisms**

| | Navigation Mechanism | | | | |
|---|---|---|---|---|---|
| | B | F | G | H | M |
| **Browsing** | | | | | |
| **With MEMOS** | 4.3 (0.8) | 2.8 (1.3) | 1.5 (0.9) | 1.3 (0.4) | 4.8 (0.4) |
| **Without MEMOS** | 4.5 (0.9) | 2.8 (0.8) | 2.3 (1.3) | 1.5 (0.9) | - |
| **Searching (no time constraint)** | | | | | |
| **With MEMOS** | 4.3 (1.3) | 2.0 (1.0) | 1.3 (0.4) | 1.3 (0.4) | 4.0 (1.2) |
| **Without MEMOS** | 4.3 (1.3) | 2.0 (1.2) | 1.8 (1.3) | 1.0 (0.0) | - |
| **Searching (time constraint)** | | | | | |
| **With MEMOS** | 4.5 (0.9) | 2 (1.2) | 1.0 (0.0) | 1.0 (0.0) | 4.3 (0.8) |
| **Without MEMOS** | 4.5 (0.9) | 2 (1.2) | 2.0 (1.7) | 1.0 (0.0) | - |

Notes :
a) scoring on a 5-point Likert scale : 1=not at all effective, 3=somewhat effective, 5=very effective
b) B=Back Button, F=Forward Button, G=Go List, H=History Window, M=MEMOS Tool

The Back button was used most often during browsing and searching tasks and ranked very high on a perceived effectiveness scale out of 5. Netscape's Forward button, Go List, and History Window were rarely used and ranked very low on the perceived effectiveness scale. The MEMOS tool was used most in the browsing session, but was ranked very high for its effectiveness under all three navigation tasks (browsing, searching, searching with time constraints). Search strategies tended to be characterized by an initial keyword search followed by an examination of search engine results. Subjects did not tend to probe deep into any particular site, typically staying within one level of the search engine results. Since site navigation trails were very short, there was little need for a history mechanism that displayed the entire history list. A quick click of the Back button returned the subjects to the desired search result page. It was observed that, of the three mechanisms that display the user's navigation history, MEMOS replaced any previous use of the Go List and History Window when it was made available.

Subjects were asked to compare the effectiveness of the Go List, History Window, and MEMOS tool along dimensions of perceived usability and usefulness. From the four pilot study subjects, MEMOS averaged the best from the group on all dimensions except for "Ease of Use" and "Least Confusing", where it tied with the Go List. The Go List is visible with one mouse click on the Netscape menu bar, whereas the MEMOS tool is not presently integrated into the Netscape interface. Users must toggle between the main Netscape window and the MEMOS window by clicking on the Windows 95 application buttons located at the bottom of the screen. A pilot study subject indicated that this "toggling between windows was a little inconvenient", thus resulting in a lower rating for ease of use measures.

In general, the pilot study results from this first session were very encouraging. Although the use of MEMOS did not appear to have an impact on navigation efficiency in this limited sample, the value of MEMOS in this pilot study was shown to have high effectiveness results. Not only was MEMOS ranked high on a perceived effectiveness scale, but it also scored well in comparison to corresponding Netscape 3.0 history mechanisms (Go List and History Window).

## Inter-Sessional Results

During the second session, subjects were asked to perform four specific search tasks, two of which were based on previously saved sessions. Table 6.3 summarizes the perceived effectiveness inter-sessional scores collected during the second session. Averages are given with standard deviations in parentheses.

**Table 6.3**
**Pilot study second session perceived effectiveness of navigation mechanisms**

| | Navigation Mechanism | | | | | |
|---|---|---|---|---|---|---|
| | B | F | G | H | BM | M |
| **Searching** | | | | | | |
| **With MEMOS** | 3.5 (1.5) | 1.5 (0.5) | 1.3 (0.4) | 1.0 (0.0) | 1.7 (0.8) | 4.8 (0.4) |
| **Without MEMOS** | 4 (0.7) | 1.8 (0.8) | 1.3 (0.4) | 1.0 (0.0) | 1.7 (0.8) | - |

Notes :
a) scoring on a 5-point Likert scale : 1=not at all effective, 3=somewhat effective, 5=very effective
b) B=Back Button, F=Forward Button, G=Go List, H=History Window, BM=Bookmarks, M=MEMOS Tool

In the second session subjects tended to use the MEMOS tool more than the Back button when it was available to them. Accordingly, MEMOS was given a very high perceived effectiveness ranking (4.8 out of the five point scale). Although all the navigation tools were available to them, Netscape's Forward button, Go List, History Window, and Bookmarks were not used by any of the pilot study subjects during this second session. Subjects were asked to compare the effectiveness of the MEMOS tool with Bookmarks, along dimensions of perceived usability and usefulness Although the sample size of this study was very small, a one-tailed t-test was performed on these results to determine any significance. Interestingly, MEMOS was significantly preferred (using a significance level of .1 due to the small sample size) over bookmarks for "ease of finding the desired page", "speed of finding the desired page", "suitability for personal use", and "best choice considering all characteristics" measures. These results were very encouraging, especially given the small sample size of 4. As with the short-term memory aid, MEMOS did not excel in its ease of use measure. Saving a session for future use requires a little time, especially when care is given in determining user-defined hierarchies. Although there were no specific questions asked to evaluate the effectiveness of the hierarchical organization option, positive comments were made on this aspect in the open-ended portion of the questionnaire. Subjects recognized that saving pages in a hierarchy is valuable for future reference. Hierarchies make a list more manageable, understandable, and thus lead to easier access to desired pages.

The efficiency and effectiveness of MEMOS was especially evident in the second session. The use of MEMOS long term memory aid resulted in quicker search times (averaging 6.1 minutes without MEMOS and 2.5 minutes with MEMOS) with fewer pages visited (averaging 12 pages without MEMOS and 6 pages with MEMOS). This improved efficiency was also reflected in very encouraging perceived effectiveness measures. The pilot study results gave a strong indication that MEMOS was perceived as a powerful tool for both intra- and inter-sessional support.

## 6.2 Full Study

The objective of this experiment was to test the intra- and inter-sessional efficiency and perceived effectiveness of the MEMOS tool against standard Netscape 3.0 history mechanisms under various user strategies (browsing, searching, and searching with a time constraint). The following hypotheses were tested.

### Hypotheses

*Hypothesis 1 (Intra-sessional Efficiency)*

> The use of the intra-sessional MEMOS tool will lead to more efficient searching.

*Hypothesis 2 (Intra-sessional Perceived Ease of Use)*

> The intra-sessional MEMOS tool will be perceived as being an easier to use navigation aid than the corresponding Netscape 3.0 history mechanisms (Go List, History Window).

*Hypothesis 3 (Intra-sessional Perceived Usefulness)*

> The intra-sessional MEMOS tool will be perceived as being a more useful navigation aid than the corresponding Netscape 3.0 history mechanisms (Go List, History Window).

*Hypothesis 4 (Intra-sessional User Strategies)*

> The intra-sessional MEMOS tool will be used more often in user browsing strategies than in user searching strategies.

*Hypothesis 5 (Inter-sessional Efficiency)*

> The use of the inter-sessional MEMOS tool will lead to more efficient searching strategies.

*Hypothesis 6 (Inter-sessional Perceived Ease of Use)*

> The inter-sessional MEMOS tool will be perceived as being an easier to use navigation aid than the corresponding Netscape 3.0 history mechanism (Bookmarking).

*Hypothesis 7 (Inter-sessional Perceived Usefulness)*

> The inter-sessional MEMOS tool will be perceived as being a more useful navigation aid than the corresponding Netscape 3.0 history mechanism (Bookmarking).

*Hypothesis 8 (Hierarchical Organization Perceived Ease of Use)*

> The ability to organize a saved session in a user-defined hierarchy will be perceived as being easy to use.

*Hypothesis 9 (Hierarchical Organization Perceived Usefulness)*

> The ability to organize a saved session in a user-defined hierarchy will be perceived as being useful.

Hypotheses 1, 2, 3, and 4 focussed on the short-term intra-sessional use of the MEMOS tool. It was expected that the MEMOS tool would perform better than the standard Netscape 3.0 history mechanisms for both efficiency (navigation time, number of pages visited) and perceived effectiveness (divided into two hypotheses for perceived ease of use and perceived usefulness). The initial pilot study results supported Hypothesis 2 and 3 since MEMOS was ranked as being the best tool in the majority of effectiveness measures. Although intra-sessional efficiency was not improved with the introduction of the MEMOS tool, it was expected that a difference would surface with a larger sample size. The pilot study results supported Hypotheses 4 since the use of the MEMOS tool was more evident in the browsing sessions than either of the searching with or without time constraint sessions.

Hypotheses 5, 6 and 7 focussed on the long-term inter-sessional use of the MEMOS tool. It was expected that the efficiency (searching time, number of pages visited) of search strategies would improve when users utilized their previously saved sessions. It was also expected that the MEMOS tool would be perceived as being more effective (divided into two hypotheses for perceived ease of use and perceived usefulness) than Netscape's bookmarking mechanism. The initial pilot study results supported both these hypotheses.

Hypotheses 8 and 9 were based on past information abstraction research. Abstraction is a powerful tool for managing complexity where a hierarchical organization is used to classify different chunks of information according to their similarities or successive detail (Ossher, 1987). The potential to reduce complexity with hierarchical organization is particularly evident when data are largely qualitative (Archer et al. 1996). Pilot study comments made on the effectiveness of user-defined hierarchies were positive and encouraging.

### *Subjects*

A total of 24 subjects were asked to perform Web browsing and searching tasks, with and without the availability of the MEMOS tool, during their first session. These subjects were asked to return a week later to perform four specific searching tasks. Subjects were business students from undergraduate, MBA, and PhD levels. 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, where 25% 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). The experimental design is discussed below for each of the two sessions.

### 6.2.1 Session 1

During the first session, a brief (approximately 5-10 minutes) Web-based tutorial was provided to familiarize the subjects with traditional Netscape 3.0 history mechanisms as well as the new MEMOS tool. A print-out of the tutorial is provided in Appendix II. This tutorial was followed by a 10 minute demonstration of these mechanisms. Subjects performed a quick navigation session were they tried each of the history mechanisms under the guidance of the experimenter. Features of each tool were re-iterated by the experimenter during this demonstration.

A three-by-two unbalanced analysis of variance design with repeated measures was adopted for the Session 1 experiment. The experimental design is shown in Table 6.4. In this experiment, Factor A represented the user strategy imposed by the experiment (browsing, searching, and searching with time constraint levels) and Factor B represented MEMOS availability (navigation with MEMOS and navigation without MEMOS levels). The standard Netscape 3.0 history mechanisms were available to the user regardless of MEMOS availability. Half the subjects (group 1) performed two browsing tasks (with and without MEMOS), a searching task with MEMOS, and a searching with time constraint task without MEMOS. The second half of the subjects (group 2) also performed two browsing tasks (with and without MEMOS), but performed their searching task without MEMOS, and searching with time constraint task with MEMOS.

**Table 6.4**
**Experimental design for session 1 efficiency and effectiveness (perceived ease of use and usefulness) of the MEMOS tool in comparison to standard Netscape 3.0 history mechanisms**

| | **Factor B (MEMOS availability) :** | |
|---|---|---|
| **Factor A (user strategy) :** | With MEMOS | Without MEMOS |
| Browsing | group 1, group 2 | group 1, group 2 |
| Searching | group 1 | group 2 |
| Searching with Time Constraint | group 2 | group 1 |

All subjects were asked to perform a browsing session with MEMOS and a browsing session without MEMOS. After each browsing session, a search 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 browsing task. Half of the subjects (group 1) searched 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) searched with a time constraint while MEMOS was available, and without a time constraint while MEMOS was not available. Since subjects were not performing all three user strategy tasks (browsing, searching, and searching with time constraint levels) for both levels of Factor B (MEMOS availability), this was an unbalanced design. This design was chosen to keep the experimental sessions within an average of one hour per subject.

Randomization of subjects occurred along the following three dimensions. A summary of subject assignment according to these randomization elements is shown in Table 6.5.

- *Level of Factor B order* : half of the subjects had MEMOS available during their first browsing/searching pair, and half of the subjects had MEMOS available during their second browsing/searching pair

- *Searching level of Factor A order* : half of the subjects searched without a time constraint while MEMOS was available, and half of the subjects searched with a time constraint while MEMOS was available.

- *Topic order* : half of the subjects performed their first browsing session with the health and fitness topic ("Fit"), and half of the subjects performed their first browsing session with the British Columbia travel topic ("BC").

**Table 6.5**
**Subject assignment according to randomization elements**

| With MEMOS first | | | | Without MEMOS first | | | |
|---|---|---|---|---|---|---|---|
| Search with Time Constraint First | | Search without Time Constraint First | | Search with Time Constraint First | | Search without Time Constraint First | |
| BC First | Fit First | BC First | Fit First | BC First | Fit First | BC First | Fit First |
| 3 subjects | 3 subjects | 3 subjects | 3 subjects | 3 subjects | 3 subjects | 3 subjects | 3 subjects |

Within this two-factor ANOVA design there was independence between cells. Each browsing/searching pair (within the same level of Factor B) was performed on two distinct topics (health/fitness and British Columbia travel). There was no content carry-over effect on a search question from its preceding browsing session since the topics were unrelated. It was assumed that there was no interface learning effect, since the history mechanisms have very simple interfaces and any necessary learning would have been completed by the end of the tutorial. A set of questions were made available for the second search question, which followed the second browsing task. Since this was the last task performed during the first experiment session, subjects had already browsed on this topic. The experimenter carefully selected a question which was not investigated during the earlier browsing session.

### 6.2.2 Session 2

Subjects were asked to return a week after completing their first experiment session to perform four specific search tasks. It was found from the pilot study that a one week interval between the two experiment sessions was sufficient to forget information such as specific URL addresses, site URL addresses, and search engine key-word parameters.

A one-factor balanced analysis of variance design with repeated measures was adopted for this part of the experiment. The factor was the applicability of MEMOS, with two levels : based on a previously saved MEMOS session file, and not based on a previously saved MEMOS session file. Two search questions were asked within each factor level for all subjects.

Search questions that were based on previously saved MEMOS sessions were carefully determined by the experimenter. These questions 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. Search questions that were not based on previously saved MEMOS sessions were based on pages that the subject viewed during a previous browsing or searching session but had not saved with the MEMOS tool. Answers to these questions were directly attainable from these previously visited pages, and there was no need to search any deeper within the page's site. A random sampling of second session questions were examined by an independent third party. This independent observer concluded that the questions were determined in a fair manner and were not biased towards or against the MEMOS tool.

### *Questionnaires*

Questionnaires used during the experimental sessions (presented in Appendix III) 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. Scale items were developed based on the following definitions of these variables :

> *Perceived Usefulness* : the degree to which a person believes that using a particular system would enhance his or her job performance.
>
> *Perceived Ease of Use* : the degree to which a person believes that using a particular system would be free of effort.

Davis (1989) pre-tested these measures in a pilot study to enhance content validity, which means that representative questions were drawn from a universal pool (Straub 1989). Davis (1989) tested his measures in two studies involving a total of 152 users and four application programs. These measures were refined and streamlined in a several step process to the six-item scales shown in Table 6.6 (extracted from his paper).

**Table 6.6**
**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 |

Davis (1989) tested these measures for reliability and construct validity. Reliability is an evaluation of measurement accuracy, i.e. the extent to which a respondent can answer the same or approximately the same questions the same way each time (Straub 1989). Davis (1989) found his scales were very reliable with Cronbach alphas of .98 and .94 for perceived usefulness and ease of use respectively. Cronbach alphas are reliability coefficients that measure the average correlation of items within a test. Construct validity asks whether the measures are true constructs describing the event or artifacts of the kind of instrument chosen. Davis' constructs showed high convergent validity (items comprising a scale measured a common underlying construct), discriminant validity (items comprising a scale could be differentiated) and factorial validity ("usefulness" and "ease of use" items formed distinct constructs). Therefore, the perceived usefulness and perceived ease of use scales proposed by Davis (1989) exhibited excellent psychometric characteristics with high reliability and construct validity.

Adams et al. (1992) replicated the work by Davis (1989) with two studies that evaluated the psychometric properties of perceived ease of use and perceived usefulness scales. One study examined heterogeneous users (across different organizations) evaluating largely similar technologies (e-mail and voice mail). A second study involved homogeneous users evaluating heterogeneous technologies (widely used wordprocessor, spreadsheet, and presentation packages). When Davis' (1989) ease of use and usefulness scales were taken to these different settings, they were still found to have very high reliability and validity characteristics. The psychometric properties of these scales were further confirmed by Subramanian (1995), where reliability, convergent validity, and discriminant validity were found to be high for the two factor model. These studies, which used different samples, demonstrated internal consistency and replication reliability of the of the two scales. Hendrickson et al. (1993) performed a test-retest procedure on these constructs in two applications across two administrations. In this study, Cronbach alphas were between .89 and .94 in the initial administration and between .93 and .96 in the second administration. Therefore the Davis (1989) constructs are quite robust and exhibit internal consistency, replication reliability, and test-retest reliability. We felt comfortable basing our questionnaires on these construct measures.

Subramanian (1995) concluded that "information systems researchers can use the perceived usefulness and ease of use constructs in varying technological and organizational contexts". However, changes may be necessary to some of the variables, so they are applicable to the given situation. 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.

The intra- and inter-sessional questionnaires used the "flexible", "confusing", and "ease of use" measures to represent the perceived ease of use construct. However, the questionnaire which was used to evaluate the MEMOS hierarchy option did not include the "flexible" measure. Subjects were asked to evaluate this option once the hierarchy was set and used to retrieve desired Web pages. Flexibility was pertinent when establishing or re-organizing a hierarchy, which was evaluated in the inter-sessional questionnaire. However, flexibility was not relevant when evaluating an established hierarchy to retrieve information.

The usefulness construct proposed by Davis (1989) included the following items: "work more quickly", "job performance", "increased productivity", "effectiveness", "makes job easier", and "useful". In the Web browser history mechanism context, "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".

"Effectiveness" for the intra-sessional questionnaire had to be expanded to "effectiveness for browsing" and "effectiveness for searching". Browsing and searching were two distinct tasks performed during the first session of the experiment, and effectiveness of the history mechanisms may differ according to the task involved. This distinction was not necessary for the inter-sessional and hierarchy evaluation questionnaires. The "useful" item was an overall measure for this construct. The measures adopted for usefulness and ease of use in our experiment are indicated in Table 6.7.

**Table 6.7**
**Perceived usefulness and ease of use measures used in the full study**

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

The questionnaires also included an overall "good choice, considering all characteristics" measure. This item was not included in the hypothesis testing, but was used as a an broad evaluation to support conclusions made in this thesis. Cronbach alphas were calculated on the respondents' evaluation of the MEMOS tool. Scores for this tool were selected rather than any of the Netscape history mechanisms since all respondents used MEMOS at some point during the experiments. This could not be said for the other history mechanisms. 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.

Literature also attempts to establish a link between the perceived ease of use / perceived usefulness constructs and actual usage. Davis (1989) found that usefulness was significantly more strongly linked to usage than ease of use. He explained this result by stating that "although difficulty of use can discourage adoption of an otherwise useful system, no amount of ease of use can compensate for a system that does not perform a useful function". Adams et al. (1992) also emphasized the importance of both ease of use and usefulness, but found that their relationship to usage was more complex. Subramanian (1995) suggested that these are not the only factors that impact predicted future usage. His study indicated that perceived usefulness was a determinant of predicted future usage, but perceived ease of use did not have a significant effect in a voice mail and customer dial-up setting. Subramanian (1995) postulated that "if technology by its nature is relatively easy to use, ease of use would have less or no impact on usage". Although Web navigation tools are relatively easy to use, we felt it was important to gather information on both perceived ease of use and perceived usefulness, despite the unclear link between ease of use and future usage.

### *Measurements*

Efficiency, perceived ease of use and usability measurements were used for both experiment sessions. Quantitative efficiency measurements such as navigation time, the number of times history mechanisms were used, the number of pages visited, and the number of pages revisited were tracked automatically by the computer. Perceived ease of use and usefulness measures were derived from the literature (as described above), and implemented in questionnaires used to gather data. Measurements are summarized in Table 6.8 with information about type (interval or ordinal), measure (efficiency, perceived ease of use and perceived usefulness), session (used in the first or second experiment session), and hypotheses (which of the previously defined hypotheses they measured). Note that any particular data collected was used only once to support some specific hypothesis.

**Table 6.8**
**Measurements of efficiency, perceived ease of use, and perceived usefulness**

| Measurement | Type[1] | Measure | Session | Hypotheses |
|---|---|---|---|---|
| navigation time | interval | efficiency | 1, 2 | 1, 5 |
| history mechanism[2] use | interval | efficiency | 1, 2 | 4, 5 |
| number of pages visited | interval | efficiency | 1, 2 | 4, 5 |
| number of pages re-visited | interval | efficiency | 1 | 1, 4 |
| flexible | ordinal | ease of use | 1, 2 | 2, 6 |
| confusing | ordinal | ease of use | 1, 2 | 2, 6, 8 |
| easy to use | ordinal | ease of use | 1, 2 | 2, 6, 8 |
| easy to find desired page | ordinal | usefulness | 1, 2 | 3, 7, 9 |
| fast at finding desired page | ordinal | usefulness | 1, 2 | 3, 7, 9 |
| effective for browsing | ordinal | usefulness | 1 | 3 |
| effective for searching | ordinal | usefulness | 1 | 3 |
| effective | ordinal | usefulness | 2 | 7, 9 |
| useful | ordinal | usefulness | 1, 2 | 3, 7, 9 |

Notes : [1] interval (direct measure) or ordinal (statement with which agreement or disagreement was indicated in a questionnaire through a 7-point Likert scale)

[2] a separate measure was used for each of the Netscape history mechanisms as well as for the MEMOS tool

## 6.3 Data Analysis

Hypotheses 1, 4, and 5 were tested by analyzing data collected during subjects' experiment sessions. 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 1 and 7 evaluated the efficiency of the MEMOS tool (for intra- and inter-sessional support), and hypothesis 4 examined intra-sessional user strategies.

Hypotheses 2, 3, 6, 7, 8, and 9 were tested by analyzing data collected from questionnaires. Hypotheses 2, 3, 8, and 9 examined the perceived ease of use and usefulness for the MEMOS tool (for intra- and inter-sessional support). For these hypotheses, each question was tested using the Wilcoxon Matched-Pairs Signed Rank test, and the null and alternate hypotheses were stated as follows :

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.

Hypotheses 8 and 9 evaluated the hierarchical option of the MEMOS tool. Questionnaire questions for these hypotheses were tested using the one-sample one-tailed Wilcoxon test, 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.

This section examines the testing of each hypotheses in detail. Testing procedures and null and alternate hypotheses will not be re-iterated.

*Hypothesis 1 :* **The use of the intra-sessional MEMOS tool will lead to more efficient searching.**

The efficiency of the intra-sessional MEMOS tool was broken down to the following sub-hypotheses :

$H_{1.1}$ The use of the intra-sessional MEMOS tool will result in fewer re-visited pages during a searching task.

$H_{1.2}$ The use of the intra-sessional MEMOS tool will result in shorter search times.

Effective use of a history mechanism, such as MEMOS, should allow the Web searcher to examine fewer pages by minimizing the amount of re-visited pages. The searcher can jump directly to a desired previous page, rather than backtracking one page at time. This strategy should reduce search time. A statistical analysis of the number of pages re-visited during the searching tasks was performed using two factors: user strategy (search with and without time constraint levels), and MEMOS availability. The interaction effect was found not significant ($F=1.65$, $p>0.05$). From the main effects, user strategy (searching with and without time constraint) was significant ($F=4.29$, $p<0.05$), but MEMOS availability was not shown to be significant. Although subjects did not use MEMOS to reduce the number of re-visited pages, the time constraint imposed on the search task had a natural effect on this reduction.

A statistical analysis of time taken during the search tasks was performed using the same two factors (user strategy and MEMOS availability). The interaction effect was found not significant ($F=2.89$, $p>0.05$). In examining the main effects, the user strategy was significant ($F=10.9$, $p<0.01$), indicating that the 5 minute time constraint given during a searching task was binding, i.e. the subject was cut off during before natural search behaviour was completed. As expected, the availability of MEMOS did not have a significant effect on search times since subjects did not use this tool to reduce the number of re-visited pages.

For each search topic (health/fitness and British Columbia), a Spearman Rank coefficient was calculated to check for any correlations between topic familiarity and search time. The correlation coefficient ($r_s= -0.12$) was not significant ($p>0.05$), and thus search time was not affected by topic familiarity. Even if this finding was significant, any correlation between search time and topic would not have affected the above statistical analysis since the subjects performed two search tasks under two distinct topics, the order of search topics was randomized, and the assignment of search topic to search task (with and without time constraints) was randomized. The correlation between browsing time and topic familiarity was also not significant ($r_s=0.12$, $p>0.05$). Spearman Rank coefficients were also calculated to examine any possible correlations between previous Web experience and experimental search and browsing times. Web experience correlations were not significant for searching times ($r_s=0.12$, $p>0.05$) or browsing times ($r_s=0.02$, $p>0.05$).

Our conclusions were that the intra-sessional use of the MEMOS tool did not improve searching efficiency. Hypothesis H1 was not supported. The potential of this tool was not realized due to its relative lack of use. When MEMOS was made available during the searching tasks, only 29% of the subjects utilized this tool to jump to previously visited sites. Interestingly, it appears that the addition of a binding time constraint does affect user search strategies. It was observed that subjects spent more time examining the result page of a search engine query before exploring any sites, when a time constraint was imposed. When exploring sites under these conditions, long search trails (following internal Web page hyperlinks) were also less common. Subjects tended to remain close to search engine result pages, rarely delving deeply into any one site. Therefore, under time constraint, backtracking through sequential links to a search result page was short, resulting in fewer re-visited pages.

*Hypothesis 2 :* **The intra-sessional MEMOS tool will be perceived as being an easier to use navigation aid than the corresponding Netscape 3.0 history mechanisms (Go List and History Window)**

Three questions from the questionnaire given in the first session were used to examine MEMOS intra-sessional perceived ease of use. Appendix IV.A shows histograms of the responses to questions $H_{2.1}$, $H_{2.2}$, and $H_{2.3}$, and results from the statistical analysis are shown in Table 6.9. Two questions ($H_{2.1}$, $H_{2.3}$) had significant results, where the null hypotheses were rejected, when comparing the Go List with the MEMOS tool. Respondents agreed that MEMOS provided more flexibility than the 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. The response to $H_{2.3}$ was mixed, and 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. Netscape's history mechanisms were accessed from buttons or menus located at the top of the Netscape window, but MEMOS was accessed from the bottom of the screen (see Figure 6.1). Therefore, activating the MEMOS window was more inconvenient than clicking on the Go Menu. Table 6.9 also shows that the MEMOS tool was very significantly preferred ($p<=0.001$) over the History Window in all ease of use aspects. Like the Go List, the History Window did not offer much flexibility, and eliminated some information while duplicating other information. Accessing the History Window was a two-click process (clicking on the Window menu followed by clicking on the History item, as shown in Figure 6.1), and was more inconvenient than the MEMOS single click at the bottom of the screen.

**Table 6.9**
**Intra-sessional history mechanism perceived ease of use (H2)**

| Question | Go List vs. MEMOS | | | | History Window vs. MEMOS | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | p | sig. | Pref. | Median | p | sig. | Pref. |
| $H_{2.1}$ : Flexible | 2.5 | .000 | *** | M | 3.5 | .000 | *** | M |
| $H_{2.2}$ : Confusing | -1.5 | .011 | * | M | -2 | .001 | *** | M |
| $H_{2.3}$ : Easy to Use | 0.5 | .051 | ns | - | 2 | .000 | *** | M |

Notes :

a) Wilcoxon Matched-Pairs Signed Rank test used for comparisons

b) Alternative hypothesis for sub-hypothesis $H_{1.1}$ and $H_{1.3}$ was median (MEMOS score minus Go List/History Window score) > 0.0

Alternative hypothesis for sub-hypothesis $H_{1.2}$ was median (MEMOS score minus Go List/History Window score) < 0.0

c) Median = estimated sample median, 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)

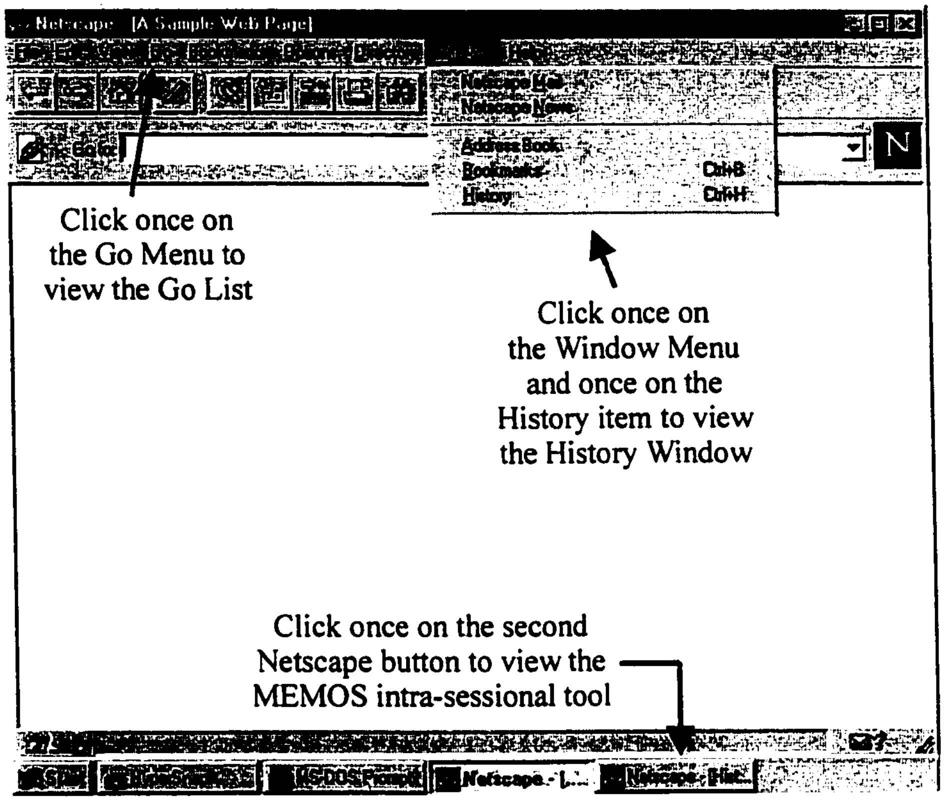


**Figure 6.1**
**Accessing intra-sessional history mechanisms in the Netscape 3.0 interface**

Responses to subject questionnaires were divided into two groups: a) those that had previous experience with a given Netscape 3.0 history mechanism; and b) those that had not used the given Netscape 3.0 history mechanism before this experiment (history mechanism experience was measured on a two point scale). Mann-Whitney U tests were performed on these independent samples to determine if previous Netscape 3.0 history mechanism experience affected corresponding mechanism questionnaire scoring. Table 6.10 summarizes these results. The ease of use measure for the Go List gave the only significant result, i.e. subjects with prior Go List experience rated its ease of use measure higher than those that had not used it before. This was also the question that was not shown to be significant when comparing the MEMOS tool with the Go List. From the comments collected during the experiment sessions, it appeared that these subjects found it more inconvenient to activate the MEMOS tool located at the bottom of the screen compared to using the Go List located in the Netscape menu bar.

**Table 6.10**
**Effect of previous intra-sessional mechanism use on perceived ease of use scoring**

| Question | Go List ($n_1$=10, $n_2$=14) | | History Window ($n_1$=18, $n_2$=6) | |
|---|---|---|---|---|
| | p | sig. | p | sig. |
| $H_{2.1}$ : Flexible | .296 | ns | .210 | ns |
| $H_{2.2}$ : Confusing | .135 | ns | .131 | ns |
| $H_{2.3}$ : Easy to Use | .01 | ** | .178 | ns |

Notes :
a) 1-tailed Mann-Whitney U test used to determine significance
b) $n_1$=sample size of subjects that had no prior experience with the corresponding mechanism
$n_2$=sample size of subjects that had prior experience with the corresponding mechanism
c) p = significance level, sig = ns (not significant), * (.05 level), ** (.01 level), *** (.001 level)

Our conclusions were that the intra-sessional MEMOS tool was generally perceived as easier to use than corresponding Netscape 3.0 history mechanisms. The lack of full interface integration made accessing MEMOS more inconvenient during a navigation session when compared to the Go List, but MEMOS was preferred in other ease of use aspects.

We combined measures used with questions $H_{2.1}$, $H_{2.2}$, and $H_{2.3}$ to perform an integrated hypothesis test. The following function was used :

$$Y_2 = 0.25M_{2.1} - 0.25M_{2.2} + 0.5M_{2.3}$$

Where $M_{2.j}$ is the estimated sample median of the difference in the MEMOS and Go List score for question j of H2.

The third question had a heavier weighting since it was an overall measure of the "ease of use" grouping. $M_{2.2}$ was subtracted from the function since it is a reverse question (on the other end of the scale). This integrated hypothesis test was only performed for the MEMOS and Go List comparison, since Hypothesis H2 is supported by all questions for the MEMOS and History Window comparison. The following hypothesis was then tested :

$H_0 : Y_2 <= 0$
$H_a : Y_2 > 0$

A Wilcoxon Matched-Pairs Signed Rank test was used and our integrated hypothesis test was shown to be significant (estimated median = 1.3, Wilcoxon Statistic = 222.0, $p = 0.001$) at a .01 level. Using this procedure, hypothesis H2 was supported. Without this procedure, H2 was still supported by two out of the three sub-hypotheses for perceived ease of use.

*Hypothesis 3 :* **The intra-sessional MEMOS tool will be perceived as being a more useful navigation aid than the corresponding Netscape 3.0 history mechanisms (Go List, History Window)**

Hypothesis 3 is broken down to five sub-hypotheses, represented by five questions from the questionnaire given in the first experiment session. Histograms of the responses to questions $H_{3.1}$ - $H_{3.5}$ are shown in Appendix IV.B, and results of the statistical analysis are given in Table 6.11.

**Table 6.11**
**Intra-sessional history mechanism perceived usefulness (H3)**

| Question | Go List vs. MEMOS | | | | History Window vs. MEMOS | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | p | sig. | Pref. | Median | p | sig. | Pref. |
| $H_{3.1}$ : Easy to find desired page | 2.0 | .000 | *** | M | 3.0 | .000 | *** | M |
| $H_{3.2}$ : Fast at finding desired page | 1.5 | .001 | *** | M | 2.0 | .000 | *** | M |
| $H_{3.3}$ : Effective for browsing | 2.5 | .000 | *** | M | 3.5 | .000 | *** | M |
| $H_{3.4}$ : Effective for searching | 2.5 | .000 | *** | M | 4.0 | .000 | *** | M |
| $H_{3.5}$ : Useful | 2.0 | .000 | *** | M | 3.5 | .000 | *** | M |

Notes :

a) Wilcoxon Matched-Pairs Signed Rank test used for comparisons
b) Alternative hypothesis for sub-hypotheses was median (MEMOS score minus Go List/History Window score) > 0.0
c) Median = estimated sample median, 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)

All sub-hypotheses for Hypothesis 3 were found to be very significant (p<=0.001) when comparing the MEMOS tool to both the Go List and History Window. The value of the MEMOS tool was recognized since subjects agreed that it was easier and faster to find a desired page, more effective for browsing and searching and, in general, a more useful tool than corresponding Netscape 3.0 history mechanisms. Comments made by subjects stressed the advantages of MEMOS recency stacking (eliminated duplicates and no loss of information), alternative viewing options (recency and frequency list), and most importantly, the opportunity to save navigation sessions for future use.

An analysis was performed to determine if previous Netscape 3.0 history mechanism experience affected corresponding mechanism questionnaire scoring for intra-sessional usefulness. Table 6.12 summarizes these results. For both the Go List and History Window, subjects that had previous experience with these mechanisms evaluated them as being more useful than subjects who had not used these mechanisms prior to this experiment. It appears that subjects that had used these mechanisms in the past recognized more of the potential of these history lists for navigation support. Although the potential of these tools was recognized for overall usefulness, experienced mechanism users did not judge specific usefulness measures differently from inexperienced users.

**Table 6.12**
**Effect of previous intra-sessional mechanism use on perceived usefulness scoring**

| Question | Go List ($n_1$=10, $n_2$=14) | | History Window ($n_1$=18, $n_2$=6) | |
|---|---|---|---|---|
| | p | sig. | p | sig. |
| $H_{3.1}$ : Easy to find desired page | .091 | ns | .354 | ns |
| $H_{3.2}$ : Fast at finding desired page | .091 | ns | .237 | ns |
| $H_{3.3}$ : Effective for browsing | .186 | ns | .335 | ns |
| $H_{3.4}$ : Effective for searching | .338 | ns | .203 | ns |
| $H_{2.5}$ : Useful | .037 | * | .027 | * |

Notes :

a) 1-tailed Mann-Whitney U test used to determination significance
b) $n_1$=sample size of subjects that had no prior experience with the corresponding mechanism
$n_2$=sample size of subjects that had prior experience with the corresponding mechanism
c) p = significance level, sig = ns (not significant), * (.05 level), ** (.01 level), *** (.001 level)

We concluded that the MEMOS tool was perceived to be more useful than corresponding Netscape 3.0 history mechanisms for intra-sessional support. Hypothesis H3 was supported.

*Hypothesis 4 :* **The intra-sessional MEMOS tool will be used more often in user browsing strategies than in user searching strategies.**

Hypothesis 4 examines the use of the MEMOS tool under different user strategies. A one-way analysis of variance was performed to analyze MEMOS use under the three user tasks (browsing, searching without time constraint, and searching with time constraint). It was found that there was a significant difference ($F=4.38$, $p<0.05$) in MEMOS use during the different tasks. In order to fully understand this result, a further analysis was performed that examined the use of the MEMOS tool under two user tasks, where those searching with and without time constraints were grouped together. Once again, there was a significant difference ($F=4.34$, $p<0.05$) in MEMOS use during browsing and searching. When MEMOS use under the two searching tasks was examined it was found that the time constraint had no significant impact ($p>0.05$) on the use of MEMOS during searching.

It was observed that navigation strategies tended to differ during the browsing and searching tasks. During browsing, when no specific goals were given, subjects tended to delve more deeply into sites through internal link traversal. A typical browsing 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 that 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 than to look through a confusing list of duplicates and missing information. Subjects that had not used history list mechanisms before, defaulted to their usual "Back" button use, commenting that they "simply forgot history lists were there". Therefore backtracking with the "Back" button was the standard means of retrieving a previous page.

Searching 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 browsing, searching with a time constraint, and searching without a time constraint. The proportion of re-visited pages was significantly higher ($F=33.15$, $p<0.001$) for the browsing session. Using the Tukey-Cramer method (Neter et al. 1985), paired comparisons indicated that the differences between browsing and searching with a time constraint, and browsing and searching without a time constraint was significant. This result supports the observation of longer navigation trails during browsing. As discussed in hypothesis 1, an imposed time constraint on searching resulted in even fewer re-visited pages and shorter navigation trails. However, this time constraint did not significantly impact the use of the MEMOS tool.

Our conclusions were that the MEMOS tool was used more during browsing than searching, due to the nature of Web navigation under these tasks. Hypothesis H4 was therefore supported. Browsing was characterized by longer navigation trails, therefore more backtracking was required to return to a desired previous page. The "Back" button was the common backtracking mechanism but, when it was used, the MEMOS tool provided greater benefit during the browsing session. It is interesting to note that the Go List was used in a similar manner, but when the MEMOS tool was made available, it tended to replace the use of the Go List. The History Window was used only very rarely by any of the subjects.

***Hypothesis 5 :*** **The use of the inter-sessional MEMOS tool will lead to more efficient searching.**

The efficiency of the inter-sessional MEMOS tool was broken down to the following sub-hypotheses :

$H_{5.1}$ The use of the inter-sessional MEMOS tool will result in shorter search times.

$H_{5.2}$ The use of the inter-sessional MEMOS tool will result in fewer visited pages during a search task.

During the second session of the experiments, subjects were asked to find answers to four specific search questions, two of which were based on their previously saved MEMOS sessions. As outlined in Section 6.2.2, questions based on saved sessions required the subjects to search approximately two levels deep from a specified saved page in order to obtain the answer. Answers to search questions that were not based on previously saved MEMOS sessions were directly attainable from previously visited (and not saved) pages. Subjects could use any technique they wished to find answers to questions. Figure 6.2

breaks down the questions by the method used for finding the answer as well as by the number of correct and incorrect answers.

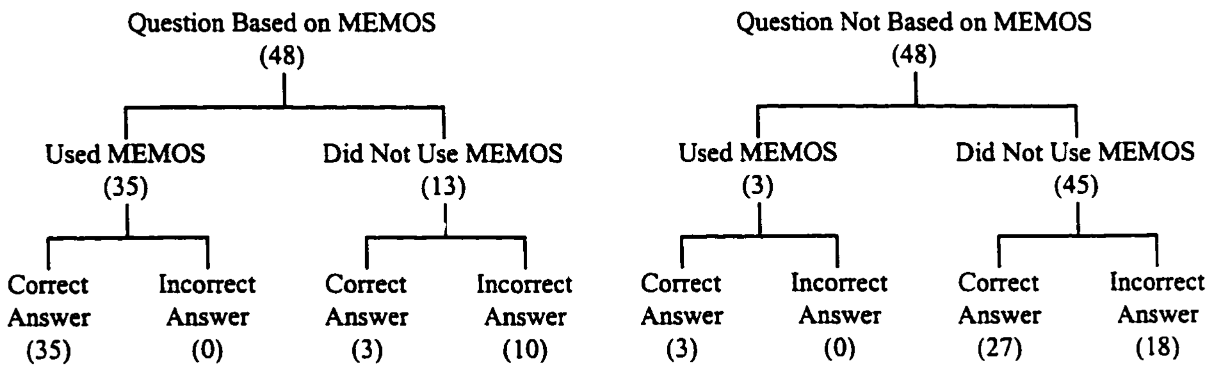


**Figure 6.2**
**Break-down of second session search answers**

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, search 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)

A one-factor analysis of variance was performed to analyze the time spent for these three search categories. The results where significant ($F=12.89$, $p<0.001$).Using the Tukey-

Cramer method (Neter et al. 1985), paired comparisons indicated that the differences between the Based/Used (average time of 2:04 minutes) and Based/Not Used (average time of 5:19 minutes) and between Based/Used and Not Based (average time of 5:03 minutes) was significant. There was no difference in searching 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 during search tasks. As with search time, these results illustrated a significant difference 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 search times with fewer pages visited.

A Spearman Rank coefficient was calculated to determine if successful use of the MEMOS tool encouraged subjects to use MEMOS again and be successful in their second MEMOS based search question. The correlation of MEMOS use during the first and second MEMOS based question was only 0.162. Therefore, success in the first MEMOS based question did not significantly ($p>0.05$) skew subjects' behaviour towards the use of MEMOS in the second MEMOS based question.

We concluded that using the MEMOS tool to save previous sessions resulted in more efficient subsequent searching when the saved sessions file was used. Hypothesis H5 was supported. Interestingly, in only 52% of the cases when MEMOS was not used was the correct answer found. It appeared that using a previously saved session to tackle a search question is more effective (right answer more likely to be found) as well as more efficient. The effectiveness of using a saved session was verified in a one-factor analysis of variance, which showed a significant ($F=31.96$, $p<0.001$) effect with MEMOS use.

*Hypothesis 6 :* **The inter-sessional MEMOS tool will be perceived as being an easier to use navigation aid than the corresponding Netscape 3.0 history mechanism (Bookmarking)**

Hypothesis 6 was examined with three questions from the questionnaire given during the second session. The results of the statistical analysis are shown in Table 6.13 and response histograms are given in Appendix IV.C. Two questions, $H_{6.1}$, $H_{6.2}$, had significant results where the null hypothesis was rejected at a .01 and 0.5 level respectively. MEMOS kept track of pages automatically and allowed the user to save an entire session at once. In contrast, bookmarks had to be saved for each page of interest as it was observed within the browser. Subjects expressed their preference for a "one-time" session save over multiple bookmark saves. Although Netscape's bookmarking tool allows for hierarchical organization within user-defined folders, most subjects confirmed that they did not use this feature. It was difficult to organize pages into meaningful folders unless it was performed on a regular and frequent basis. Comments made by subjects indicated that the option to save pages into user-defined hierarchies when saving a session, gave MEMOS added flexibility over the bookmarking hierarchical organization feature that was rarely used.

The third overall ease of use question was not found to be significant. While answering this questionnaire, respondents were asked to consider the session saving process as well as inter-sessional use of the MEMOS tool. Comments made by the subjects indicated lower scores on $H_{1.3}$ due to the lengthier saving process when compared to bookmarks. Bookmarking a page usually only required two mouse clicks : one to open the bookmarks menu and another to click on the "Add Bookmark" option. But this was done all at one time, rather than scattered at intervals throughout the session as required for saving bookmarks.

Saving a session required more time and effect, especially if care was taken in hierarchical organization.

**Table 6.13**
**Inter-sessional history mechanism perceived ease of use (H6)**

| Question | Bookmarks vs. MEMOS | | | |
|---|---|---|---|---|
| | Median | p | sig. | Pref. |
| $H_{6.1}$ : Flexible | 2.5 | .000 | *** | M |
| $H_{6.2}$ : Confusing | -1.0 | .012 | * | M |
| $H_{6.3}$ : Easy to Use | 0.0 | 0.352 | ns | - |

Notes :

a) Wilcoxon Matched-Pairs Signed Rank test used for comparisons

b) Alternative hypothesis for sub-hypothesis $H_{6.1}$ and $H_{6.3}$ was median (MEMOS score minus Bookmarks score) > 0.0

Alternative hypothesis for sub-hypothesis $H_{6.2}$ was median (MEMOS score minus Bookmarks score) < 0.0

c) Median = estimated sample median, p=significance level, sig. = ns (not significant), * (.05 level), ** (.01 level), *** (.001 level), Pref. = significant preference over the history mechanism pair tested (M=MEMOS, B=Bookmarks)

As with the intra-sessional analysis, responses to subject questionnaires were divided into two groups: a) those that had previous experience with bookmarking (20 subjects); and b) those that had not used bookmarks before this experiment (4 subjects). Mann-Whitney U tests were performed on these independent samples to determine if previous bookmarking experience affected questionnaire scoring. For the measures of flexibility, confusion, and ease of use, none of the statistics were significant (p>0.05). This illustrates that prior experience with bookmarks did not influence the relative evaluation of bookmarking and MEMOS.

We concluded that the MEMOS tool is more flexible and less confusing than Netscape's bookmarking mechanism for inter-sessional support due to the integration of hierarchical organization with the saving procedure. However session saving in an organized hierarchy is perceived to be more time consuming since it is concentrated at one time and requires more mental and physical effort than typical bookmark saving.

We combined questions $H_{6.1}$, $H_{6.2}$, and $H_{6.3}$ to form a function, and performed an integrated hypothesis test. The following function was used :

$$Y_6 = 0.25M_{6.1} - 0.25M_{6.2} + 0.5M_{6.3}$$

Where $M_{6.j}$ is the estimated sample median of the difference in the MEMOS and bookmarks score for question j of H6.

The third question had a heavier weighting since it was an overall measure of the "ease of use" grouping. $M_{6.2}$ was subtracted from the function since it is a reverse question (on the other end of the scale). The following hypothesis was then tested :

$H_0 : Y6 <= 0$
$H_a : Y6 > 0$

A Wilcoxon Matched-Pairs Signed Rank test was used and our integrated hypothesis test was shown to be significant (estimated median = 0.75, $p = 0.023$) at a 0.05 level. Using this procedure, hypothesis H6 was supported. Without this procedure, H6 was also supported by two out of the three sub-hypotheses for perceived ease of use.

*Hypothesis 7 :* **The inter-sessional MEMOS tool will be perceived as being a more useful navigation aid than the corresponding Netscape 3.0 history mechanisms (Bookmarking)**

Hypothesis 7 was represented by four intra-sessional questionnaire questions. Statistical analysis results are given in Table 6.14, and Appendix IV.D shows response histograms for both MEMOS and bookmarks. All sub-hypotheses for Hypothesis 7 were found to be significant ($p<0.01$) when comparing the MEMOS tool to bookmarking. Comments made by subjects stressed the advantage of being able to save entire navigation sessions at once without explicitly saving the URL of each page. It was generally agreed that bookmarks are 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 for duplicates, which may lead to confusion when using bookmarks for later retrieval. MEMOS allowed the users to save entire navigation sessions under a session name and user-defined hierarchies. Subjects remarked that this new method of saving Web pages allowed for large amounts of information to be stored without becoming overwhelmed by volume.

An analysis was performed to determine if previous bookmarking experience affected its scoring for perceived usefulness. For the measures of ease of find desired page, speed at finding desired page, effectiveness, and usefulness, all the Mann-Whitney U statistics were not significant ($p>0.05$). This showed that prior experience with bookmarks did not have a significant impact on their evaluation.

**Table 6.14**
**Inter-sessional history mechanism perceived usefulness (H7)**

| Question | Bookmarks vs. MEMOS | | | |
|---|---|---|---|---|
| | Median | p | sig. | Pref. |
| $H_{7.1}$ : Easy to find desired page | 2 | .001 | *** | M |
| $H_{7.2}$ : Fast at finding desired page | 2 | .001 | *** | M |
| $H_{7.3}$ : Effective | 2.5 | .000 | *** | M |
| $H_{7.4}$ : Useful | 1.5 | .002 | ** | M |

Notes :

a) Wilcoxon Matched-Pairs Signed Rank test used for comparisons
b) Alternative hypothesis for sub-hypothesis $H_{7.1}$ minus $H_{7.5}$ was median (MEMOS score - Bookmarks score) > 0.0
c) Median = estimated sample median, p=significance level, sig. = ns (not significant), * (.05 level), ** (.01 level), *** (.001 level), Pref. = significant preference over the history mechanism pair tested (M=MEMOS, B=Bookmarks)

We concluded that the MEMOS tool was perceived to be more useful than bookmarking for inter-sessional support. Hypothesis H7 was supported.

*Hypothesis 8 :* **The ability to organize a saved session in a user-defined hierarchy will be perceived as being easy to use.**

At the end of the second session, subjects were given a questionnaire which addressed the hierarchy option of the MEMOS tool. Two questions, $H_{8.1}$ and $H_{8.2}$, examined the ease of use of this option. Subjects were asked to score the different measures from the viewpoint of using the MEMOS hierarchy, once it has been created, to find a desired page. Results from the statistical analysis are given in Table 6.15, and histograms of respondent scores are shown in Appendix IV.E. Both ease of use sub-hypotheses were shown to be very significant ($p<0.001$) when evaluating the hierarchy option. Although hypothesis 6 indicated that the creation of a user-defined hierarchy can require some effort and time, once a logical hierarchy is set up, it is significantly easier to use, because it breaks lists into manageable chunks. Hypothesis 8 was supported.

**Table 6.15**
**Hierarchical organization perceived ease of use (H8)**

| Question | Median | p | sig. |
|---|---|---|---|
| $H_{8.1}$ : Confusing | 2.5 | .000 | *** |
| $H_{8.2}$ : Easy to Use | 5.5 | .000 | *** |

Notes :

a) 1-tailed Wilcoxon Signed Rank test used
b) Alternative hypothesis for sub-hypothesis $H_{8.1}$ was median < 4.0
Alternative hypothesis for sub-hypothesis $H_{8.2}$ was median > 4.0
c) Median = estimated sample median, p=significance level, sig. = ns (not significant), * (.05 level), ** (.01 level), *** (.001 level)

*Hypothesis 9 :* **The ability to organize a saved session in a user-defined hierarchy will be perceived as being useful.**

Hypothesis 9 was examined by four questions which addressed the usefulness of the MEMOS hierarchy option. The statistical analysis results for these individual questions are provided in Table 6.16, and the histograms of respondent scores are given in Appendix IV.F. As with the ease of use measures, all the usefulness measures for the hierarchy option have very significant results ($p<0.001$). The ability to save Web pages under different levels of hierarchy was perceived to be both very easy to use and useful. Hypothesis 9 was supported.

**Table 6.16**
**Hierarchical organization perceived usefulness (H9)**

| Question | Median | p | sig. |
|---|---|---|---|
| $H_{6.1}$ : Easy to find desired page | 6.0 | .000 | *** |
| $H_{6.2}$ : Fast at finding desired page | 6.0 | .000 | *** |
| $H_{6.3}$ : Effective | 6.0 | .000 | *** |
| $H_{6.4}$ : Useful | 6.5 | .000 | *** |

Notes :

a) 1-tailed Wilcoxon Signed Rank test used
b) Alternative hypothesis for sub-hypothesis $H_{6.1}$ - $H_{6.4}$ was median > 4.0
c) Median = estimated sample median, p=significance level, sig. = ns (not significant), * (.05 level), ** (.01 level), *** (.001 level)

### *Summary*

In this chapter, we outlined the experimental design from which we tested our nine hypotheses. These hypotheses examined the efficiency, perceived ease of use, and usability of the MEMOS tool compared to standard Netscape 3.0 history mechanisms.

In terms of efficiency, we hypothesized that the MEMOS tool would lead to more efficient searching for both the intra- and inter-sessional navigation scenarios. Our findings indicated that the intra-sessional potential for this tool was not realized due to its relative lack of use. Using MEMOS to navigate within a particular session did not improve searching efficiency (H1). However, inter-sessional efficiency for this tool was highly significant (H5). Using a previously saved session to tackle a search question was faster than trying to find it through standard methods. Effectiveness (ability to find a correct answer) was also found to be significantly improved when using a saved session for searching.

The MEMOS tool was evaluated for ease of use along three dimensions : intra-sessional support, inter-sessional support and the hierarchy option. As an intra-sessional tool, MEMOS was generally easier to use than corresponding Netscape 3.0 history mechanisms (H2). However the lack of full Netscape interface integration made accessing the MEMOS tool more inconvenient when compared to the Go List. Results were also mixed for the intra-sessional MEMOS tool (H6). MEMOS was more flexible and less confusing than Netscape's bookmarking mechanism, but the saving of 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 undoubtably reveal more mental and physical effort for bookmark organization. Once a logical hierarchy was set up with MEMOS, it was significantly easier to use when access was needed in a later session (H8).

Usefulness was also evaluated along the intra-sessional, inter-sessional, and hierarchy option dimensions. We could confidently conclude that MEMOS was perceived to be more useful than the corresponding Netscape 3.0 history mechanisms for both intra- and inter-sessional support (H3, H7). Similarly, the hierarchy option was also deemed very useful (H9). All measures for usefulness were shown to be highly significant.

Hypothesis 4 examined the use of MEMOS under browsing and searching strategies. We concluded that the MEMOS tool was used more during browsing than searching, due to the nature of Web navigation under these tasks. MEMOS provided greater benefit during the browsing session since browsing was characterized by longer navigation trails, requiring more backtracking to return to a desired previous page.

At this point we have achieved all our research goals and have completed our examination of the three specific user interface components, as outlined in research framework : (i) text and voice output mode (interface presentation); (ii) information abstraction (interface organization); and (iii) World Wide Web history mechanisms (interface access mechanism). The next chapter discusses the implications of our findings and proposes future research related to this study.

# Chapter Seven

# Findings and Conclusions

The objective of our research was to study how the user interface should be designed to facilitate the information access and decision making process. In particular, we focused on three specific components of interface presentation, organization, and access mechanisms: voice and text output mode, information abstraction, and Web history tools. We developed a research framework to explore the interactive relationships among the decision making, information access and user interface domains. Establishing links across our framework can help provide design guidelines for developing more usable systems. Our findings are summarized in this chapter, with respect to our research framework and the seven specific research goals outlined in section 2.5. We also state the conclusions and implications of our research findings, and suggest directions for future research.

## 6.1 Findings

In this section we present two views of our findings. First we present our discoveries in the format of our research framework, followed by a discussion of our findings according to the seven specific research goals outlined in section 2.5.

### *Overview*

A modified version of our research framework is presented in Figure 7.1. The user interface components include only those that were specifically examined in this research. Ten of the main links that were established in our research among the decision making, information access and user interface domains are shown. A more detailed description of these links, and their associated discoveries, is presented in Table 7.1.

### *Detailed Findings*

In this section we present our findings according to the specific research goals outlined in section 2.5. Our first and second research goals were to develop a further understanding of the information access and decision making strategies, and to examine the effects of cognitive style on the use of information abstraction in a multiple alternative decision making task. Our fourth research goal, which was to investigate decision makers' search patterns in an hierarchical information space when its information structure was not imposed, is also discussed here. We conducted an empirical study with an experimental apartment selection interface that offered three levels of information abstraction. We observed patterns in information search and performed a statistical analysis on the effects of individual characteristics. We observed that when users where not constrained by a built-in information structure, there was a spectrum of information abstraction use. Some subjects utilized primarily top-down (29%) or opportunistic (17%) search strategy, while the majority (54%) combined top-down and opportunistic behaviour. Our most important findings were that the propensity to use a top-down search strategy a) was directly related to a tendency to use a compensatory decision making strategy, b) became less over the search time in favour of a more opportunistic approach, and c) was related to the tendency of using an alternative-

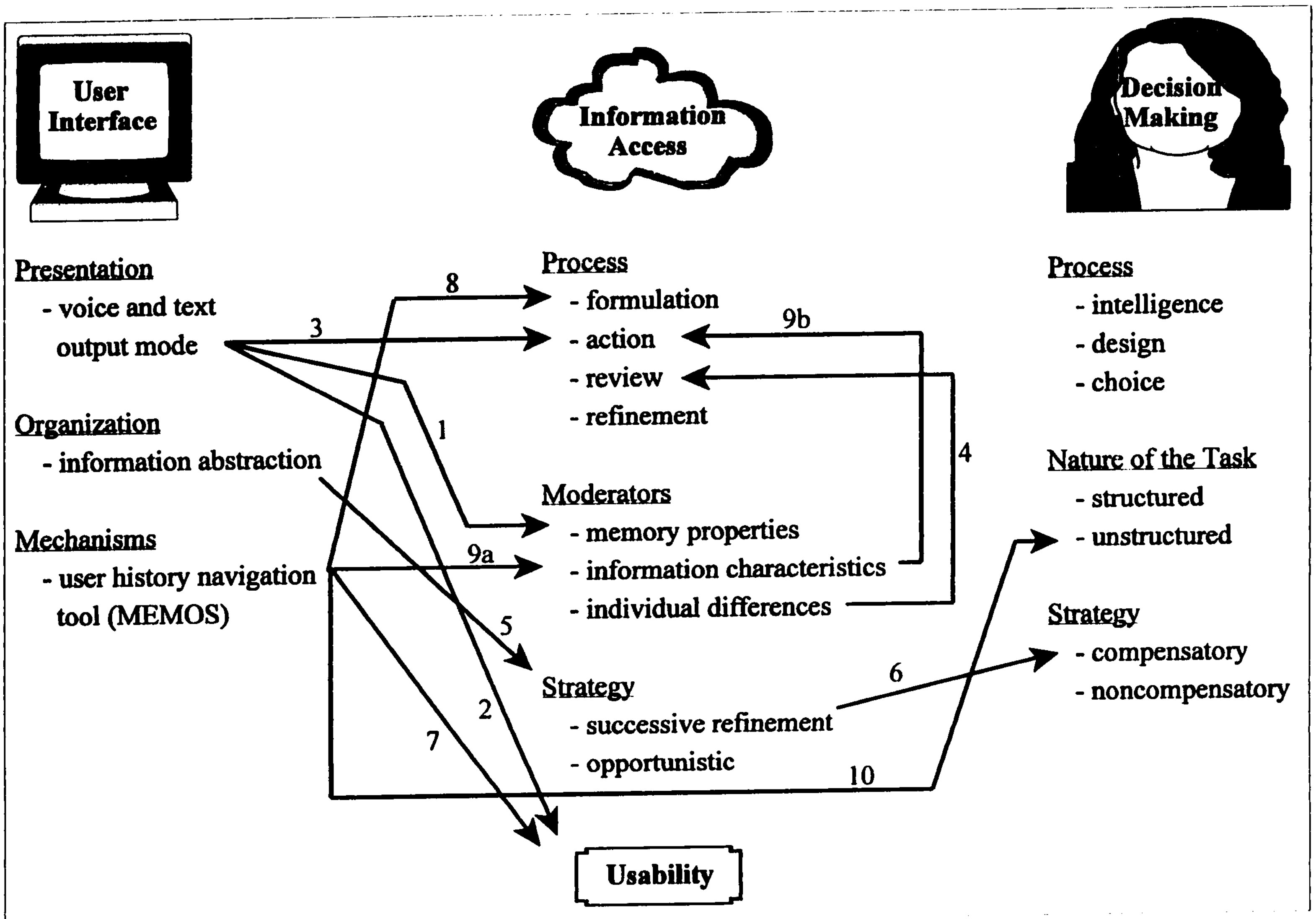


**Figure 7.1**
**Research framework links**

**Table 7.1**
**Research framework links and research findings**

| Link # | Linking Component | Linked Component | Research Finding |
|---|---|---|---|
| 1 | Voice and Text Output Mode (User Interface Presentation) | Memory Properties (Information Access Moderator) | The combination of both modes (voice and text) helped subjects to remember the information better (not statistically investigated) |
| 2 | Voice and Text Output Mode (User Interface Presentation) | Usability | Preference for both (text and voice) over voice output mode |
| 3 | Voice and Text Output Mode (User Interface Presentation) | Action (Information Access Process) | Information access was faster with text output mode than with voice or both output modes |
| 4 | Individual Differences (Information Access Process) | Review (Information Access Process) | Analytics spent more time reviewing attributes but reviewed fewer attributes than Heuristics |
| 5 | Information Abstraction (User Interface Organization) | Strategy (Information Access) | When information is presented in varying levels of abstraction, a combined top-down/opportunistic strategy is most common, with increasing degree of opportunism exhibited over time |
| 6 | Successive Refinement (Information Access Strategy) | Compensatory (Decision Making Strategy) | Top-down search strategies are congruent with compensatory decision strategies |
| 7 | User History Navigation Tool (User Interface Mechanism) | Usability | The MEMOS tool and its ability to save session in user-defined hierarchies, were perceived to be easier to use and more useful than corresponding Netscape 3.0 history mechanisms |
| 8 | User History Navigation Tool (User Interface Mechanism) | Formulation (Information Access Process) | MEMOS was used more during browsing than searching |
| 9a | User History Navigation Tool (User Interface Mechanism) | Information Characteristics (Information Access Moderator) | Using previously saved session (a much smaller subset of Web pages) reduced information overload |
| 9b | Information Characteristics (Information Access Moderator) | Action (Information Access Process) | Reduced information overload resulted in faster subsequent searching |
| 10 | User History Navigation Tool (User Interface Mechanism) | Unstructured (Decision Making Nature of the Task) | The use of previously saved sessions, hierarchically organized, resulted in more effective and efficient searches by applying information structure (abstraction) to an unstructured (hypermedia) environment |

wise strategy. Our analysis did not reveal any effects of individual differences (cognitive style or user experience) on the use of information abstraction or search/decision strategies. We did, however, find that Analytics spent more time reviewing attributes but reviewed fewer attributes than Heuristics.

Our third research goal was to examine our interface presentation component, voice and text output modes. A direct comparison was made between these output modes by presenting the same information for the same length of time for each mode (Voice, Text, and Both voice and text). For task efficiency, the Text mode resulted in shorter decision times than Voice or Both. We suggest that Voice may have disrupted or replaced the reading of information. For mode preference, we found that Both was preferred over Voice, but there was no significant difference between Text\Voice and Both\Text output mode pairing. It appears that by adding Voice to Text, a positive effect (assisting remembering) as well as a possible negative effect (slowing reading rate) were added. But adding Text to Voice resulted in the addition of only positive effects (assisting remembering and increasing communication rates).

The fifth research goal was to examine patterns in Web navigation. Typical navigation sessions begin with a search engine query using general keywords. The results from this search engine then serve as a starting point for subsequent browsing or searching sessions. We observed that during browsing tasks, when no specific goals were given, Web users tended to delve more deeply into sites through internal link traversal. Users would only examine a few (often only one) distinct sites, but would spend considerable time navigating through the various pages of those sites. Searching, on the other hand, tended to be characterized by shorter navigation trails into more distinct Web sites. When a solution to a particular search question was not immediately obvious, Web searchers returned to the search result page to examine another avenue.

Our sixth and seventh research goal was to develop a Web history navigation tool and conduct an experimental study which evaluates its efficiency and perceived ease of use and usefulness. A Memory Extender Mechanism for Online Searching (MEMOS) tool was developed to provide both intra- and inter-sessional support. This tool can be used to navigate among pages within a particular session, or save all or part of a navigation session in user-defined hierarchies. We found that MEMOS did not improve intra-sessional efficiency due to its relative lack of use, but inter-sessional efficiency for this tool was very significant. Using sessions previously saved through the MEMOS tool to tackle search questions resulted in faster and more correct answers than trying to use standard methods (search engines, etc.). The perceived usefulness of the MEMOS tool was found to be very significant in all aspects. But the perceived ease of use measures were mixed for both intra- and inter-sessional support. It was not possible to integrate MEMOS fully into the Netscape 3.0 tool bar interface, thus making it more inconvenient to access than the corresponding Go List. In addition, the hierarchical saving of pages required more time and effort than bookmark saving. However, overall evaluations for the MEMOS tool were excellent. When asked which history mechanism was a "good choice, considering all characteristics", MEMOS was very significantly ($p<0.001$) preferred to the Go List, History Window, and Bookmarks.

The MEMOS tool we developed extended our research on information abstraction by allowing user-defined hierarchies. Most of our subjects utilized this option to save Web pages in at least a two-level hierarchy. Once a logical hierarchy was established, users found it to be significantly easy to use. The hierarchical option was also deemed to be very useful.

## 7.2 Conclusions

The fundamental issue addressed in this study is how to improve the human computer interface to support information acquisition and decision making tasks. We developed a research framework to explore specific links between decision making, information access and user interface domains. Through our examination of three specific interface components (text and voice output modes, information abstraction, and World Wide Web history mechanisms) we were able to establish important links across our research framework, which can then be used to provide guidelines for interface designers. We organize our conclusions according to these interface components, emphasizing our major contributions to interface design guidelines.

### *Voice and Text Output Modes*

We found that adding Voice to Text did not significantly alter the perceived utility of Text, but adding Text to Voice significantly improved its utility. This has an important implication for interface designers considering multiple output modes. For example, adding a small text display to a telephone interface which only presents a voice mode, can improve the usability of the system. However, usability may not be improved when adding voice to a computer interface which already displays information through text. In fact, it may slow down the information access process, since we found that the time taken to complete a task where information was accessed in Text mode was faster than corresponding Voice and Both modes.

Interface designers must also consider the application of the system when making output mode decisions. If the system is likely to be used by a wide variety of people, including individuals with hearing or visual disabilities, combining text and voice output modes may be beneficial due to its universality characteristic. In addition, combining text and voice output modes may help users to remember information better in environments where multiple attributes need to be compared.

### *Information Abstraction*

Through our observations of information abstraction use in a system that did not impose an information structure, we found that hierarchical data structures can be helpful in decision-making based on data retrieval. But users should not be constrained to a hierarchical structure, since this would tend to interfere with natural tendencies towards opportunistic episodes. Since users prefer to minimize effort (Todd and Benbasat 1993), a constrained environment could result in accessing less information, and thus affect the decisions made. Although our study did not reveal any significant effect for individual differences on search patterns or output mode, interface designers should not favour any particular style. Ideally, an interface should provide flexibility to allow users to follow their natural information acquisition strategies and preferences.

### *Web History Mechanisms*

In the World Wide Web environment, effective use of navigation histories can be powerful tools for navigation support. Web navigation is a recurrent task where more than half of the pages accessed are revisits, so history information can be a valuable tool to help users navigate the immense and complex Web environment. However, the history mechanisms that currently available commercial browsers support seem to have been designed by intuition rather than empirical findings. In particular, history list mechanisms, such as Netscape's Go List or History Window, are poorly designed and have negatively influenced user perceptions of their utility. We have developed an advanced history mechanism, MEMOS, which overcomes many of the shortcoming of corresponding browser tools. 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 session.

Previously saved sessions are a small subset of Web pages that can be used for future information access. 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. Interface designers for large information spaces must try to incorporate tools that allow the user to create relevant information sub-spaces.

We have found that the application of information abstraction through user-defined hierarchies is an efficient, effective, and 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 searching and organization of information. Applying structure though interface organization components (information abstraction) to an unstructured environment (hypermedia) can result in more effective and efficient user interactions.

## 6.3 Future Research

In this study we examined the effects of three interface components on decision making and information access. This section presents two views of possible future research. First we present suggestions in the format of our research framework, followed by specific suggestions to gain further understanding of the interface components we examined.

### *Overview*

In our framework we have outlined some links between decision making, information access, and user interface domains, generated from our research. Researchers can use this type of framework to establish many more specific interconnections between these fields. This section presents a few suggestions for future research beyond the interface components examined in this dissertation.

#### Presentation

Other modes of presentation should be examined for their effects on moderators such as human memory. In environments where multiple attributes need to be compared, decision makers must try to retain and remember more information at once. The mode of presenting information may help a user to remember the information better in this kind of environment. These presentation modes should also be investigated under different decision making tasks (structured vs. unstructured) to examine appropriate linkages.

### Organization

Researchers should investigate possibilities of combining some of the benefits of structured and unstructured information organization. In traditional databases search is by attribute, attributes tend to be well defined, and searches are deterministic by nature. Hypermedia systems offer great benefit by allowing the user to determine his/her own path through the information space, but experience difficulty in finding specific information in large environments. Applying a common hidden structure (containing standardized attribute or key word information) to hypermedia pages would facilitate the information access process by providing higher recall and precision characteristics. Although this may be difficult to apply in a very large hypermedia environment, such as the Web, researchers should continue to investigate the possibilities of combining structured with unstructured organization.

### Mechanisms

A benefit of directories is that they can add structure to an otherwise unstructured environment, through the application of information abstraction. This is becoming increasingly important as the Web and the number of its users 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 the vast information space into manageable sub-spaces.

### *Specific Suggestions*

This section presents specific limitations and future research possibilities for the three interface components examined in this dissertation (text and voice output mode, information abstraction, and Web history mechanisms).

(1) Our multiple alternative decision making experiment attempted to make a direct comparison of voice and text output modes by providing the same information during the same length of time. However, it is difficult to isolate the context from the psychological impact. A synthesized voice may not demonstrate effects similar to human pre-recordings. Text may prove to be better than voice if misunderstanding of voice leads to possible errors. Further research is necessary to examine these issues and to make output comparisons in broader decision settings.

(2) We examined output mode preferences and use of information abstraction in an experimental setting that did not evaluate the quality of decision making. It would be useful to investigate how these tools may or may not affect decision quality, where the decision result could be evaluated for correctness or optimality.

(3) Our multiple alternative decision task was limited to the evaluation of four alternatives. Future research should examine the effect of differing numbers of alternative on user performance and preference of information abstraction. This would help us to further understand the impact of abstraction on the use of decision strategies.

(4) Much of the empirical research on decision making is performed on rather closed and structured tasks. We should try to select problems which display some of the less structured nature of business problems. This would widen the scope and relevance of this type of work.

(5) This study only gave a preliminary investigation of Web navigation behaviour. Further research in the area is needed so that software designers can understand how best to support the Web user.

(6) Our research on Web navigation tools was limited to two sessions, approximately one week apart. A true representation of inter-sessional history mechanism use should involve many more sessions over a longer period of time. Ideally, the MEMOS tool should be installed on several computers and used over a period of a couple of months. This would allow us to examine natural navigation behaviour and fully evaluate the efficiency and effectiveness of MEMOS as well as existing history mechanisms.

(7) Our experimental Web setting was not a true online experience. Thousands of pages were downloaded to a local server to minimize variability of Web page retrieval times. It would be useful to examine Web navigation behaviour and history mechanism use in an actual Web environment. Variable delays encountered in practical Web page retrieval may have a substantial effect on user behaviour.

(8) Information abstraction can be a valuable tool for reducing complexity. The Web is a highly complex environment with vast amounts of decentralized and unstructured data. We have applied the concept of information abstraction to one small aspect of the Web and have found very favourable results.

Future research should investigate other avenues for information abstraction to effectively organize and present information on the Web. For example, abstraction can provide a basis for presenting information within a site or a particular Web page. More generally, abstraction may be used to provide summaries of sites before retrieving full documents. Many other uses of information abstraction within this context can and should be investigated.

In conclusion, the work presented in this dissertation investigates the effects of three user interface components on decision making and information access behaviour by establishing some specific links between these domains. Decision making and information access are vast topics, and our examination of these areas is very limited. Similarly, our investigation into user interface components was limited to text and voice output mode, information abstraction, and Web history mechanisms. This research should be expanded to establish more connections among these domains, thus providing interface designers with effective guidelines to create usable systems. We hope to continue our research in this area and make valuable contributions to further the understanding of these complex processes and the user interface tools that support them.

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# Appendix I
# MEMOS Pilot Study Questionnaires

During the pilot study, subjects completed perceived use and effectiveness questionnaires after each navigation task. One set of navigation tasks (browsing, searching with time constraint and searching without time constraint) was performed with MEMOS available, and another set of navigation tasks (browsing, searching with time constraint and searching without time constraint) was performed without MEMOS available. The next four pages show the questionnaires that were supplied after each task completion. Subjects were asked to only fill out the portion that pertained to the task just completed.

The "Compare the Go List, History Window, and MEMOS Tool" questionnaire was given to pilot study subjects at the end of their first session. The "Compare Long Term Memory Aids: Bookmarking vs. MEMOS" questionnaire was given at the end of the second session.

Following the pilot study, modifications were made to the procedures and questionnaires before the full experimental study was undertaken. The modified questionnaires appear in Appendix III.

**Subject :** ________

## Browsing :

Check the appropriate one of five circles for the following :

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| **Back Button :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **Forward Button :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **Go List :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **History Window :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **Bookmarking :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |

## Searching without Time Constraint :

Check the appropriate one of five circles for the following :

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| **Back Button :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **Forward Button :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **Go List :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **History Window :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **Bookmarking :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |

**Searching with Time Constraint :**

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| **Back Button :** | Did Not Use ○ | . . . ○ | Used Occasionally ○ | . . . ○ | Used Often ○ | Not at all Effective ○ | . . . ○ | Somewhat Effective ○ | . . . ○ | Very Effective ○ |
| **Forward Button :** | Did Not Use ○ | . . . ○ | Used Occasionally ○ | . . . ○ | Used Often ○ | Not at all Effective ○ | . . . ○ | Somewhat Effective ○ | . . . ○ | Very Effective ○ |
| **Go List :** | Did Not Use ○ | . . . ○ | Used Occasionally ○ | . . . ○ | Used Often ○ | Not at all Effective ○ | . . . ○ | Somewhat Effective ○ | . . . ○ | Very Effective ○ |
| **History Window :** | Did Not Use ○ | . . . ○ | Used Occasionally ○ | . . . ○ | Used Often ○ | Not at all Effective ○ | . . . ○ | Somewhat Effective ○ | . . . ○ | Very Effective ○ |
| **Bookmarking :** | Did Not Use ○ | . . . ○ | Used Occasionally ○ | . . . ○ | Used Often ○ | Not at all Effective ○ | . . . ○ | Somewhat Effective ○ | . . . ○ | Very Effective ○ |

**Subject : ________**

## Browsing :

**Check the appropriate one of five circles for the following :**

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| **Forward Button :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |
| **Go List :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |
| **History Window :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |
| **Bookmarking :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |
| **MEMOS Tool :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |

## Searching without Time Constraint :

**Check the appropriate one of five circles for the following :**

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| **Back Button :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |
| **Forward Button :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |
| **Go List :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |
| **History Window :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |
| **Bookmarking :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |
| **MEMOS Tool :** | Did Not Use · · · Used Occasionally · · · Used Often<br>○ ○ ○ ○ ○ | Not at all Effective · · · Somewhat Effective · · · Very Effective<br>○ ○ ○ ○ ○ |

## Searching with Time Constraint :

**Check the appropriate one of five circles for the following :**

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| **Back Button :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **Forward Button :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **Go List :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **History Window :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **Bookmarking :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |
| **MEMOS Tool :** | Did Not Use . . . Used Occasionally . . . Used Often<br>○ ○ ○ ○ ○ | Not at all Effective . . . Somewhat Effective . . . Very Effective<br>○ ○ ○ ○ ○ |

**Subject : __________**

## Compare the Go List, History Window, and MEMOS Tool

For each of the following, rank the history tools in the order that they best answer the statement (from best to worst).

Enter: "G" for Go List
"H" for History Window
"M" for Memos Tool

| | Best | | Worst |
|---|---|---|---|
| Ease of Use .......................................................... | | | |
| Greatest likelihood of finding desired page ......... | | | |
| Fastest speed in finding desired page .................. | | | |
| Greatest flexibility ............................................. | | | |
| Least confusing ................................................... | | | |
| Friendliest Interface .......................................... | | | |
| Most suitable for my use ................................... | | | |
| Most likely to use again (given the opportunity) .. | | | |
| Best, considering all characteristics .................... | | | |

**Please enter your comments on the efficiency and effectiveness of the Go List, History Window, and MEMOS Tool below :**

Subject : ____________

# Compare Long Term Memory Aids : Bookmarking vs. MEMOS

For each of the following, rate the long term memory aids on the degree to which they best answer the following statements :

| | BOOKMARKS | | | | | | | MEMOS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Strongly Disagree | | | | | | Strongly Agree | Strongly Disagree | | | | | | Strongly Agree |
| Very easy to use | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Very easy to find desired page | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Very fast at finding desired page | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Very flexible | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Not at all confusing | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Very friendly interface | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Very suitable for my use | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Very likely to use again (given the opportunity) | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Very good choice, considering all characteristics | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

**Please enter your comments on the efficiency and effectiveness of Bookmarks and the MEMOS Tool as a long term memory aid below :**

______________________________________________

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# Appendix II

# MEMOS Online Tutorial

# Welcome to the Web Navigation Aid Experiment

During this first session of the Web Navigation Aid Experiment, you will be asked to perform some Web browsing and searching tasks. You may use any of the navigation aids provided by Netscape Navigator 3.0 (Back button, Forward button, Go List, History Window, and Bookmarks) and you will be introduced to an advanced history mechanism called MEMOS (Memory Extender Mechanism for Online Searching).

For this experiment, a portion of the Web has been downloaded to the local drive. This ensures that you will not have to wait long for pages to appear in your Web browser. The AltaVista Search Engine is provided to allow you to search documents by keywords.

Click on the links below to learn necessary information for this experiment. If you have any questions at any point during this tutorial or during the experiment, please feel free to ask the experimenter. The experiment will begin as soon as you have completed this tutorial.

- Browsing vs. Searching
- Netscape History Mechanisms
- MEMOS History Tool
- AltaVista Search Engine

# Searching Vs. Browsing

**Searching**
Searching for information is a focused task that has a very specific objective (which can often be decomposed into subgoals). On the Web this typically involves a user supplying a list of key words or phrases to a search engine. The user would then proceed to examine the resulting Uniform Resource Locator (URL) links provided by the search engine to locate the desired information.

**Browsing**
Browsing for information is more exploratory, vague, and non-specific than searching. Browsing can be broken down into :

- ***Goal-Directed Browsing*** - there is a general goal that guides the user and this goal may be discovered or reformulated in the course of browsing
- ***Casual Browsing*** - purely random browsing for information with no goal.

Browsing on the Web typically involved link traversal, where the user browses from one URL to another by following URL "hyper-links".

**An Example**
If a user examines Web pages to find out the eating habits of the Rock Hopper Penguin, he/she would be employing a ***searching strategy*** with a very specific goal. However, if a user that is interested in penguins examines Web pages to gain gereral knowledge on this topic, he/she would be employing a ***goal-directed browsing strategy***. There is a general goal to gain knowledge on these types of birds, but there are no specific questions to answer. A user that jumps from topic to topic, just to see "what's out there" would be exhibiting a ***casual browsing strategy*** since his/her browsing behaviour is considered random.

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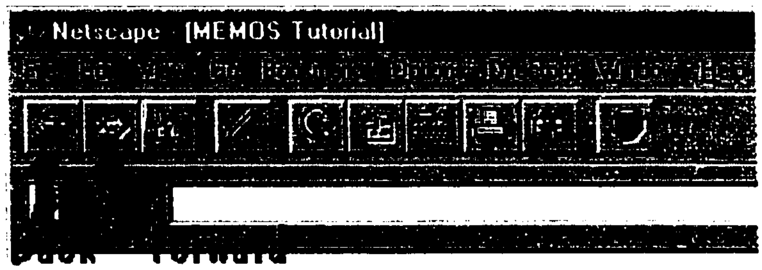
Back to Main Tutorial Page

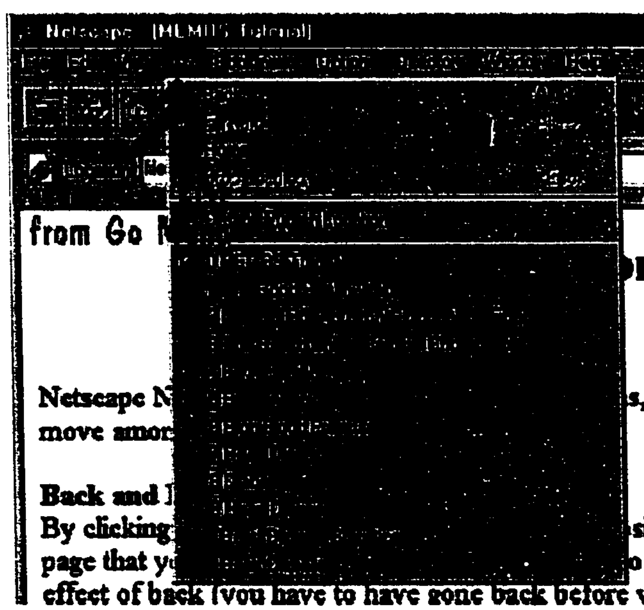
# Netscape History Mechanisms

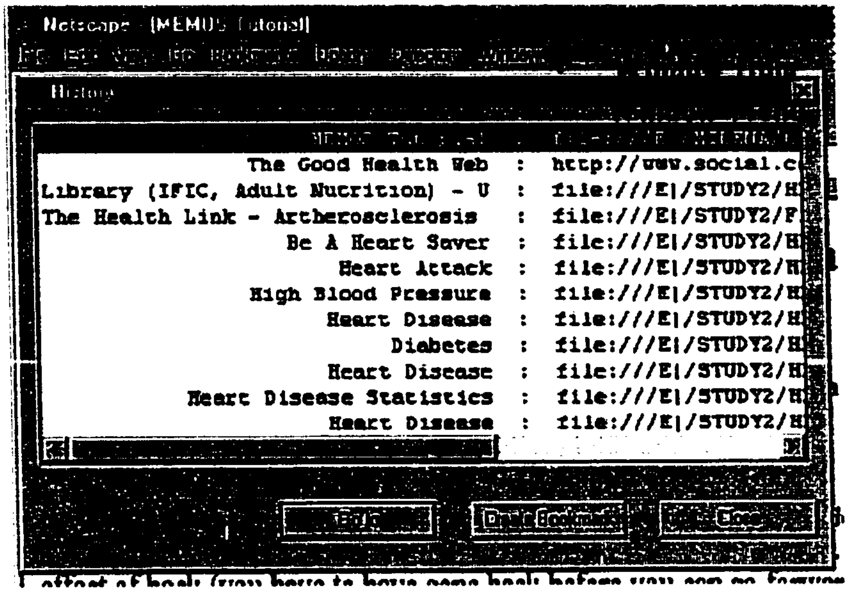
Netscape Navigator has ***Back*** and ***Forward*** buttons, a ***Go List***, ***History Window***, and ***Bookmarks*** to help you move among pages that you have already visited.

**Back and Forward Buttons**
By clicking the **Back** button on the toolbar or choosing Back in the Go menu, Netscape will load the page that you visited immediately before jumping to the present page. The **Forward** button undoes the effect of back (you have to have gone back before you can go forward).

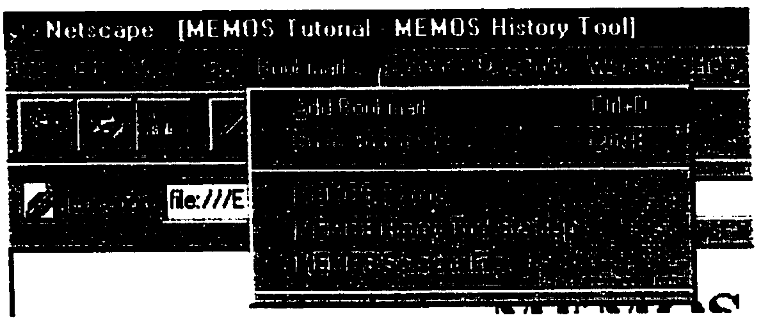



**Go List and History Window**
A list of pages you have recently visited can be viewed through the **Go List** or the **History Window**. The Go List is found under the Go menu (under the second horizontal line) and the History Window is opened by choosing History in the Window menu. The History Window displays both the page titles and their URLs, but the Go List only shows page titles. You can jump to any entry in either of these lists by clicking on them once (Go List) or twice (History Window).






**Bookmarks**
You can define bookmarks at pages you may wish to return to later. Bookmarks differ from the history mechanisms listed above in that they provide long-term inter-sessional information. You must explicitly specify that a page is to be bookmarked when you are on that page, whereas history lists are updated automatically. To set a bookmark for a Web page, click on the "***Add Bookmark***" option in the "***Bookmarks***" menu as shown in the snapshot below :

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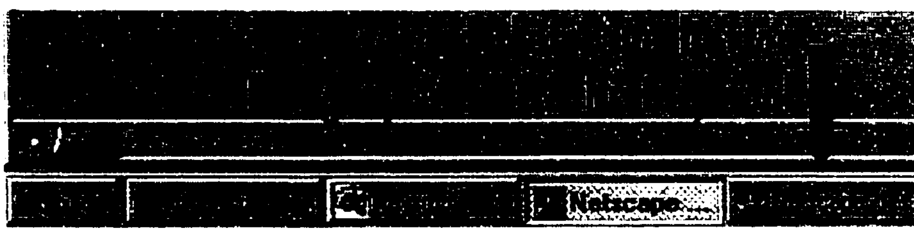
Back to Main Tutorial Page

# MEMOS History Tool

MEMOS (Memory Extender Mechanism for Online Searching) is an advanced history tool that supports you during a Web navigation session and allows navigational information to be saved for future session use. While you are navigating through the Web you can bring up the MEMOS history tool by clicking on the second Netscape button located at the bottom of your screen (as shown in the snapshot picture below). By clicking on these two Netscape buttons you can toggle between the main Netscape window and the MEMOS window.



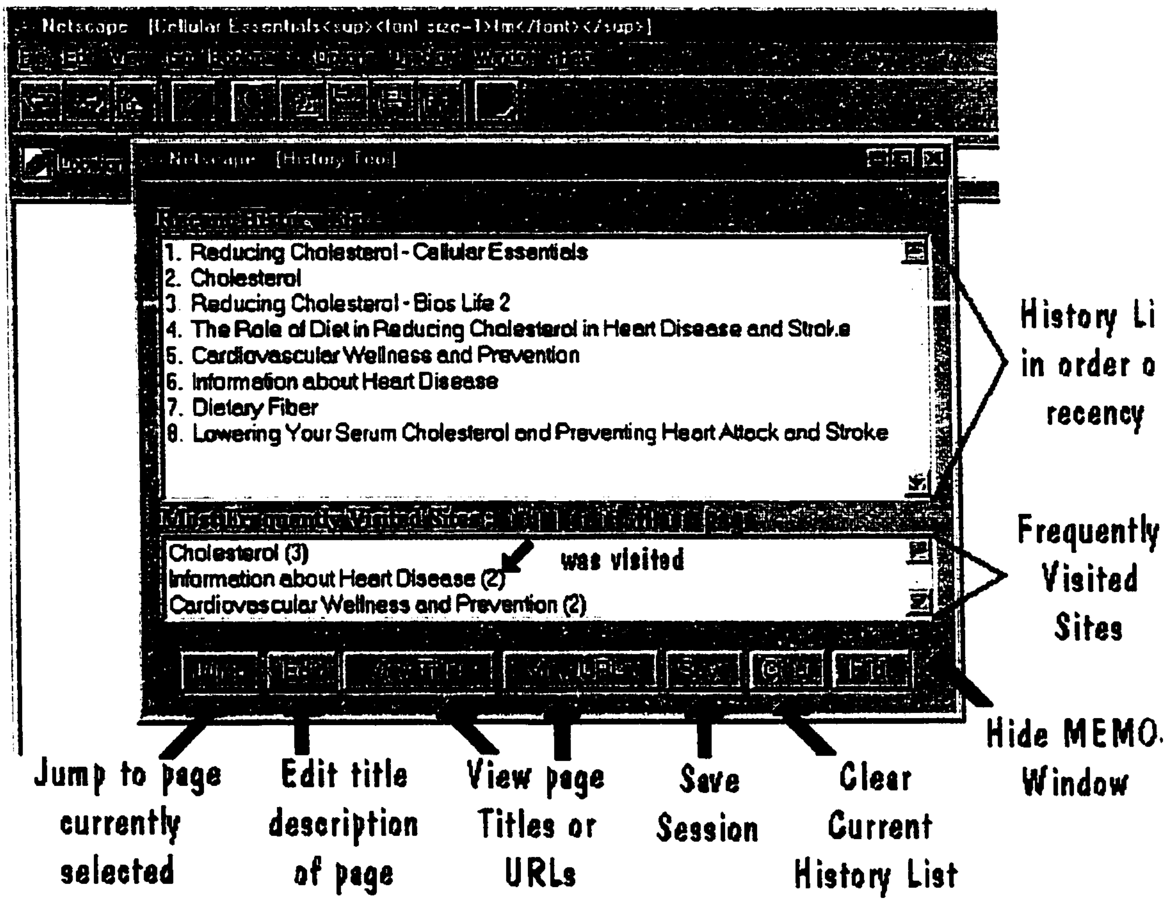
Within a navigation session, MEMOS provides :

- **a recency ordered list** : the most recently visited URLs are shown at the top of this list, which does not contain any duplicates
- **a frequency ordered list** : the most revisited pages appear at the top of this list. Access counts are given in brackets beside each entry in the frequency list.

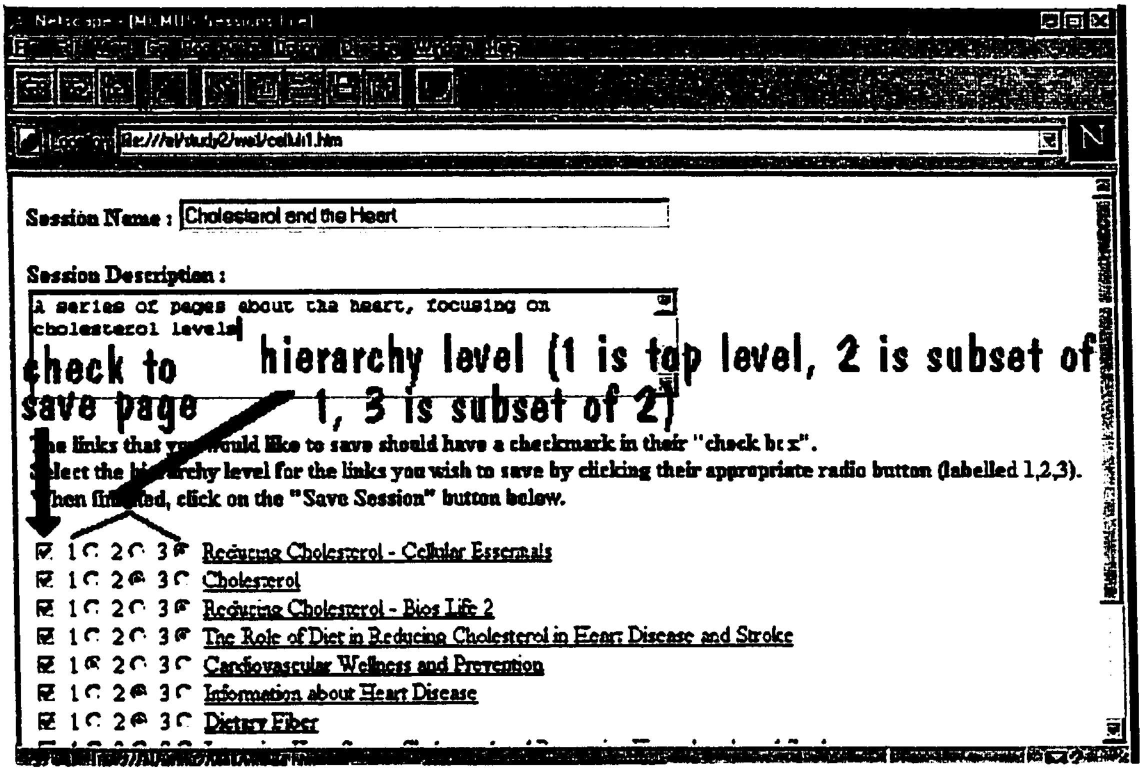
You can jump to any item in either the recency or frequency list (only one item from either list can be selected at one time). Other features of the MEMOS tool include :

- page title descriptions in either recency or frequency list can be modified by selecting the "***Edit***" button
- items in both lists can be shown as page titles or URLs by selecting the "***View Titles***" or "***View URLs***" buttons
- current recency and frequency lists may be cleared at any time by selecting the "***Clear***" button
- the MEMOS window can be hidden behind the main Netscape window by selecting the "***Hide***" button

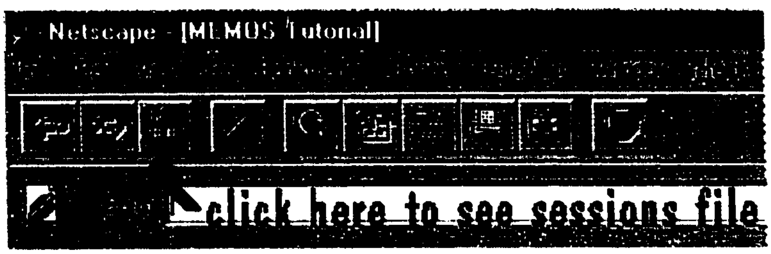
Here is a snapshot of what the MEMOS tool looks like during a navigation session :



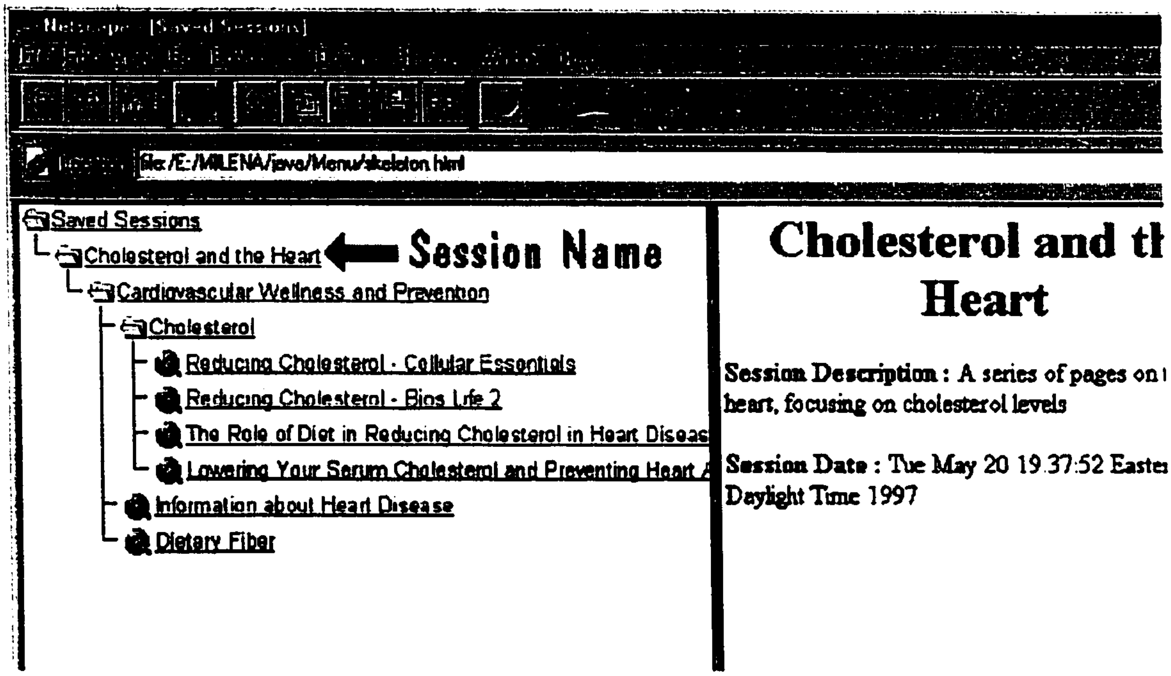

You will notice that a "Save" button is provided that allows you to save a navigation session for future use. When clicking on "Save" you will be asked to give your session a name and you will have the opportunity to decide which pages you would like to save and the hierarchy of your saved pages. You may save Web pages in three hierarchy levels to indicate main and sub-pages. When selecting a second or third level hierarchy, you will be asked to indicate the appropriate parent page. Here is a snapshot of a MEMOS saving screen :




When you save your session, it will be appended to a sessions file which contains any other sessions you may have saved earlier. You may view your sessions file at any time by clicking on the "Home" button in the Netscape toolbar.



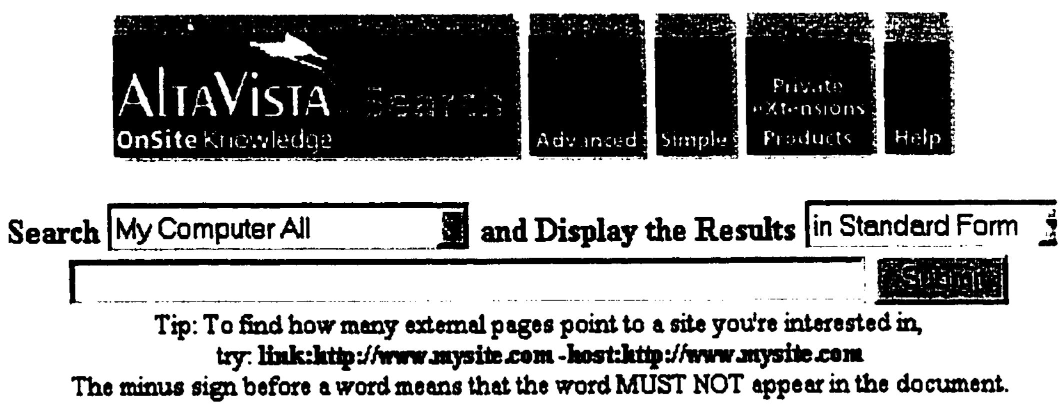

A page with subpages is indicated by a folder icon ( ). Click on the icon to open the folder and see its subpages (or subfolders). A page without subpages is indicated by a globe icon ( ). If you click on the page name (beside a folder or globe icon), you will be taken directly to that page. The ability to save navigation sessions for future use means that the MEMOS history tools provides short-term intra-sessional and long-term inter-sessional support. Here is a snapshot of a MEMOS sessions file :




Back to Main Tutorial Page

# AltaVista Search Engine

This experiment uses a "local" Web. The popular AltaVista Search Engine is available to search this local Web. This tool allows you to search Web pages by keywords. To access the search engine at any time select "AltaVista Search Engine" from the bookmarks (under the second line separator). If you have any questions about search engines, please feel free to ask the experimenter. A snap-shot of the AltaVista Search Engine is shown below :

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Back to Main Tutorial Page

# Appendix III

# MEMOS Full Study Questionnaires

Subject : ____________

## Compare Short Term Memory Aids : Go List vs. History Window vs. MEMOS

For each of the following, rate the short term memory aids on the degree to which they best answer the following statements :

| | Go List | | | | | | | MEMOS | | | | | | | History Window | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Strongly Disagree | | | | | | Strongly Agree | Strongly Disagree | | | | | | Strongly Agree | Strongly Disagree | | | | | | Strongly Agree |
| Flexible | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Confusing | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Easy to use | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Easy to find desired page | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Fast at finding desired page | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Effective for browsing | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Effective for searching | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Useful | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Good choice, considering all characteristics | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

Did you use the Go List during this session? Y / N
Did you use the History Window during this session? Y / N

Have you used the Go List in the past? Y / N
Have you used the History Window in the past? Y / N

**Please enter your comments on the efficiency and effectiveness of the Go List, MEMOS, and History Window :**

______________________________________________

______________________________________________

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______________________________________________

______________________________________________

Subject : ____________

# Compare Long Term Memory Aids : Bookmarking vs. MEMOS

For each of the following, rate the long term memory aids on the degree to which they best answer the following statements :

| | BOOKMARKS | | | | | | | MEMOS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Strongly Disagree | | | | | | Strongly Agree | Strongly Disagree | | | | | | Strongly Agree |
| Flexible | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Confusing | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Easy to use | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Easy to find desired page | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Fast at finding desired page | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Effective | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Useful | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Good choice, considering all characteristics | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |

Did you use Bookmarks during this session? Y / N     Have you used Bookmarks in the past? Y / N

**Please enter your comments on the efficiency and effectiveness of Bookmarks and the MEMOS Tool as a long term memory aid below :**

Subject : ___________

# Evaluate the MEMOS Hierarchy Option

For each of the following, rate the MEMOS hierarchy option on the degree to which it best answers the following statements :

| The option to save my sessions in a hierarchical manner ... | Strongly Disagree | | | | | | Strongly Agree |
|---|---|---|---|---|---|---|---|
| is confusing | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| is easy to use | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| makes it easy to find the desired page | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| allows me to quickly find the desired page | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| is effective | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| is useful | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| is a good option, considering all characteristics | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

**Please enter your comments on the efficiency and effectiveness the MEMOS hierarchy option below :**

______________________________________________

______________________________________________

______________________________________________

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______________________________________________

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______________________________________________

| | First Time | | | A few months | | | More than one year |
|---|---|---|---|---|---|---|---|
| How long have you been using the Web? | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

| | Not at all familiar | | | | | | Very familiar |
|---|---|---|---|---|---|---|---|
| How familiar were you with health and fitness before your first session? | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| How familiar were you with British Columbia before your first session? | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

# Appendix IV
# Histograms of Questionnaire Responses For the Full Study

A.Hypothesis H2 Histograms

B.Hypothesis H3 Histograms

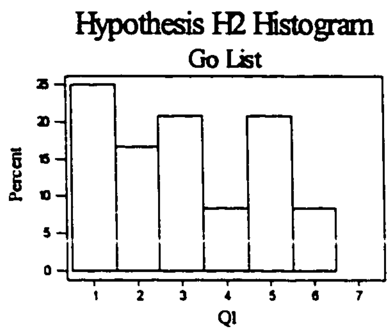
C.Hypothesis H6 Histograms

D.Hypothesis H7 Histograms

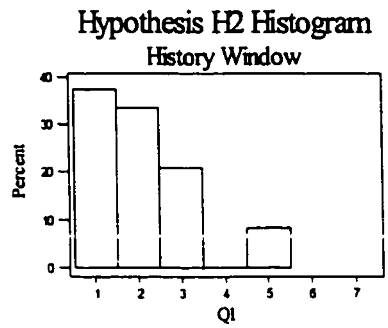
E.Hypothesis H8 Histograms

F.Hypothesis H9 Histograms

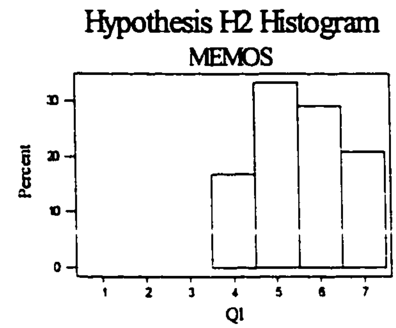
## A. Hypothesis H2 Histograms



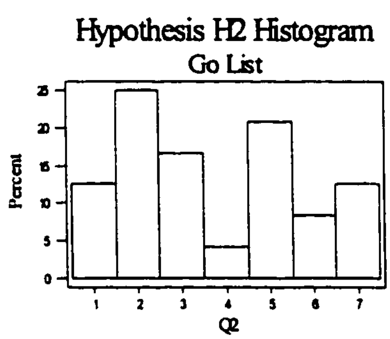

$H_{2.1}$ (Q1-1: Go List)



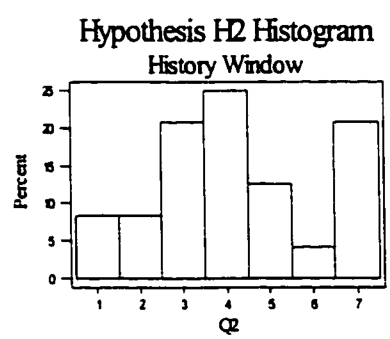

$H_{2.1}$ (Q1-1 : History Window)



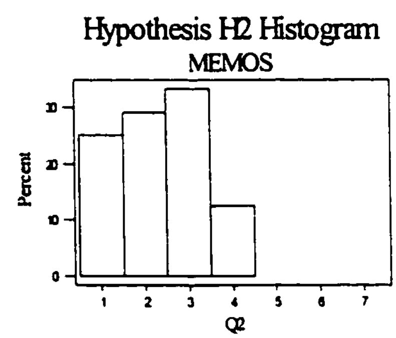

$H_{2.1}$ (Q1-1 : MEMOS)



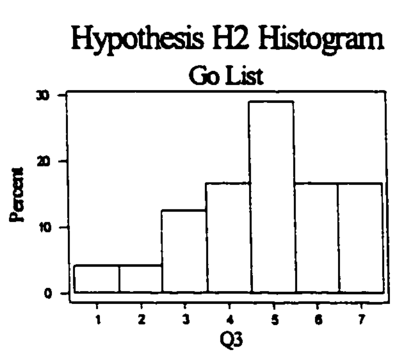

$H_{2.2}$ (Q1-2: Go List)



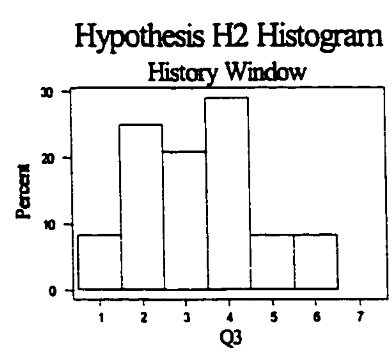

$H_{2.2}$ (Q1-2 : History Window)



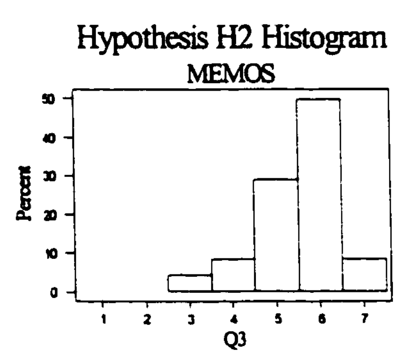

$H_{2.2}$ (Q1-2 : MEMOS)




$H_{2.3}$ (Q1-3: Go List)

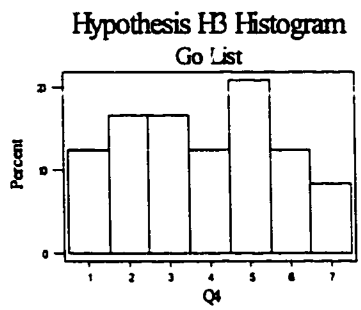



$H_{2.3}$ (Q1-3 : History Window)

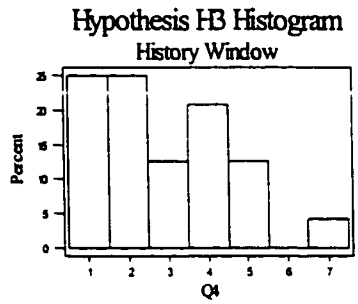



$H_{2.3}$ (Q1-3 : MEMOS)

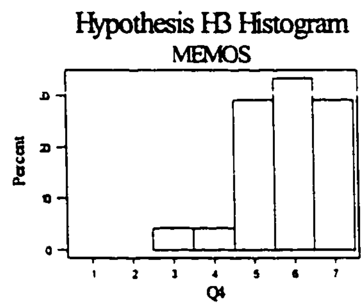
## B. Hypothesis H3 Histograms



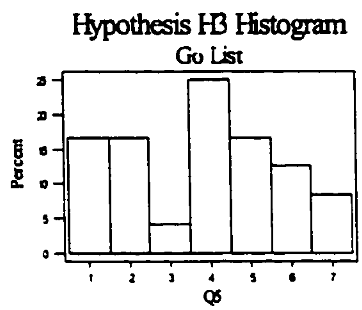

$H_{3.1}$ (Q1-4: Go List)



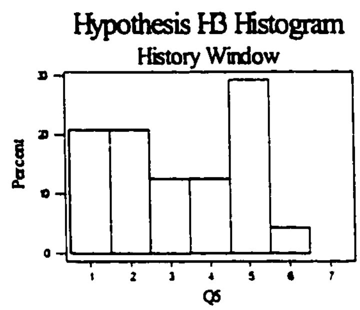

$H_{3.1}$ (Q1-4 : History Window)



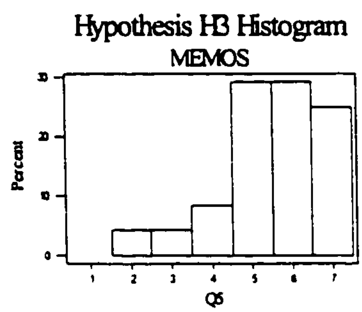

$H_{3.1}$ (Q1-4 : MEMOS)



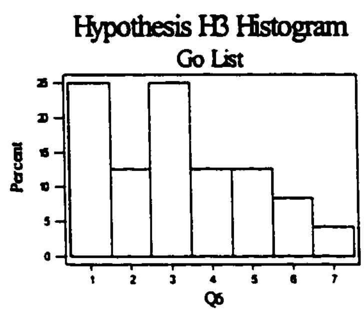

$H_{3.2}$ (Q1-5: Go List)



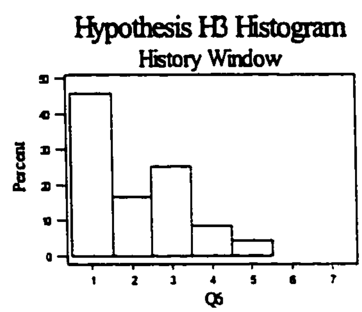

$H_{3.2}$ (Q1-5 : History Window)



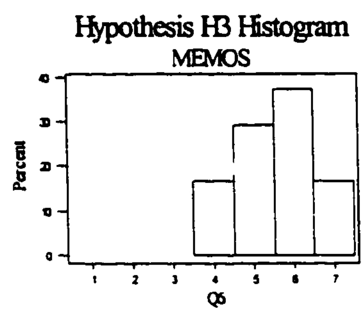

$H_{3.2}$ (Q1-5 : MEMOS)



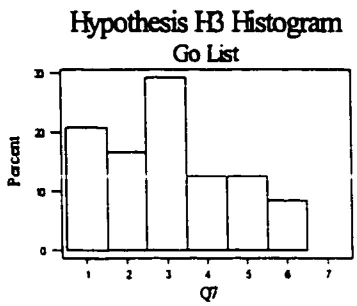

$H_{3.3}$ (Q1-6: Go List)



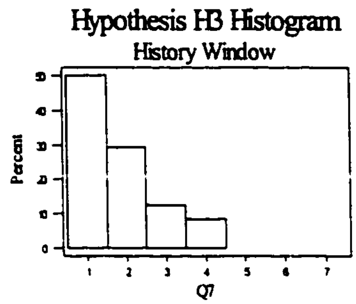

$H_{3.3}$ (Q1-6 : History Window)



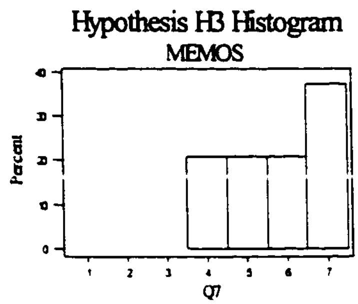

$H_{3.3}$ (Q1-6 : MEMOS)



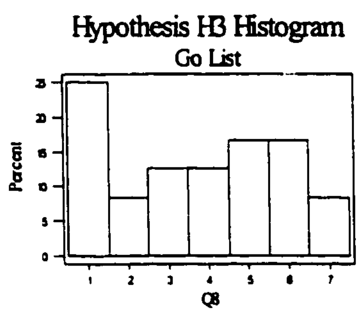

$H_{3.4}$ (Q1-7: Go List)



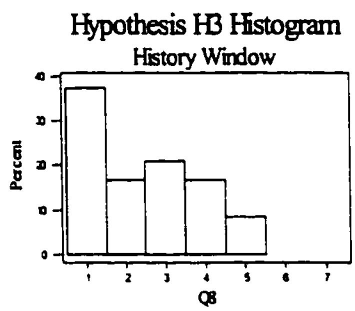

$H_{3.4}$ (Q1-7 : History Window)



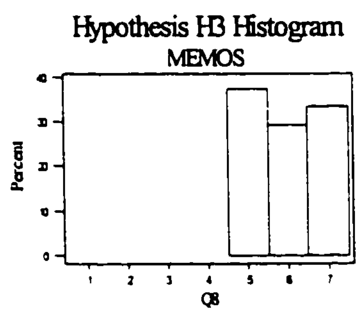

$H_{3.4}$ (Q1-7 : MEMOS)




$H_{3.5}$ (Q1-8: Go List)

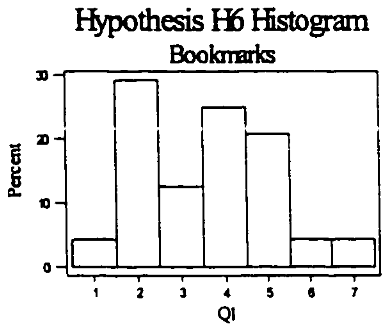



$H_{3.5}$ (Q1-8 : History Window)

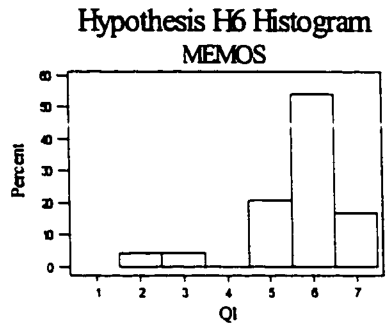



$H_{3.5}$ (Q1-8 : MEMOS)

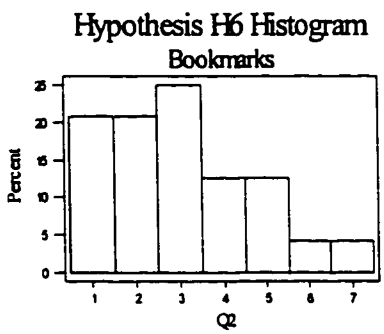
## C. Hypothesis H6 Histograms



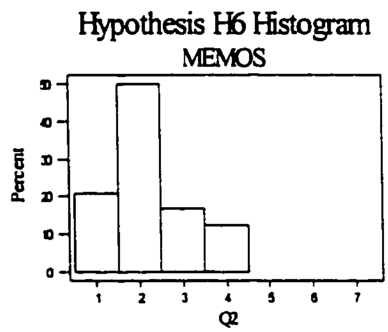

H 6.1 (Q2-1: Bookmarks)



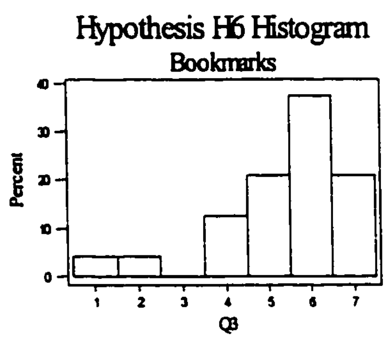

H6.1 (Q2-1 : MEMOS)



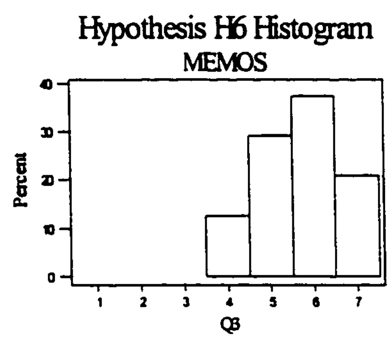

H 6.2 (Q2-2: Bookmarks)




H6.2 (Q2-2 : MEMOS)

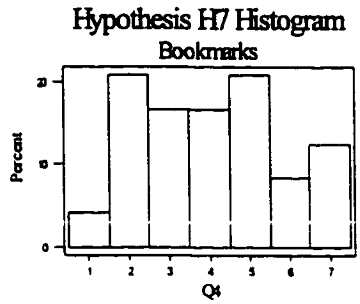



H 6.3 (Q2-3: Bookmarks)

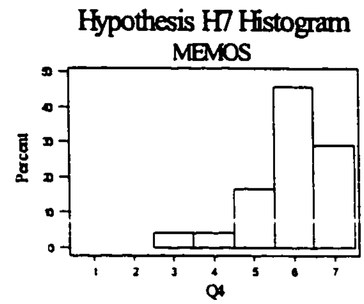



H6.3 (Q2-3 : MEMOS)

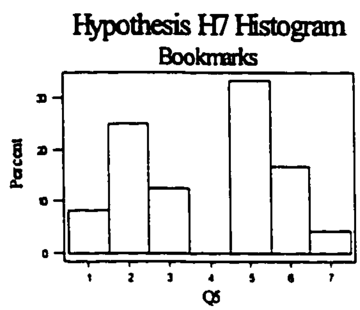
**D. Hypothesis H7 Histograms**



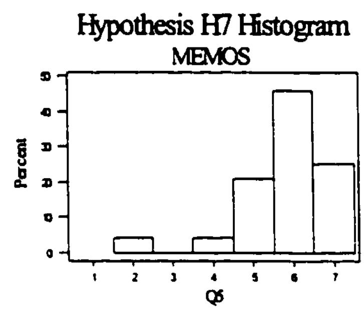

$H_{7.1}$ (Q2-4: Bookmarks)



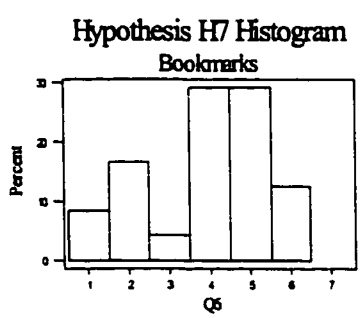

$H_{7.1}$ (Q2-4 : MEMOS)



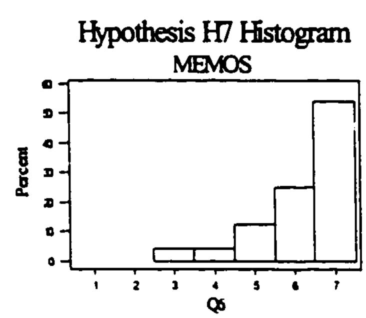

$H_{7.2}$ (Q2-5: Bookmarks)



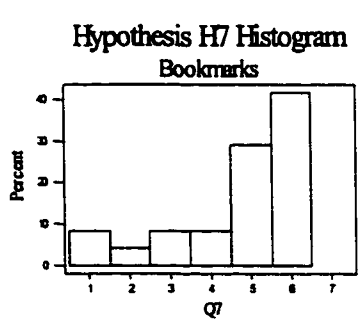

$H_{7.2}$ (Q2-5 : MEMOS)



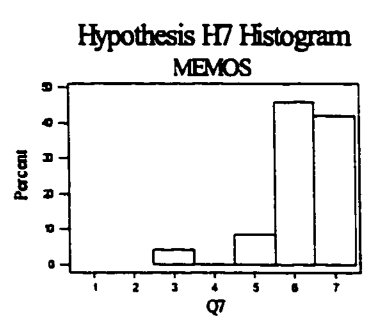

$H_{7.3}$ (Q2-6: Bookmarks)




$H_{7.3}$ (Q2-6 : MEMOS)

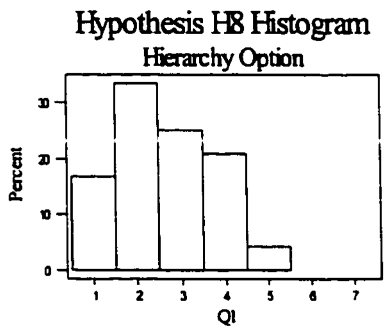



$H_{7.4}$ (Q2-7: Bookmarks)

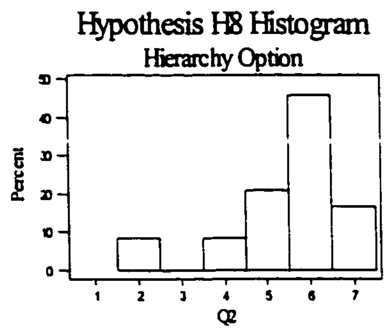



$H_{7.4}$ (Q2-7 : MEMOS)

## E. Hypothesis H8 Histograms

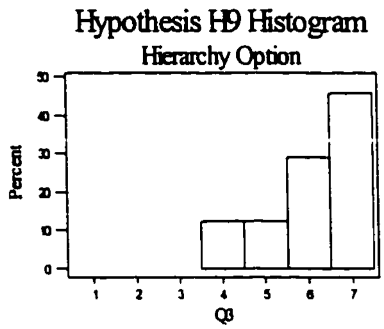



H 8.1 (Q3-1)

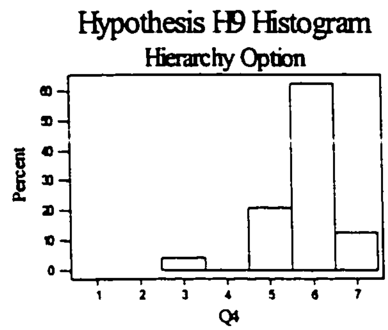



H8.2 (Q3-2)

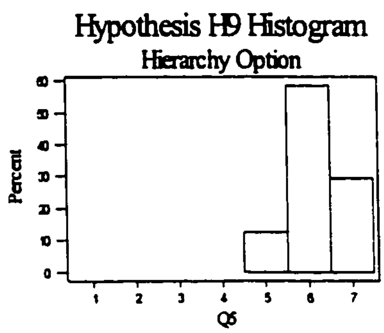
## F. Hypothesis H9 Histograms



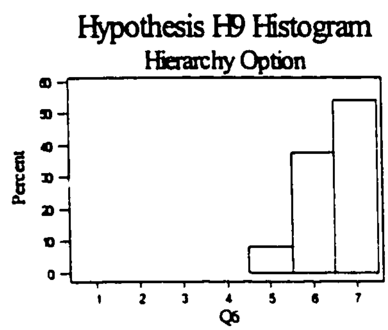

$H_{9.1}$ (Q3-3)




$H_{9.2}$ (Q3-4)




$H_{9.3}$ (Q3-5)




$H_{9.4}$ (Q3-6)