CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

NAVIGATION THROUGH HIERARCHICAL MENU STRUCTURES:

DOES IT HELP TO HAVE A MAP?

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Arts in

Psychology

by

Patricia Anne Billingsley

January, 1984

The Thesis of Patricia Anne Billingsley is approved:

California State University, Northridge

ACKNOWLEDGEMENTS

The author wishes to thank Dr. Tyler Blake, Dr. Michael McCauley, and Dr. Mark Sanders for their support and inspiration throughout this research effort. She is especially grateful to her husband, John Merritt, for his thoughtful comments, enduring patience, and constant encouragement.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

NAVIGATION THROUGH HIERARCHICAL MENU STRUCTURES:

DOES IT HELP TO HAVE A MAP?

by

Patricia A. Billingsley

Master of Arts in Psychology

The human-computer interface for many information retrieval systems is a hierarchical menu structure. Although this type of interface has several advantages for novice users, there is potential for confusion and disorientation when menu structures are large and complex. Two experiments were conducted on-line to examine how novice users of a menu-based data retrieval system learn to navigate through the menu structure to find goal items, and to evaluate two different kinds of learning aids suggested by previous researchers.

In Experiment 1, 30 subjects were asked to play the "Animal Hunt" game. The game required each subject to search through hierarchical menus of descriptive terms to find 45 target animals. The menu choices became progressively more specific as subjects moved deeper into the

hierarchy, closer to the target animal. For the first trial block (nine searches), subjects in the control group had no learning aids to help them remember where target animals were found. Subjects in the index group used a linear alphabetized index that showed the correct sequence of menu choices leading to every target animal in the game. Subjects in the map group used a map-like diagram of the database structure to find targets. At the end of trial block one, all subjects continued with trial blocks two through five with no additional help from the map or index aids.

The results of a three (group) by four (trial block) mixed design showed no significant differences between the three groups that could be attributed to the learning aid manipulation. However, the potential effect of the aids may have been diminished because subjects saw them only in the first trial block. Since they had not yet had a chance to learn overall game strategy, subjects may not have realized how to use the aids to improve their game-playing performance.

In Experiment 2, data from the control group in Experiment 1 was compared to that of subjects in two new index and map groups, who were asked to play the same "Animal Hunt" game, but in the context of a slightly altered experimental paradigm. Both new groups worked through the first trial block without any help from either the map or index aids, to ensure that they understood how the game was played. They were then given the map or index to study. After five minutes of study time, the aids were taken away and the subjects completed the remaining four trial blocks of the game.

The results showed that the control group had significantly poorer overall performance than either the map or index group. Performance data included both the total time used to complete a search and the number of incorrect menu choices made while searching. Of greatest interest was the significant group by trial block interaction in the menu choice error data. In the fourth and fifth trial blocks, subjects were asked to search for animals on menu pathways that, until that point, had been studied in the map or index but never practiced. Under these conditions, subjects in the map group demonstrated significantly better search performance than either the index group or control group. Access to the map appeared to facilitate the development of a useful and memorable mental model of the menu structure.

This conclusion has implications for the optimal design of menu-based systems. It suggests that, in addition to traditional training about system operation, users should be given maps of even simple menu structures. Once they understand basic procedures, users should find that a map helps them both to understand and to efficiently navigate through the hierarchy of choices.

INTRODUCTION

The advent of computer-based information retrieval systems has given many non-programmers access to large files of stored data. Computers are helpful, and indeed almost necessary, whenever the information being handled is very complex or includes a large amount of data. There are many ways to structure data in such a system, including relational, network, and hierarchical organizations. Regardless of the data structure chosen by the database designer, the overall design must include a retrieval scheme that allows users to access information or functions such as an option in a word processing system, the name and salary of an employee, or the amount of fuel on board an airplane. Such systems can greatly simplify an information gathering task, once the user understands the way in which information is made available by the system.

Designers cannot expect casual users of database systems to be familiar with the details of the internal organization of the stored information, but it is not always clear where "internal" stops, and "external" begins (Cuff, 1980). People make assumptions about the structure of databases, often assuming that they are constructed in accordance with the user's mental model of the data attributes. They may have difficulty, and react negatively, if required to navigate through data organized in some other way. Even if the overall logical contents of a database are fairly clear in a casual user's mind from session to session, when the details of the actual organization of the material do not match his or her persistent mental picture, the resulting incongruity may make it that much more difficult to use the system (Cuff, 1980; Durding, Becker, & Gould, 1977).

Many systems currently in use were designed using a hierarchical structure for storing data. Studies have shown that both the complex comprehension and the memorization of information is easier for subjects using a hierarchical format than a relational one (Brosey & Shneiderman, 1978). Research has suggested that subjects use hierarchic principles in retrieval strategies to help them recall information that is initially presented in an unstructured form (Bower, Clark, Lesgold, & Winenz, 1969). It has even been proposed that all items in semantic memory are stored in a series of interconnected hierarchical structures (Collins and Quillian, 1969). The merit of such a memory schema is that each cue associated with a stored item depends on its superordinate. Thus, the retrieval of a small initial set of cues should make it easy to recall a further larger set, and so on to a very large number of final categories, which has the advantage of "cognitive economy" (Broadbent, Cooper, & Broadbent, 1978, p. 486).

In an information retrieval system, one way to allow access to hierarchically-structured data is through the use of sequentially presented menus. Sequential menu selection takes operators from general descriptors at the top of the hierarchy down through increasingly specific category descriptors. At the lowest, most specific level, they can select the desired goal item (Miller, 1981). At each level, the system displays a new group of more specific choices that branch from the chosen high level option. There may be more than one page of menu options at any given level, depending on the size and complexity of the database. This design helps to reduce the amount of data that any one user must search to find a particular item or option. When information is presented from the general to the specific, the pattern of choices made by the user at each level can lead quite directly to the targetted data.

A menu selection system requires little user training and has the advantage that the actual process of working through the menus lets people know about other available options and information (Shneiderman, 1978). However, the initial process of learning about the way in which the information is organized may put a considerable load on the short term memory of new system users, especially when goal items are more than four or five levels deep in the data structure (Calhoun, 1978; Engel & Granda, 1975; Miller, 1981). This load may never be fully relieved if the user only accesses information in the system from time to time, and therefore has little opportunity to build up a workable mental model from session to session.

The memory load problem is a function of the fact that not all available options or pieces of data can be displayed on the computer screen at a given time, so that the user is required to integrate information across a series of sequentially presented displays. Most systems allow the user to "page" back and forth through the menus, but unlike paging through a book, only one screenful of the structure can be viewed at any one time (Miller, 1981). Cuff (1980) describes the problem well:

> One can easily lose track of where one is going, since the casual user's relative unfamiliarity with the system makes it

> difficult to remember an entire strategy in the way that an absorbed regular may do....Situations are bound to arise where a user, selecting from choices offered by the system, requires more information to make that selection than is currently on show. The user may have forgotten earlier output, be uncertain of the meaning or consequences of some choices, or want to dig around a little first (p. 174).

The nature of these systems requires either that the sequence of choices be completely self-evident or that the user learn a particular access path to reach a given piece of information or goal. In the context of this discussion, an access path is made up of the specific pattern of choices that the user makes in working through the system from the most general level to the specific desired piece of data. These paths can be of differing lengths, with different numbers of choice points at each level. Usually one sequence of choices follows logically and semantically from another, but this is not always the case. Bower et al. (1969) mention the fact that many words have ambiguous meanings, so that the intended sense of a given word or phrase can be established only by seeing it in relation to its total hierarchical context.

Once in the menu structure, users who find themselves following an inappropriate path must be able to retrace their steps through the sequence of decision points in order to begin searching down alternative pathways. Until they are quite familiar with the system, new users are likely to find themselves "lost" in the structure of the hierarchy. The resulting disorientation can have several negative effects, including frustration on the part of users when they realize that they don't know how to proceed, a loss of productive time, and greater inefficiency manifested by the choice of inappropriate or unnecessarily long access paths.

Anecdotal evidence concerning this type of problem comes from experience working with operators of the Navy Tactical Data System (NTDS). NTDS operators are required to manipulate a highly complex hierarchical database that consists of different types of requests for information and arrays of possible choices of action, most in the form of highly abbreviated acronymns. One typical user of the system, the Air Controller, has access to a total of 220 different options, displayed on 19 pages of menus. Operators may be required to negotiate through as many as five levels of menus to reach a desired option, and they move back and forth between levels of the hierarchy in a continuous flow of operations. Although the system provides the option to move back to the starting point at any time, new users often report that they "get lost" within the structure, and waste valuable time reorienting before they can perform the next required function.

With the realization that users can and do become disoriented in a hierarchical structure, it becomes important to examine what the user is being asked to do. The retrieval task involves elements of problem solving, short and long term memory, and concept formation. At the initial point of interaction with the system, the user probably knows what piece of information he or she is seeking, and must solve the problem of finding out where in the system the particular data item is stored. The system reveals itself only one layer at a time, and the user doesn't initially know how early decisions will affect the range of choices available later. In many ways the task is like learning a maze, except that the maze is a mental rather than a physical one (Baker & Goldstein, 1966). The new user may have no idea of the type of structure being dealt with, and even if it is recognized as a hierarchy, there is typically no information concerning its breadth or depth.

With an identified goal item in mind, the user begins searching through the system. The first trial and error foray results in knowing not only how to reach the desired goal, but also how to reach other goal items that are encountered along the way. It is during these original attempts to reach data items that the user begins to build up an internal representation of the data structure, however inappropriate it might be. Scheerer (1963) described the Gestalt view of problem solving, which emphasized the tendency of the mind to organize, integrate, and perceive situations, including problems, as total structures. This point is reiterated by Miller (1969) who states that "cognitive order is achieved through categorical structure, and task structure is revealed by the categorical structure of the information used in the decision process" (p. 560).

The user's initial coding of information into some sort of internal representation is particularly important since it is to be used in later induction. Hunt (1966) discussed the necessity of such coding in concept learning, and its function of reducing the number of symbols that must be stored in memory at any one time. He added, however, that if the symbolic representation is to be of any use at all, it must contain information that is relevant to the concept, which in this case is the hierarchical structure of the database. At the time of forming an internal representation, the concept learner may not know what information is important to abstract from the presented material. If the concept learner's hypothesis is wrong, the information that he or she chooses to store may be of no use for further problem solving within the same framework (Hunt, 1966); at the worst extreme, it may make problem-solving impossible.

In a discussion of the particular problems associated with sequential concept learning, Gregg (1966) stated that although one can think of concepts as logical abstractions, their representation in human memory must be concrete. Specific serial lists, associative connections, and rules relating these elements must be understood by the concept learner before it can be said that he or she has truly learned a concept. Without such information and structure, the learner will be incapable of generating any behavior whatever (Gregg, 1966). However, evidence presented by Bower et al. (1969) indicated that when a learner is provided with a systematic retrieval plan for organizing large blocks of information, such plans are sufficient to produce very high levels of recall. Once users recognize the hierarchical nature of the stored information, and have formed a valid internal representation of its specific structure, retrieval of any particular data item should be effected with relative ease and efficiency.

There are several candidates for the types of systematic retrieval strategies that might be made available to or encouraged in users. One such candidate is the use of spatial/locational information to supplement the semantic or logical relationships between data items at different levels of a hierarchy. There is a large body of research that supports the idea that both semantic and locational attributes of written information are encoded into memory at the time of reading (Bower,1970; Brooks, 1968; Mandler, Seegmiller, & Day, 1977; Rothkopf, 1971; Schulman, 1973; Zechmeister, McKillip, Pasko, & Bespalec, 1975). Zimmerman and Underwood (1968) make the strongest statement concerning the dual encoding of semantic and spatial information. They assert that "position knowledge of a spatial-temporal nature is such a fundamental dimension of memory that it is an integral part of the learning process" (p. 307).

The experiment conducted by Zechmeister et al. (1975) is a good example of the type of paradigm used by researchers in this area of investigation. Sixty four subjects were asked to read a lengthy prose passage, and then tested for information recall, memory for location of information answers, and discrimination of correct information answers in a multiple choice test format. The researchers found that spatial memory was highly reliable, and significantly greater for correct as opposed to incorrect information answers. One of the most interesting findings was that letting subjects know that they would be asked about the location of information did not effect their ability to recall spatial locations. The researchers felt these results implied that visually mediated spatial memory is a fundamental attribute of the text-encoding process, functioning independently of specific instructions to attend to spatial information.

There is evidence from the verbal learning literature to support the idea that subjects take advantage of the spatial structure of hierarchically-organized information when it is made available to them by the experimenter, and that they recreate the structure on paper when asked to recall all the items in a given hierarchy (Bower et al., 1969; Broadbent et al., 1978). It has been suggested that the relative ease with which subjects comprehend and memorize data items in hierarchical models, as opposed to relational models, is a function of the inherent structure conveyed by the hierarchy itself (Brosey & Shneiderman, 1978). It is only in recent years, however, that researchers have begun to consistently recommend that designers of information retrieval systems incorporate graphical or pictorial representations of data structures into the computer software controlling users' access to stored data, thus taking advantage of the internal representation capabilities that humans are known to have.

McGee (1976), in a discussion of user criteria for data model evaluation, introduces the concept of "picturability". He suggests that the display of structures in pictorial form is particulary helpful for the initial learning of data models. He asserts that "such pictures not only help with the initial comprehension of the model, but also provide a reference point to which the user may return repeatedly as he uses the model" (p. 374). The use of pictorial coding in addition to symbolic (semantic) coding is urged by Fitter and Green (1979), who argue that "symbolic representations require concious cognitive processing, whereas analogical or pictorial information is perceived immediately" (p. 238), although no data is cited to support this contention. They conclude that "if graphic notation can reveal the structure inherent in the underlying data or the process by which entities are manipulated, then it will be superior to a linear symbolic language" (p. 255).

There have been few specific suggestions for ways in which pictorial user aids or graphics might be incorporated into menu-based hierarchical information systems, in spite of the fact that "the limited number of choices on any frame and the information about the sequence of frames that led to the current one provide a narrow context within which it is easy to design effective user aids" (Shneiderman, 1980, p. 238). The concept of a "visible audit trail of choices" was discussed by Engel and Granda (1975, p. 16). They presented an example aid in their menu design guidelines that is quite similar to an aid provided to users of multiple files in the UNIX operating system (Kernighan, n. d.). The system keeps a running record of menu choices on display for users, so that they are at least aware of the particular pathway they are following at the moment. An example "trail" might look like this: /ANIMAL/CARNIVORE/FOUND IN CAPTIVITY/LION/. The trail might look very different if the user were attempting to find RABBIT or DAISY.

Unfortunately, such a system allows the user to look at only one pathway at a time, and may not be particularly helpful for building up a valid internal representation of the entire structure. Smith (1981) suggested displaying both current and lower levels in the hierarchy at the same time to give the user a deeper view of the structure, but added that this option is viable only where space permits. The NTDS operators mentioned earlier in this paper devised their own method for keeping lower level choices in the hierarchy in view at all times. Some of them drew small "maps" of the database structure and taped them to their consoles, where they could be referenced easily at any point. However, it may be both inefficient and unreliable to leave the creation of these aids to the operators themselves, especially since they may not even think of the possibility of mapping out the structure until they have had numerous trial-and-error runs through the data.

A totally different approach is discussed by Durding et al. (1977), who recognized the need for users to have an overview of the data structure, but didn't feel that aids for helping users develop such an overview must necessarily be an internal part of the computer system itself. They suggested having the user develop a particular query sequence (in this case, a series of menu choices) by filling in some physical form or skeleton which is consistent with the general organization of the data. This may indeed be a valuable training aid, but it requires users to have the correct forms and writing instruments with them at the time of composing a query, and also requires that every query be thought out before accessing the system. While minimizing entry errors, it does not necessarily make the user aware of all the options available. A system that seems far superior, although more expensive to implement, was described by Cuff (1980). In this system, a graphical network representing a database is displayed and a query is built up by a series of lightpen hits along data paths, combined with selections from a list of functions.

Although many recommendations have been made concerning the desirability of including graphical or pictorial representations of data structures in information retrieval systems, there is very little empirical research that either confirms or disconfirms the value of such aids. The concept is well supported by other lines of research, but it has not been examined systematically in the context of computer-based systems. The only facet of the problem that appears to have been investigated experimentally concerns the way in which a hierarchical structure is initially learned. At least two researchers have addressed this issue; unfortunately they did not investigate ways in which the learning process could be made simpler.

Crothers (1969) was interested in how subjects learned the structure of a hierarchy that could be graphically represented by a binary tree. He used data arranged in three levels, with one data item at the top level, two at the second level, and four at the third level, although subjects were never shown this arrangement. In this study, the data items were all CVC nonsense syllables of low association value, chosen with the restriction that no two syllables could have the same intial or final consonant. Instead of displaying all the elements of a tree concurrently in graphic form, Crothers presented information to subjects in the form of statements like "A SUR is a type of PIL". Each statement described the relationship between items on two different levels of the tree, so that the author could observe the relationship of learning patterns to the serial order and presentation frequency of such statements. His primary interest was in whether subjects could build up an internal representation of the tree that would allow them to answer questions about it with greater accuracy than could be achieved by simply learning a series of random paired associates.

Crothers expected that the entire tree, or at least subtrees or paths, would be learned as a unit, but analysis of the patterns of subject responses did not support this expectation. He adds, however, that "the further question of whether S, after learning a tree, could state or sketch its graph structure was not investigated. What the data do indicate is that such knowledge, if present at all, did not influence his manner of learning subsequent trees" (Crothers, 1969, p. 288). Crother's results seem to indicate that subjects may not use hierarchical representations for data unless they are specifically told that such a model is appropriate in the learning context. Apparently even the use of the phrase "X is a type of Y" was not enough to bring such a structure to mind. Crothers implied, however, that if subjects had been shown all elements of the tree at once in graphic form, they would have immediately grasped the structure of the data.

Baker and Goldstein (1966) used a computer to simulate an actual information retrieval task. They were also interested in how easily subjects could learn to negotiate through what they called a "mental maze" of nonsense syllables. A subject was required "to develop the structure of the maze intellectually, based upon his determination of the relations among the alternatives he discovers" (p. 226). However, the authors conceived of a mental maze as being non-spatial in character, and in fact deliberately randomized the position of elements at any given level in the hierarchical structure to prevent any spatial learning.

Although the focus of the study was on how many data items should be shown to subjects at any one time, the learning condition that Baker and Goldstein refer to as "sequential" is analogous to a typical sequential menu selection system. Subjects were required to search for goal items by making choices from a series of menus, each containing a small number of possible options, and each branching off along a different access path. The hierarchical nature of the structure was never explicitly stated to subjects, and it could be argued that the constant repositioning of choices within each level might have made the recognition of such a structure somewhat more difficult.

The hierarchy used in the study was relatively complicated, with goal items as many as five levels deep in the structure. The hierarchy was not symmetrical, and the number of options at any given level along the different pathways varied between one and four. Subjects in the "sequential" condition were given eight goal items to find, and were required to continue searching for and finding the goal items until they reached the criterion level. This was defined as finding each of the eight goal items using the minimum number of steps through the hierarchy, by making the correct sequence of nonsense syllable choices from the series of displays, and thereby reaching the goal items in the most direct manner.

An analysis of the number of trials to reach criterion showed great individual differences in the ease with which subjects were able to learn the structure of the hierarchy. Trials to criterion varied from 9 to 121 across 10 subjects, and the time required to reach criterion ranged from 7 to 97 minutes. (These values do not include 16 initial practice trials for all subjects, or the final 8 criterion trials.) The authors made no attempt to explain the large individual differences, and they gave very little information about their subjects other than that 9 were male and the remaining 11 were female.

There are several important research questions that have not been addressed by previous investigators, but which have implications for the optimal design of menu-based information retrieval systems:

1. How do novice users of hierarchical menu-based systems begin searching for goal items when they are first exposed to an unfamiliar database? Baker and Goldstein (1966) looked at the development of mental models, but with a database where data elements were neither semantically meaningful nor positionally stable. They didn't begin measuring performance until subjects had completed 16 practice trials to familiarize themselves with the task, so all information about initial learning strategies was lost. Crothers (1969) also used nonsense syllables, and it appeared that his subjects were not fully aware of the nature of their task.

2. What sorts of individual differences may affect the ability to negotiate through a series of menus to find goal items, and to remember the patterns of menu choices that lead to those items? Neither Baker and Goldstein (1966) nor Crothers (1969) discussed subject aptitudes or characteristics that might help explain performance variation.

3. Can learning aids that show specific data pathways help users improve their speed and accuracy in retrieving information?

4. Are aids that provide information about both the semantic and the spatial organization of a database more effective than those that stress only semantic associations between data elements?

To begin to answer these four questions, an experiment was designed to permit an empirical evaluation of user performance with a menu-accessed hierarchical database. The entire experiment was conducted on-line, so that subjects worked interactively with the computer program as stimulus material was presented. The subject's task was to search for a series of target data items, moving progressively through a series of menus presented one by one on the computer display screen. The subject could move forward or backward through the menus, choosing an option from each menu that would lead either to a new menu of choices or to a display of goal items, until the correct goal item was found. A subject's overall performance was a function of his or her ability to remember the sequence of menu choices leading to every target item, so that each one could be reached with maximum efficiency. The search process was very realistic, requiring subjects to use skills that would also be necessary in an operational computer environment.

It was hypothesized that subjects could most easily accomplish this task by recognizing and internalizing the overall structure of the database, using both semantic and spatial relationships between data elements that could be derived from working through the menus. To facilitate the initial learning process, some subjects were given indexed information about specific semantic pathways that led through the levels of the hierarchy directly to targetted data items. Other subjects were given a map of the entire data domain that showed each data pathway and the semantic ties between elements, but also related the pathways to each other in an overall spatial context. A control group of subjects had no index or map to use.

Although previous researchers seem to have assumed that individual differences were unimportant, the present study attempted to assess the influence of several types of aptitudes and demographic variables on task performance. First, it was hypothesized that memory for spatial relationships between elements in a spatial domain would be a critical individual aptitude, correlated with the ability to organize the overall menu structure spatially and to remember the position of semantic data elements in that structure. It was hypothesized that a spatial memorization schema would facilitate the development of maximally efficient search strategies. Previous research (Egan, Bowers, and Gomez, 1982) investigating the performance of novice users during the first two hours of contact with a text editor showed that spatial memory was a significant predictor of number of errors made and of the time spent correcting errors.

Secondly, although Egan et al. (1982) found that paired associate memory was not a significant predictor of performance on the same word processing tasks, they considered it important to examine the relationship between this aptitude and menu search performance. Since subjects were required to remember strings of data elements that formed specific data pathways, the ability to link words in memory could make their task easier.

Tests of spatial and paired associate memory were administered to all subjects. They were also questioned about their age, handedness, and previous exposure to computers, programming, and word processors. The overall experiment was designed to test three different hypotheses about the relationship between memory abilities, menu search efficiency, and access to indexed or mapped data information during initial learning trials:

1. High spatial memory subjects will perform better across all conditions.

2. Subjects in the data map condition will perform better than subjects in the data index condition, and both groups will surpass the performance of the control group.

3. Since subjects with a high aptitude for spatial memory will probably take advantage of the spatial information inherent in the task structure anyway, spatial cueing (exposure to the data map) is not expected to have much effect on their performance. For subjects with low spatial memory aptitude, the novel information provided by the map is expected to have a greater positive effect on search performance.

EXPERIMENT 1

Method

Subjects

The subjects of the study were 54 undergraduate and graduate psychology students, 27 males and 27 females, who participated either as part of a course requirement, or on a volunteer basis.

Apparatus and Materials

Computer. An Apple II microcomputer equipped with dual disk drive and a Mountain Computer real-time clock were used for controlling stimulus presentation and for data storage during the experiment.

Pretests. Subjects were assumed to vary substantially along several different dimensions that could affect their performance on the task. In an attempt to understand how these individual differences might interact with initial learning conditions, subjects were given two pretests prior to assignment to experimental groups.

The first pretest, the Building Memory Test, was taken from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harman, and Derman, 1976) published by the Educational Testing Service (ETS). The test was modified slightly so that a more accurate scoring procedure could be used. In the original version of the test, a multiple choice paradigm was used to facilitate scoring. Unfortunately, the method chosen by the test designers made it impossible to know if a subject's answer was truly correct. Subjects could mark "A" on the test and be referring to any one of a variety of possible "A" answers, when only one of the "A"s was actually correct. A test scorer would have no way of determining the "A" intended by the subject, so every "A" answer would be marked correct. In the modified test, subjects had to indicate a specific and unique response to each item, thereby greatly reducing ambiguity in the scoring procedure.

The test procedure required subjects to study a map showing 12 different buildings located on a grid map of streets. After two minutes, the map was taken away and replaced with an answer sheet, which was the same grid map minus the buildings. The answer sheet also showed the 12 buildings along the left side of the page, each one identified with a number. Subjects were asked to indicate the proper position of each structure by writing its associated number on the map. After two minutes, the answer sheet was taken away. The procedure was then repeated with a second map showing 12 new buildings on a different grid, and a corresponding answer sheet.

Spatial memory ability, as measured by this modified test, was used as a blocking variable. Subjects were assigned to experimental groups so that equal numbers of high, medium, and low ability subjects were tested under each of the experimental learning conditions. Cutoff scores separating the three groups were based on data collected by Billingsley (1981) from 59 undergraduate students of both sexes. These data, rather than the data reported by ETS, were used to determine cutoff scores, since the 1981 test had been administered using the modified procedure. Based on the distribution of spatial memory scores derived from the 1981 data, subjects were assigned to groups as follows: scores that fell between zero and 11 (out of a possible 24) were assigned to the low spatial memory group; scores between 12 and 17 were considered medium ability level; and those between 18 and 24 were considered "high". In the 1981 study, approximately 33 percent of the subjects fell into each of these groups.

The second test, the First and Last Names Test, was a measure of associative memory taken from the same Educational Testing Service test battery. It required subjects to study a list of 15 full names, first and last, for two minutes. They were then shown a list of just the last names in a scrambled order, and they had two minutes to write down the correct first name to go with each last name. After completion of the first list, they were shown a second list of 15 names to memorize, and the test procedure was repeated.

Associative memory test scores were obtained for use as covariate predictors in later data analysis. Both tests are printed in full in Appendix A. Table 1 shows the only normative data available for scores on the original version of the Building Memory Test and the First and Last Names Test (from Ekstrom et. al, 1976), as well as summary statistics from Billingsley (1981).

Database. A hierarchical database/menu structure was created for this experiment. Since little could be assumed about specialized knowledge that all subjects would share, the information domain was chosen to be as familiar as possible while still retaining enough complexity to allow several levels of descriptors for goal items. The final version of the database used common animals as the goal items, (i.e., the endpoints of pathways in the hierarchical tree structure.)

All of the menu choices on the pathways leading to the goal animals were familiar adjectives that could be used to describe

Table 1

Normative Pretest Data

Pretest	Sample	Mean	S.D.	Reliability
Building Memory Test	558 Male Naval Recruits	10.90	4.7	.80
	Billingsley (1981)	14.37	6.1	Unknown
First and Last Names Test	292 12th Grade Males	19.01	7.5	.86
	333 12th Grade Females	23.2	5.7	.79

different types of animals. The specific sequence of adjectives describing each animals was semantically valid, but descriptors were deliberately selected to introduce some ambiguity and confusion into the subject's task. Without such ambiguity, the task could have been a trivial exercise in choosing descriptors from mutually exclusive categories.

Introducing ambiguity into the descriptor sequences also helped to make the search task more realistic. The common problem of choosing universally recognizable one- or two-word descriptors for commands and data items in information retrieval systems has been investigated by Furnas, Gomez, Landauer, & Dumais (1982). They found that the average likelihood of any two people using the same main content word to describe an object ranged from .07 to .18 in the variety of information domains they studied. To these researchers, the results had serious implications for computer systems in which information retrieval depends on lexical agreement between users and system designers. These data suggest that untrained users will fail to guess the correct descriptors even for familiar data items 80 to 90 percent of the time.

In light of these results, the objection could be raised that deliberately introducing ambiguity created possible confounding of the effects of the high memory load imposed by the task with the effects of confusion resulting directly from the ambiguity. These two factors will almost always be confounded, however, since there is little or no stress on memory when menu choices are obvious and mutually exclusive.

Computer program. The interactive program controlling stimulus presentation was written in BASIC. The part of the program visible to subjects included an initial example search problem in the "Animal Hunt" game and 30 menus choices with four or five choices on each menu. Choice 4 was always "Back one menu" and choice 5 was always "Back to main menu", with the first two or three choices consisting of descriptors of animals, or actual animal names. Subjects indicated their choice by entering the number corresponding to the option desired. During each search, the name of the target animal was displayed continuously at the top of the screen.

The program kept track of the specific sequence of choices each subject made, and compared the actual number of choices made to the lowest possible number of choices required to reach the target animal. The program let subjects know when they reached a target animal, and displayed a congratulatory message if they reached an animal using the fewest possible number of moves. The computer also kept track of the time required to complete each search. The complete program is printed in Appendix B.

Learning aids. One group of subjects used a hardcopy "data index" in the first trial block to search for the nine animals identified as targets. The index listed all 18 target animals alphabetically in a column on the left side of the page. On the right side was a corresponding column that showed the sequence of menu choices that would lead the subject to the animal in question. To help clarify the categorization scheme, two animals similar to the target animal were listed next to each target animal. However, subjects were told that they would not be required to remember anything about these example animals.

In the data index condition, subjects received all of the semantic information required to find any particular animal, as well as exposure to all the remaining animal names and descriptors. They could also learn about the hierarchical organization of the menus if they happened to recognize the repetition in menu choices leading to animals that were closely related in the context of the game. For example, two index entries might read:

DUCK DOMESTICATED • FARM • BARNYARD

SHEEP DOMESTICATED • FARM • PASTURE

Subjects could derive structural information if they noticed that the sequence of menu choices was the same for both animals until the menu with both PASTURE and BARNYARD appeared.

Another group of subjects used a "data map" as an aid for finding animals during the first nine searches. The map showed every menu in the hierarchy, giving subjects the opportunity to view the overall dimensions of the database and the relationship between animal descriptors and animal types on different branches of the tree. The same information was present in both the index and the map, but the map also provided subjects with a succinct, non-redundant pictorial representation of the hierarchical structure. Figures 1 and 2 show the data index and data map.

Final questionnaire. A final questionnaire was completed by each subject at the end of the experimental test session. This form asked about such demographic variables as age, sex, handedness, and programming and computer experience. It also included questions about strategy used to find target animals, and asked subjects to draw their

DATA INDEX

ALLIGATOR DEER CALF	COMMERCIAL • SKINS • LEATHER
CAMEL ELEPHANT MULE	DOMESTICATED • PACK
CROCODILE PENGUIN SALMON	WILD • WATER • NON-MAMMAL
DOVE PHEASANT TOUCAN	WILD • AIR
DUCK PIG CAT	DOMESTICATED • FARM • BARNYARD
ELK COUGAR MOOSE	WILD • LAND • BIG GAME • FOREST
FOX SEAL MINK	COMMERCIAL • SKINS • FUR
GOOSE CHICKEN TURKEY	COMMERCIAL • FOOD • POULTRY
HAMSTER GUINEA PIG GERBIL	DOMESTICATED • PET • SMALL • FURRY
LEOPARD GORILLA PANTHER	WILD • LAND • BIG GAME • JUNGLE
OTTER BEAVER HIPPO	WILD • WATER • MAMMAL
PARROT PIGEON CANARY	DOMESTICATED • PET • SMALL • FEATHERED
PONY DOG HORSE	DOMESTICATED • PET • LARGE
RABBIT MOUSE MONKEY	COMMERCIAL • LABORATORY
SHEEP COW GOAT	DOMESTICATED • FARM • PASTURE
TIGER CHIMPANZEE BEAR	WILD • LAND • CIRCUS
TROUT TUNA SHARK	COMMERCIAL • FOOD • FISH
ZEBRA LION RHINOCEROS	WILD • LAND • BIG GAME • PLAINS

Figure 1. Data Index

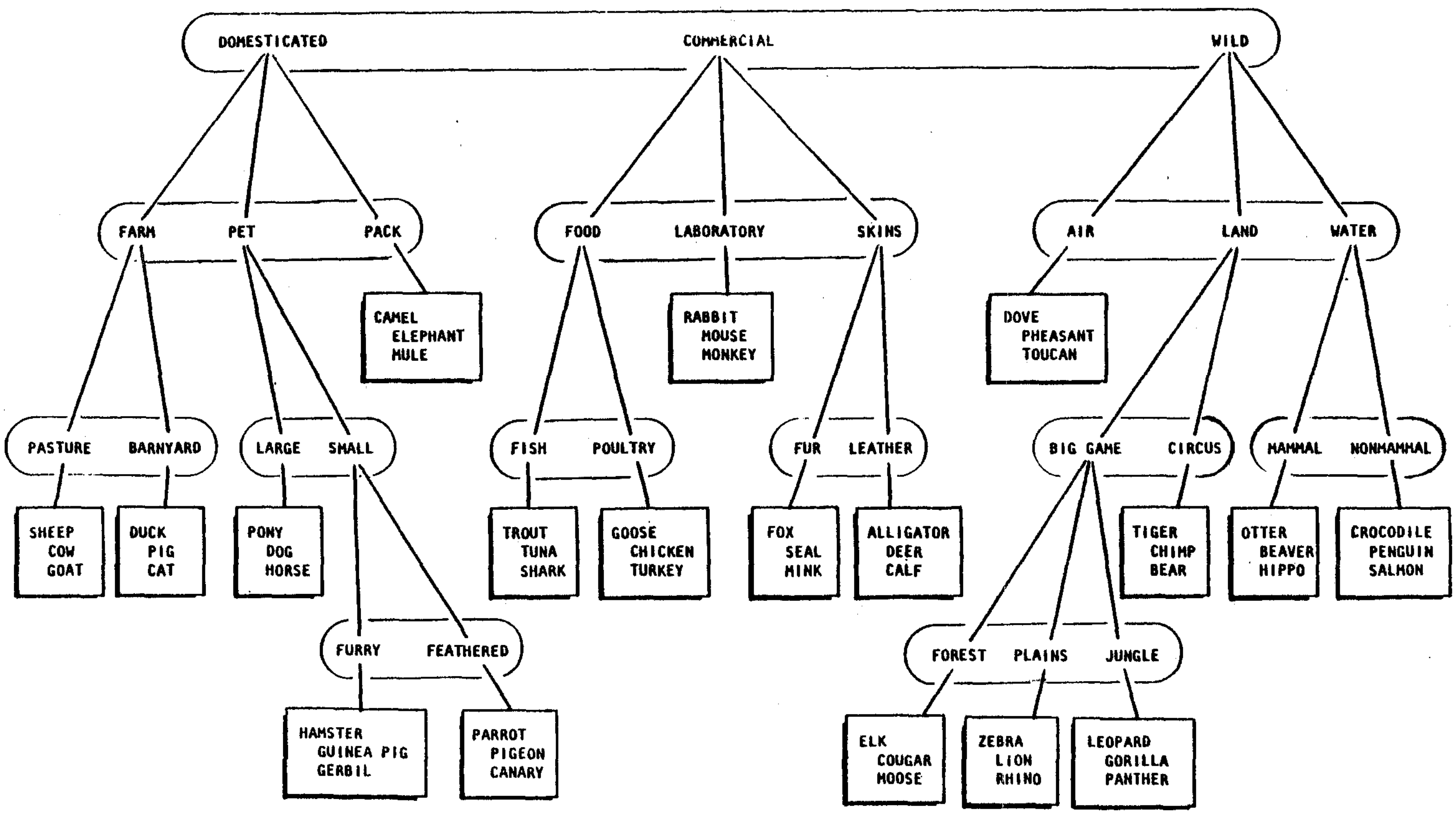


Figure 2. Data Map

model of the data structure in as much detail as possible. A copy of the final questionnaire is printed in Appendix C.

Procedure

Each test session was conducted by the same experimenter in the same experimental room. Test times were randomized across groups with respect to the time of day and day of the week of testing. All sessions were conducted across a three week period toward the end of the Spring semester. One and one-half hours were allotted for testing each subject.

Pretest. When subjects first arrived at the experimental room, they were given the two pretests. The Building Memory Test was administered first, and took approximately 10 minutes. After subjects completed the Building Memory Test, the experimenter scored it while subjects worked on the First and Last Names Test.

Using the predetermined cutoff scores from the Building Memory Test data, subjects were placed in the high, medium, or low spatial memory group. Within memory groups, subjects were randomly assigned to experimental conditions. This blocking procedure was done to ensure that equal numbers of high, medium and low ability subjects were tested under each of the three experimental conditions. Six subjects, equally divided by sex, were tested at each of the three memory levels under each of the three conditions, adding to a total of 54 subjects.

Experimental test session. After completing the pretests, the subject was asked to sit in front of the computer, which had been set up for the test session in advance by the experimenter. Two typed pages of instructions were read aloud by the experimenter while the subject followed along on his/her own copy. Halfway through the instruction, the subject used the computer to enter his/her name and the date into the system, and worked through a simple example problem with the experimenter's guidance. A copy of the instructions read by subjets in all three groups is printed in Appendix D.

The experiment was presented as an "Animal Hunt" game. On each trial, subjects were required to find an animal which was named at the top of the display screen. They were told that each animal could be located by picking the correct descriptor choice from each menu that appeared on the screen, and that they might have to work through as many as four different menus to reach a target animal. Subjects were not told of the hierarchical nature of the data structure, nor of its particular breadth and depth characteristics. Questions about general procedures were answered by the experimenter. Subjects were also told that if at some point in the game they felt completely unable to find a given target animal, they could notify the experimenter and she would give them a clue. Clues were never more than an indication of which of the three main branches of the tree the subject should focus on. Unfortunately, data concerning the exact number of clues given was not collected. A reasonable estimate would be that one in every five subjects requested a clue at some point, and no more than three subjects required more than one clue in a test session.

The game was set up so that subjects were required to find only nine of the 18 possible target animals in the hierarchy on the first three trial blocks. Subjects in the data index and data map groups used those aids during the first trial block to locate animals and to guide their search through the various menus. Those two groups of subjects were told that the aids would not be available after the first trial block was completed. All subjects were urged to find target animals in the least possible time, using the fewest possible menu choices.

Goal animals were chosen on the basis of pilot testing that established which animals were the most difficult to find in the menu structure. The final set of goal animals represented a balanced mixture of easy and difficult targets distributed evenly across the first and second groups of searches. Once the first nine target animals had all been found once, the second trial block began. From that point on, any learning aids were taken away and testing procedures were exactly the same for all three groups. The second and third trial blocks required subjects to find the original nine animals again, and the fourth and fifth trial blocks introduced nine new target animals that had to be located. The order of presentation of target animals was randomized by the computer for each trial block. At the end of the fifth trial block, the subject was asked to complete the final questionnaire. The subject was then debriefed by the experimenter, who explained the objective of the testing.

Logic of trial block sequence. The particular sequence of repeated searches across trial blocks was chosen to try to simulate, on a very small scale, a situation where users become accustomed to retrieving a certain set of data elements from a database on a regular basis. Trial blocks one through three required the user to find the same set of animals, in a scrambled order, three times in a row.

However, occasions are likely to arise when less familiar data items are sought by a user. It is important that whatever mental model the user has formed of the data structure is appropriate for all the data items in it. For this reason, the less familiar set of goal animals was introduced in trial blocks four and five. Subjects in the map and index groups were exposed to all the animal names and locations when they used one of the aids in the first trial block, although they were required to navigate through complete data pathways for only the first group of nine animals. Therefore, the hypothesis could be tested that exposure to the map would give subjects a more enduring mental model of the data structure than would exposure to the data index, and that the mental model resulting from the map would include all the target animals, not just the initial set of nine that subjects searched for in trial blocks one, two, and three. To assess the effect in later statistical analysis, "Trial Block" was included as the within-subjects independent variable in a mixed design.

Clockboard malfunction. About two thirds of the way through the experiment, the clockboard malfunctioned and stopped generating seconds-per-search data. Since many subjects were already scheduled to participate, the decision was made to continue with the experiment, substituting a stop watch for the clockboard. However, since it would have been impossible to gather precise time data for each separate search without greatly disturbing a subject's concentration and flow of operations, time data were gathered for each trial block as a whole.

This required a slight change in procedure. Subject were asked to alert the experimenter at the end of each trial block, at which time the experimenter manually recorded the time elapsed from the beginning of that trial block. Since the program automatically displayed a message indicating the completion of each trial block, the new procedure did not affect task difficulty.

Results

Preliminary Data Analysis Program

A BASIC program was written to read the data from each subject's file and print it in a form suitable for further analysis. Performance data from each of the 45 searches was presented first, including the name of the target animal, the total number of choices made, the time (in seconds and hundredths of seconds) spent finding it, and the number of seconds per choice (computed by dividing time by choices).

The second part of the program computed summary statistics across trial blocks. The average choices per search (computed by adding all the total choice scores in a trial block and dividing by nine) and the average time per search (computed by adding all the total time scores in a trial block and dividing by nine) were the outcome measures used in the rest of the data analysis.

Procedure for Handling Outliers and Missing Data

Looking at the choice data, it was not uncommon to find that a subject had done very well finding most of the animals in a given trial block, and very poorly finding one or two. It was necessary to determine which of the individual choice scores were statistical outliers, so that they could be dealt with in a way that would reduce their influence on the average score computed for each trial block while still reflecting a decrement in the subject's performance. To this end, outliers were identified and handled using a standard statistical procedure which allows the scores to be included in the distribution as extreme values, but not so extreme as to distort further analysis.

First, the mean and standard deviation of the 36 choice scores generated by each subject were computed. Of the 45 searches that each subject completed, the first nine were not included in the analysis because the control/index/map manipulation took place during trial block one.

Next, the upper cutoff score for outliers was computed by multiplying the standard deviation by three and adding it to the mean. Based on a normal distribution of data, 97.5% of all valid scores would fall below the upper cutoff score, and all that did not could be considered outliers. If any of a subject's choice scores were higher than the cutoff limit, those scores were replaced with the computed cutoff score for the remainder of the analysis. No more than two choice scores had to be adjusted in this manner for any subject. The total number of adjusted scores was very similar across groups: eight in the control group and in the map group, and ten in the index group.

Because of the clockboard failure, time data for individual searches were available for only 41 of the 54 subjects. For the remaining subjects, average search time per trial block could have been computed by dividing the manually-clocked trial block times by nine. However, this allowed no identification of, and therefore adjustment for, outliers in the time data for individual searches. Since there were outliers in the choice data, the likelihood of corresponding time outliers was very high.

It was determined, therefore, that the time data from the 13 manually-clocked subjects were not detailed enough to allow reliable interpretation, and that those 13 subjects would have to be eliminated from further analysis. Of the 41 remaining subjects, an attempt was made to keep as many as possible in the analysis, while maintaining equal numbers in each of the three experimental groups and a relatively balanced design.

The final set of 30 subjects consisted of 16 males and 14 females: five each in the map and index groups, and six males and four females in the control group. However, balancing by sex was considered secondary to balancing by Building Memory Test scores, since spatial memory was the principal blocking variable. With fewer subjects in the analysis, Building Memory Test scores could not be used as a true blocking variable, but they could be used as covariates. The relative success of the balancing is shown by the correspondance in Building Memory Test means and standard deviations across the three groups, as shown in Table 2.

Data Analysis

All subsequent analyses were done using BMDP program 2V (Dixon, 1979) for analysis of variance and covariance including repeated measures, and the SPSS package (Nie, Jenkins, Steinbrenner, & Bent, 1970) for computing Pearson *r* correlation coefficients. All analysis programs were run on the Cyber 750 computer at California State University, Northridge.

Results of the analyses of choice data and time data are discussed

Table 2

Means and Standard Deviations of Pretest Scores

Across Groups in Experiment 1

Pretest	Statistic	Control	Index	Map
Building Memory Test	Mean	16.10	16.10	15.90
	S.D.	5.26	5.92	5.67
First and Last Names Test	Mean	18.80	20.20	17.20
	S.D.	7.47	7.74	8.59

separately. The correlation between total time scores (the sum of average times in trial blocks two to five) and total choice scores (the sum of average choices in trial blocks two to five) was .75 ($p < .001$). Each dependent variable was examined using univariate analysis of variance because the patterns in both time and choice data were of critical research interest. For both dependent variables, a three (group) by four (trial block) mixed design was used. The analysis was done only on data from trial blocks two to five because subjects in the map and index groups had essentially perfect scores in trial block one.

Choice Data

Table 3 shows the means and standard deviations for choice data by group and by trial block. The analysis of variance table is presented in Table 4. The only significant effect was that of trial blocks ($F(3,81) = 20.06$, $p < .001$). Although this effect accounted for 79% of the variance, as measured by eta squared, it was not considered particularly meaningful except as an indicator of the success of the trial block manipulation. As expected, performance declined sharply (i.e., time scores and choice increased) in trial block four, when subjects were first asked to search for the second set of target animals.

Time Data

Table 5 shows the means and standard deviations for the time data by group and by trial block. The analysis of variance (Table 6) shows no significant effect of group membership or a trial block by group interaction. As with the choice data, the significant trial block effect ($F(3,81) = 21.72$, $p < .001$) was not considered particularly

Table 3

Means and Standard Deviations of Choice Scores

Across Groups and Trial Blocks in Experiment 1

Block	Statistic	Control	Index	Map	Marginal
1	Mean	12.11	3.04	3.33	
	S.D.	4.08	.01	.61	
2	Mean	9.02	7.65	8.23	8.30
	S.D.	3.68	2.86	3.58	
3	Mean	6.97	5.80	6.26	6.34
	S.D.	4.35	2.55	2.36	
4	Mean	12.31	11.81	10.70	11.60
	S.D.	5.49	3.41	2.45	
5	Mean	7.06	6.80	6.99	6.95
	S.D.	4.02	3.74	2.25	
	Marginal	8.84	8.01	8.04	

Table 4

Analysis of Variance for Choice Scores

in Experiment 1

Source	df	MS	F
Group	2	8.80	.36
Error 1	27	24.76	
Trial	3	165.72	20.06*
Trial by Group	6	2.13	.26
Error 2	81	8.26	

* $p < .001$

Table 5

Means and Standard Deviations of Time Scores

Across Groups and Trial Blocks in Experiment 1

Block	Statistic	Control	Index	Map	Marginal
1	Mean	52.80	19.85	27.52	
	S.D.	17.00	5.28	7.55	
2	Mean	32.31	39.66	38.78	36.92
	S.D.	15.24	19.14	18.57	
3	Mean	22.18	24.05	22.24	22.82
	S.D.	14.49	10.57	8.17	
4	Mean	35.33	48.66	38.08	40.35
	S.D.	14.13	17.85	7.33	
5	Mean	19.16	23.69	22.23	21.70
	S.D.	12.71	13.02	6.95	
	Marginal	27.25	34.01	30.08	

Table 6

Analysis of Variance for Time Scores

in Experiment 1

Source	df	MS	F
Group	2	461.96	1.21
Error 1	27	381.61	
Trial	3	2746.43	21.72*
Trial by Group	6	96.12	.76
Error 2	81	126.47	

* $p < .001$

important, although it accounted for 72% of the variance, as measured by eta squared.

Correlations

Tests measuring the correlations between total choice scores, total time scores, scores on the two pretests, and sex showed that the only significant correlation was between sex and total time scores (r = -.37, p <.05). This result indicated that males tended to be faster than females across all groups. A more detailed examination of the correlations within each group, as shown in Table 7, indicates that sex was significantly correlated both with total choices (r = .72, p <.01) and with total time (r = .75, p <.01) in the control group, but not in the map or index group. This may indicate a sex by group interaction, such that males are able to perform the experimental task more efficiently than females when working without access to an index or map. This possible gender effect could be investigated more thoroughly by testing larger numbers of subjects of both sexes under the same conditions as the control group.

Analyses of Covariance

In an attempt to correct the data for some of the possible sources of unwanted variance, two analyses of covariance were run with sex as the covariate and either choices or time as the dependent variable. Sex did not achieve significance as a predictor of either time or choice scores, and the overall outcome of the tests of main effects and interactions did not change. Analyses of covariance were not run using Building Memory Test scores or First and Last Names Test scores as covariates because the correlations between these measures and the

Table 7

Correlations Between Pretest Scores and Performance Scores in Experiment 1

	Building Memory	First and Last Names	Gender
All Groups (N = 30)			
Total Time	-.23	-.27	-.37*
Total Choices	-.22	-.19	-.29
Control Group (N = 10)			
Total Time	-.40	-.45	-.75**
Total Choices	-.49	-.42	-.72**
Index Group (N = 10)			
Total Time	-.54	-.29	-.10
Total Choices	-.26	.08	-.05
Map Group (N = 10)			
Total Time	.43	-.16	.08
Total Choices	.29	-.16	-.09

* $p < .05$

** $p < .01$

performance data were not significant.

Final Questionnaire Data

As can be seen in Table 8, an examination of the pattern of responses on the final questionnaire showed that the three groups were very similar in their responses on most items. The question about game strategy yielded little useful information because most subjects could not articulate their thought processes. The most interesting finding concerned subjects' ability to draw a picture of the menu structure. Only three subjects in the control group and two in the index group were able to draw a picture that matched the actual structure. While this supports that contention that it may be difficult to generate a mental model of an unfamiliar structure without seeing a physical representation of it, the results from the map group do not necessarily support this view.

Only six of the ten subjects in the map group could recreate the map, although they had used it throughout trial block one. This result may indicate that the rest of the game imposed such a heavy cognitive load on subjects that it interfered with their memory for the map. It had been assumed that knowledge of the map structure would be reinforced during trial blocks two through five, but this assumption was not supported by the data.

Discussion

The results showed that neither group membership nor group by trial block interaction significantly effected the pattern of time and choice data. This suggests that using a map or index to locate target animals in the first nine searches of the experiment is no more

Table 8

Final Questionnaire Data

Across Groups in Experiment 1

Variable	Control	Index	Map
Number of subjects	10	10	10
Mean age	22.00	20.10	23.80
Number left-handed	1	1	0
Number computer-experienced	2	1	1
Number able to draw map	3	2	6

effective than playing the game unaided. On the other hand, the index and map aids appeared to be at least as helpful as no aids at all when subjects were required to remember correct sequences of menu choices in trial blocks two through five.

It had been predicted that prior knowledge of the overall structure of the data would have the greatest impact on performance in trial block four, since at that time subjects were required to search for the less familiar group of target animals. Trends in the data did appear to be in that direction, but the variability in performance may have diminished the statistical significance of the effect.

There are several aspects of the task that may account for the observed results. Although subjects worked with the map or index for three and one-half minutes, on the average, during the first trial block, they also had to absorb a lot of other procedural information during that time: they had to learn the sequence of system prompts and required inputs in the game dialogue, they had to learn how to interpret and follow the map or index, and they had to try to remember correct menu choice sequences. Although having access to all the correct answers in trial block one was intended to be advantageous, it may have had the opposite effect. As a consequence, subjects in the map and index groups had no chance to practice error-recovery procedures.

Subjects in the control group had a much earlier opportunity to learn the mechanics of moving around in the menu structure. They quickly became familiar with error messages, and developed strategies for retracing their routes and continuing with the search when they reached a dead end. Subjects in the map and index groups were not required to learn these strategies until trial block two, after the aids had been taken away.

Unfortunately, this particular paradigm seems to have introduced confounding between the effects of exposure to learning aids and the effects of lack of opportunity to develop game strategies. Subjects may be unable to take advantage of information about data structures before they understand the value of such information in the overall task context. It could be argued that subjects simply needed more time working with the map or index, but it is probably not that clear-cut. The more accustomed they became to depending on an aid, the less they might learn about the structure of the system. They would then be at an even greater disadvantage when the aid suddenly became unavailable.

In an attempt to eliminate any possible confounding between exposure to navigation aids and information overload, a second experiment was conducted using a slightly different design. In this version, subjects were shown the map or index only after they had played the game long enough to understand game rules and strategy. Theoretically, they would then be able to take fuller advantage of the aids since they would understood how the information embedded in the aids could be used.

EXPERIMENT 2

Method

Subjects

Subjects in the experiment were 16 undergraduate and graduate students (six male and ten female) at California State University, Northridge, who participated either to fulfill a course requirement or on a volunteer basis.

Apparatus and Materials

All apparatus and materials were the same as those used in Experiment 1, except that the faulty clockboard was replaced with a new one that functioned correctly throughout the experiment.

Procedure

Subject assignment. Using a restricted randomization procedure, subjects were assigned to either the map group or the index group. The restriction involved maintaining the proportion of males to females across groups, such that each group contained three males and five females.

Due to the limited number of subjects available, the decision was made to assign all subjects to either the map or index group, and to use data from the control group in Experiment 1 for later comparisons. This may have affected the internal validity of the design, because of possible differences in subject history and selection. However, it was justified on the basis that the treatment of the control group, had there been one, would have been exactly the same as it was in the first experiment. The changes made in the experimental paradigm for

Experiment 2 affected only the index and map groups.

Pretests. As in Experiment 1, the Building Memory Test and the First and Last Names Test were administered to subjects at the beginning of the experimental session. However, since scores on neither test had been significantly correlated with performance in Experiment 1, no attempt was made to match subjects by pretest scores across groups.

The tests were included for two reasons: First, if the paradigm used in Experiment 1 was faulty, the relationship of pretest scores to performance may have been obscured by other factors. Secondly, since the data from the index and map groups in Experiment 2 would be compared to the data from the control group in Experiment 1, it was critical to have as much similarity in treatment across groups as possible. The summary statistics for pretest scores across groups are shown in Table 9.

Experimental test session. Subjects in both groups were given the same instructions that the control group received in Experiment 1. They were told the basic rules of the game and worked through the example problem. Like the control group, they were not told about the availability of navigation aids. The only special instruction they received was to stop playing the game at the end of trial block one (indicated by a displayed message), at which time they were to notify the experimenter.

After they completed trial block one, subjects were given either the map or the index to study, depending on their previous group assignment. They were told that they would have five minutes to study

Table 9

Means and Standard Deviations of Pretest Scores

Across Groups in Experiment 2

Pretest	Statistic	Control	Index	Map
Building Memory Test	Mean	16.10	16.88	17.88
	S.D.	5.26	5.44	5.30
First and Last Names Test	Mean	18.80	16.00	12.63
	S.D.	7.47	8.16	7.60

the aid, and that they should try to learn the correct sequence of menu choices for all 18 target animals. At the end of five minutes, the aid was taken away, and subjects resumed playing the game. They received no additional help during trial blocks two through five. At the end of the experimental session, subjects completed the final questionnaire.

Results

Data Analysis

All analyses were performed on data from trial blocks two through five, the trial blocks following the experimental manipulation. Initially, statistical outliers in the choice and time data were identified and replaced with adjusted scores using the same procedures described in Experiment 1. No more than two scores from any single subject needed to be adjusted; three adjustments were made in both the index group data and the map group data.

As in the Experiment 1 analysis, each dependent variable was examined using univariate analysis of variance. All analyses were based on a three (group) by four (trial block) mixed design. The correlation between total time scores and total choice scores was .88 (p <.001).

Choice Data

Table 10 shows the means and standard deviations for the choice data by group and by trial block. The correspondence in group summary statistics for trial block one is reassuring. It demonstrates that, prior to the experimental manipulation, the performance of the control group in Experiment 1 was quite similar to that of the two groups in Experiment 2.

Table 10

Means and Standard Deviations of Choice Scores

Across Groups and Trial Blocks in Experiment 2

Block	Statistic	Control	Index	Map	Marginal
1	Mean	12.11	12.85	12.84	
	S.D.	4.08	4.52	3.92	
2	Mean	9.02	5.12	6.04	6.90
	S.D.	3.68	1.83	3.16	
3	Mean	6.97	5.39	4.83	5.83
	S.D.	4.35	2.94	1.64	
4	Mean	12.31	8.37	4.72	8.76
	S.D.	5.49	4.49	2.23	
5	Mean	7.06	5.45	3.61	5.50
	S.D.	4.02	2.68	.44	
	Marginal	8.84	6.08	4.80	

The analysis of variance is presented in Table 11. The main effect of trial block was significant ($F(3,69) = 7.40$, $p < .01$) and accounted for 19% of the variance, as measured by eta squared. Of greater interest, the main effect of group membership was significant ($F(2,23) = 155.42$, $p < .001$), as was the interaction of groups by trial blocks ($F(6,69) = 16.44$, $p < .005$). The group effect accounted for 61% of the variance, and the interaction effect accounted for 6%, as measured by eta squared.

Specific comparisons between group means were done using directional *t* tests, on the basis of a priori hypotheses concerning the differential performance of groups across trial blocks. Computations were performed using the *t* test for differences among several means (Bruning & Kintz, 1979) with a critical *t* set at approximately 1.67 (df=69) for one-tailed tests at the .05 level of significance. Table 12 shows the results of comparisons between group means for individual trial blocks and for all trial blocks summed. Figure 3 is a graph of the interaction between groups and trial blocks.

Tests of the differences between overall group means showed that, although control group performance was significantly worse than that of either the index or map group, the index and map groups were not significantly different from each other. This general pattern holds across all trial blocks. The control group made significantly more unnecessary choices than the map group in all trial blocks, and significantly more than the index group in trial blocks two and four. It seems very clear that subjects who had the opportunity to study either aid had a clear advantage over subjects who saw neither.

Table 11

Analysis of Variance for Choice Scores

in Experiment 2

Source	df	MS	F
Group	2	155.42	5.50**
Error 1	23	28.28	
Trial	3	49.30	7.40***
Trial by Group	6	16.44	2.47*
Error 2	69	6.67	

* $p < .05$

** $p < .01$

*** $p < .001$

Table 12

Comparisons Between Choice Score Cell Means

in Experiment 2

Block	Control minus Map	Control minus Index	Index minus Map
All	4.04*	2.76*	1.28
2	2.98*	3.90*	-.92
3	2.14	1.58	.56
4	7.59*	3.94*	3.65*
5	3.45*	1.61	1.84

* Difference exceeds critical difference of 2.08 computed using $\underline{t}(69) = 1.67$, $\underline{p} < .05$

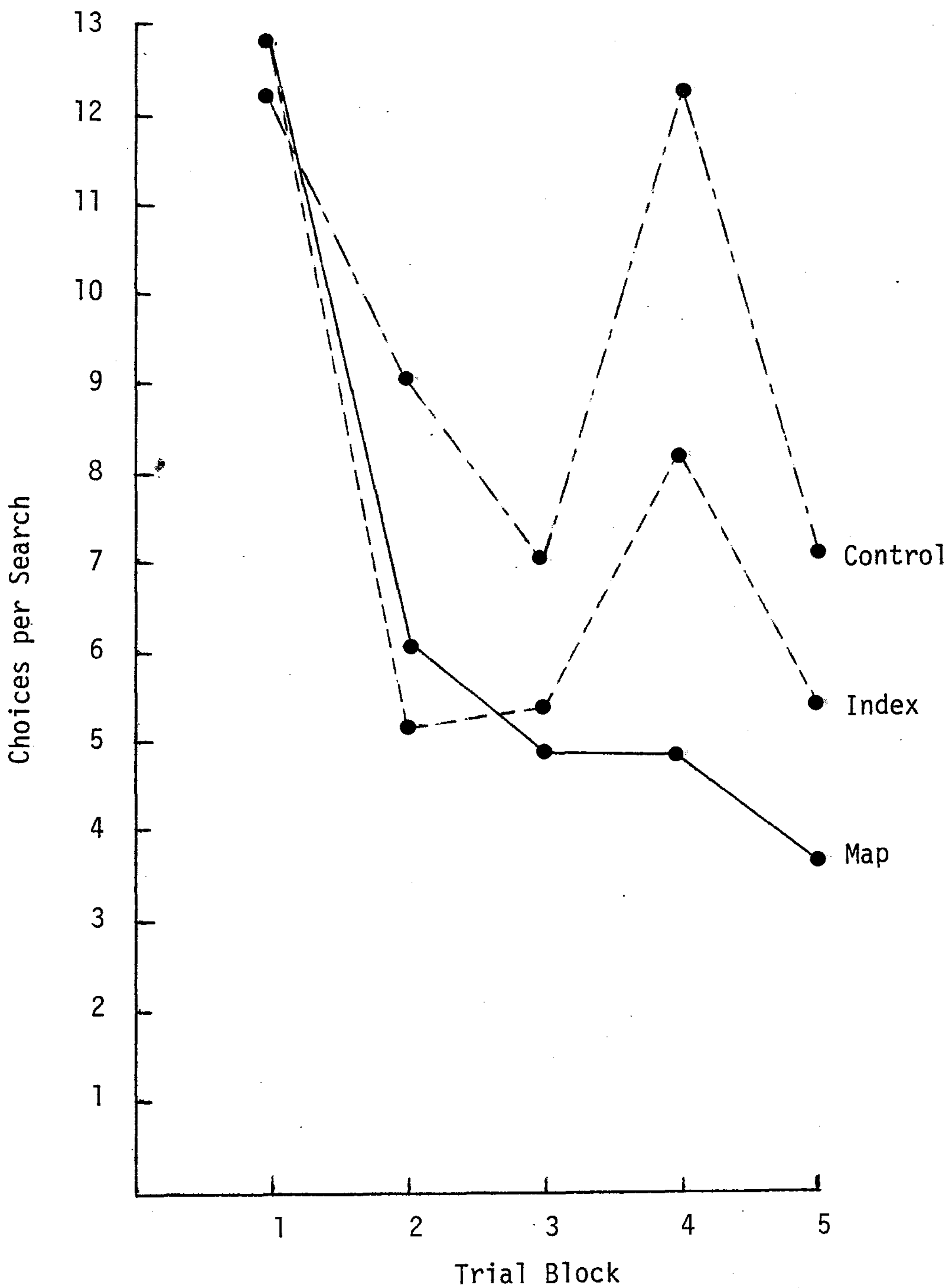


Figure 3. Mean Choices per Search by Group Across Trial Blocks

In trial blocks two and three, subjects searched for the same nine target animals that they had seen in trial block one, and the map and index groups did not differ significantly in performance. However, this pattern broke down in trial block four, when the second group of target animals was introduced. Although subjects in both groups had had the chance to study the correct menu choices for these nine targets, they had not needed to use or remember that information in trial blocks two and three. The expected forgetting was evident in the index group's performance scores for trial block four, when they made 55% more choices than they had in trial block three, on the average. In marked contrast, subjects in the map group actually made slightly fewer choices, on the average, in trial block four than they had in trial block three.

Although the difference between the map and index groups in trial block five was not significant, this is probably due to the fact that the map group subjects were already so close to error-free performance. The best possible average choice score for trial block five was 3.22 (the sum of the minimum required choices for all nine searches, divided by nine), and the map group mean score was 3.61 choices, with a standard deviation of only .44 choices. This "floor" effect did not allow the map group subjects to demonstrate any further improvement.

The graph of the interaction suggests that the control and index group subjects would have continued to show improvements in performance if the experiment had been extended beyond five trial blocks. However, the database used in this study was far smaller than most used in real-world applications. Extrapolation from the data, although a risky practice, suggests that users with access to a map of a complex data structure would learn more about that structure than users with only an index of data pathways. The relative utility of the map would be particularly evident if the aids became unavailable to system users at some point.

Time Data

Table 13 shows the summary statistics for time data by group and by trial block. As is apparent from the analysis of variance table (Table 14), only the main effect of trial blocks was significant ($F(3,69) = 13.38$, $p < .001$), accounting for 42% of the variance as measured by eta squared. Although trends in the time data were in the same direction as those in the choice data, neither the main effect of group membership nor the trial block by group interaction was significant because of the greater variability in time scores.

This greater variability could have been a function of the greater possible range in time score values, since no limits were placed on the amount of time a subject could spend considering which choice to make. In addition, time scores were more likely to show individual variation than choice scores because of the number of subject variables that could have influenced performance. These included reading speed, typing speed, motivation, and the perceived tradeoff between time and errors. Unfortunately, it was not possible to ensure that subjects were equivalent along all these dimensions prior to testing.

To try to remove, or at least correct for, some of the variability in subjects' time data, an analysis of covariance was run using average search time on the first trial block as the covariate. (As the reader

Table 13

Means and Standard Deviations of Time Scores

Across Groups and Trial Blocks in Experiment 2

Block	Statistic	Control	Index	Map	Marginal
1	Mean	52.80	73.13	68.79	
	S.D.	17.00	25.67	22.28	
2	Mean	32.31	21.55	24.81	26.69
	S.D.	15.24	9.41	14.36	
3	Mean	22.18	16.80	19.17	19.60
	S.D.	14.49	7.81	11.17	
4	Mean	35.33	30.65	19.12	28.90
	S.D.	14.13	15.09	10.44	
5	Mean	19.16	15.47	10.94	15.90
	S.D.	12.71	8.49	4.69	
	Marginal	27.25	21.12	18.51	

Table 14

Analysis of Variance for Time Scores

in Experiment 2

Source	df	MS	F
Group	2	734.16	1.95
Error 1	23	376.54	
Trial	3	952.91	13.28*
Trial by Group	6	120.26	1.68
Error 2	69	71.75	

* $p < .001$

will recall, data from the first trial block was collected prior to the experimental manipulation.) As can be seen from the results in Table 15, time on the first trial block was a highly significant predictor of performance on the remaining trial blocks ($F(1,22) = 16.70$, $p < .001$). This suggests that subjects should have been timed on a sample exercise prior to assignment to experimental groups. If groups had then been balanced on the basis of pretest time scores, variability in the experimental time data could have been substantially decreased.

In the analysis of covariance, the main effect of group membership was significant ($F(2,22) = 7.69$, $p < .01$). The t test for differences among several means showed that while the control group took significantly more time that either the map or index group across trial blocks two through five ($t(69) = 1.67$, $p < .05$), the map and index groups were not significantly different from each other. The adjusted group means are shown in Table 16.

Subjects in the index group took 82% more time, on the average, to locate target animals in trial block four than they had in trial block three, while map group subjects required no additional time. However, in spite of the large difference in group scores in trial block four, the overall trial block by group interaction was not significant.

Final Questionnaire Data

Summary statistics from the final questionnaire are shown in Table 17. The groups were very similar except with respect to age: the map group subjects were two years older than the control and index group subjects, on the average.

The most interesting result concerns the number of subjects who

Table 15

Analysis of Covariance for Time Scores

in Experiment 2

Source	df	MS	F
Group	2	1721.20	7.69*
Covariate	1	3736.64	16.70**
Error 1	22	223.81	
Trial	3	952.91	13.28**
Trial by Group	6	120.26	1.68
Error 2	69	71.75	

* $p < .01$

** $p < .001$

Table 16

Adjusted Cell Means for Time Scores

in Experiment 2

Trial Block	Control	Index	Map
2	35.62	18.84	23.38
3	25.49	14.08	17.75
4	38.63	27.94	17.69
5	22.47	12.77	9.52

Table 17

Final Questionnaire Data

Across Groups in Experiment 2

Variable	Control	Index	Map
Number of subjects	10	10	10
Mean age	22.00	20.10	23.80
Number left-handed	1	1	0
Number computer-experienced	2	1	1
Number able to draw map	3	2	6

were able to draw a map of the data structure, after the experiment was completed. Map-drawing ability was judged on the basis of two pre-determined criteria: the map had to show a hierarchical arrangement of data elements, and at least half of those elements had to be named. All eight map group subjects were able to draw a map that met these criteria, compared to only three of ten (30%) in the control group and three of eight (37%) in the index group.

Discussion

Several of the results support the hypothesis that subjects who study a data map have an advantage over subjects who study only a data index or no aid at all. Although the benefit of the map was not immediately obvious when subjects searched for items from a small and familiar set of targets, it became quite apparent when they were required to retrieve data items that were not part of this initial, well-learned set.

Like the map group subjects, index group subjects had studied the correct pathways for reaching all 18 target animals. However, they were much more likely to have forgotten the correct sequences of menu choices for the second nine targets by the time they had completed trial blocks two and three. In contrast, the map group subjects retained most of that information for use in trial block four.

Another interesting result was the outcome of the map-drawing exercise in the final questionnaire. The success of the map group was not unexpected, considering that those subjects had had the chance to study the actual map for five minutes. However, results for subjects in the other two groups indicate that most of them were not able to spontaneously generate an accurate mental model of how the data elements were organized. The results may indicate that most people without computer experience do not think in terms of a hierarchical structure without being given that model explicitly.

Looking at all the data from Experiment 2, it appears that giving subjects a map of a hierarchical data structure benefits them in two ways: First, it provides them with an overall model of the structure that they might not otherwise generate. Secondly, it gives subjects information about the spatial location of each data element to supplement their understanding of the semantic relationship between elements and descriptors in the data domain. The combination of these two factors seems to aid subjects in remembering how to access elements in data structures with a hierarchical organization.

DISCUSSION OF OVERALL RESULTS

The general objective of this research effort was to better understand how novice users of a menu-based data retrieval system learn to locate goal items in a data structure. This study attempted to look primarily at two facets of the problem, although there are many possible ways in which such an examination could be approached. The first point of interest was the evalutaion of two types of learning and memory aids that have been suggested by other researchers in this area; the second concerned the sorts of individual differences that might influence the efficiency with which users retrieved goal items.

The first type of aid evaluated was a linear index of data pathways. Although each pathway was complete and correct in itself, the overall index did not facilitate the formation of a single conceptual model in a user's mind, and may in fact have inhibited the formation of such a model. In contrast, the map aid contained all the information in the index, and simultaneously gave the the user an overall spatial representation of the data structure as a branching hierarchical "tree".

The performance of subjects aided by either the map or the index was compared to the performance of control subjects working with no explicit information about the structure of the database. These control subjects permitted an assessment of how well subjects can develop a workable mental model of data structures when they see only one screenful of information and options at a time.

Two pretests were administered to each subject to try to determine whether certain types of memory abilties might be significant predictors of search task performance. The pretests were related to the types of learning aids tested. The Building Memory Test, a measure of spatial memory ability, was thought to be related to the cognitive capability that might make the map a more effective aid; a subject with a low level of spatial memory ability might perform very well in the data map condition, since he or she would be receiving memory cues that they would not ordinarily have access to. Similarly, the First and Last Names Test of paired associate memory was thought to measure an aptitude related to a subject's ability to benefit from exposure to the data index.

Although helping people learn to work with menu structures has been an issue of interest to human-computer interaction researchers for some time, new technological developments have made the existing problems particularly salient. The introduction of televised viewdata systems to the general public in Britain and other European countries has given menu search tasks new importance. With most current systems, users make selections from a series of menus that appear on their TV screens, allowing them to navigate through a data structure that contains many different types of information. Users can search freely through the viewdata database, but the service is not free. In addition to fees for connect time, users are also typically charged by the page for data coming from information provider (IP) data banks.

Recent research on user behavior with viewdata systems has pointed out the magnitude of the problems that new users may have.

Tombaugh and McEwen (1982) and van Ness and Tromp (1979) both discussed the frequency with which their subjects either got lost in the menu structures or became so frustrated that they wanted to give up searching altogether. On the average, subjects in the Tombaugh and McEwen study made twice as many choices as necessary to reach common data items. User problems could have stemmed from the ambiguity inherent in the English language, as discussed by Furnas et. al (1982). This ambiguity makes it difficult for any two people to agree on the proper descriptors for goal objects. Alternatively, or simultaneously, problems could be a function of the inability of subjects to integrate information across displays, which is a direct result of the excessive memory requirements of the system.

The results of the viewdata studies indicate that system designers must be sensitive to both the psychological (and financial) stresses imposed by hierarchical structures that put excessive demands on users. When viewdata was first offered to the British public, only those index pages at the top of the hierarchical information structure could be accessed free of charge. As users penetrated to the information banks of the different IP's, they were charged a certain fee for each page they selected, including those pages that were nothing more than menus leading to other pages. However, there were so many complaints from users who got lost in the pages of the IP menus (and then had to pay for their mistakes) that many IP's changed their strategy. Now most IP menu pages can also be accessed free of charge, or IP's have integrated information and menus into the same page so that users feel the charges are justified (Winsbury, 1981).

The results of the study conducted here indicate that other solutions may be possible. Giving users the opportunity to study a pictorial, map-like representation of the structure of a menu-based system may help them to develop a workable mental model of the way data elements interrelate. The spatial/locational information inherent in a map appears to provide additional mnemonic cues for remembering data pathways to desired goal items.

However, the combined results of Experiment 1 and 2 also indicate that the time at which a map is introduced can be critical. Users first need to understand the information and task environment, particularly how to recover from errors. If they are required to learn both general system procedures and map-usage procedures at the same time, there is the chance that it will take them longer to really understand either one. Giving users sufficient time to study a map, once they are familiar with the task itself, makes it much easier for them to appreciate and utilize the benefits it offers.

It may be difficult to develop maps of data structures when those structures are large and complex, as is the case in many information retrieval applications. However, maps need not show all the detail in the system as long as they supply a global sense of organization. More specific information can always be made available in sub-maps, just as an atlas may contain maps of a continent, a country on the continent, and a city in that country.

The map-making process should be well worth the effort, both in terms of increased system productivity and increased user satisfaction. The less frustration users experience in learning to use a system, the more likely they will be to continue to use it. Only after they know how to navigate through the system will users be able to take full advantage of its information retrieval capabilities.

Recommendations for Future Research

Unfortunately, there has been very little research examining the appropriate use of menus in a computing environment. This study looked at only a few of the issues that could have been investigated, and there are several ways in which this research could be expanded and elaborated.

There are other task variables that should be investigated. For example, more studies of users working with large databases are needed. Both van Ness and Tromp (1979) and Tombaugh and McEwen (1982) used fairly large prototype databases to look at user behavior with viewdata systems, but the actual viewdata system is larger still. Secondly, it is important to develop search tasks that are as authentic as possible, since performance on a highly-structured but unrealistic task may have little bearing on behavior in a real-world environment, with its extra demands on users. However, to capture the complexity of a realistic search task, experimenters must have access to adequate computer resources and a believable data domain. Finally, it would be very useful to study changes in performance across periods of time longer than one or two hours.

The significance of poor performance, and the accompanying psychological stress, also varies as a function of the task environment. Often, if users are required to perform data retrieval as part of a job, they must learn to use a system efficiently or lose the job. The consequence of poor design may be especially critical in such situations, but there has been little research addressing the possible tradeoffs between designing for maximum productivity and designing for ease-of-use. However, for systems in which user participation is purely voluntary, designers may be more attuned to user concerns. Particularly when increased system use means increased profits, there is greater incentive for conducting user-oriented human factors research.

Several different kinds of data maps and data indices should be evaluated, using similar search tasks. The design of the map used in this study was based largely on intuition; there were no guidelines available that specified how such a map should look. One alternative that comes immediately to mind is to use a hierarchy turned on its side, so that a user can follow a pathway from left to right across a page, rather than from top to bottom. It would be interesting to find out if the apparent advantage of spatial information in a top-down hierarchy is preserved when the arrangement of data items is less like that of a traditional organizational chart. The effectiveness of alternative arrangements of data items may depend on certain cultural characteristics; designers must consider the direction in which people in a target population read and write across a page.

Studies should be conducted in which subjects are given more autonomy in the way they choose to use a map or index, rather than requiring that they view an aid for a specified amount of time at a specified point in the sequence of operations. Of course, enough must be known about subject behavior under strictly controlled conditions before data from a more free-form paradigm can be evaluated in the overall task environment. It would also be interesting to see how subjects perform when encouraged to develop their own maps, either with or without templates provided by the experimenter.

Finally, the search should continue for situational factors and individual characteristics that will help predict performance in a data retrieval task of this nature. Protocol analysis might be a useful tool for discovering more about the strategies subjects use; many people find it difficult to describe their thought processes after a task is completed. Too little is known about the influence of prior experience with computers, programming, keyboards in general, or some combination of these elements on a user's ability to retrieve information from an unfamiliar data domain. Research should also be conducted on memory for the location of objects in two-dimensional space, using maps of both realistic physical locales and semantically organized information structures.

If these suggested studies were all conducted, the accumulated results would form preliminary guidelines for the design of effective navigation aids for information retrieval systems. These guidelines would suggest design strategies based on the size and type of the database, the nature of the task, and the characteristics of the user population. Based on the research reported here, the guidelines would recommend that developers provide maps of data structures with every new system, both to minimize the frustration users experience when navigating through an unfamiliar data domain, and to maximize their efficiency in the data retrieval task.

REFERENCES

Baker, J. D., & Goldstein, I. Batch vs. sequential displays: Effects on human problem solving. Human Factors, 1966, 8, 225-235.

Billingsley, P. A. The Effect of Spatial Cues on Memory for the Organization of Information. Northridge, CA: California State University, Northridge, unpublished paper, May 1981.

Bower, G. H. Analysis of a mnemonic device. American Scientist, 1970, 58, 496-510.

Bower, G. H., Clark, M. C., Lesgold, A. M., & Winenz, D. Hierarchical retrieval schemes in recall of categorical word lists. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 323-343.

Broadbent, D. E., Cooper, P. J., & Broadbent, M. H. P. A comparison of hierarchical and matrix retrieval schemes in recall. Journal of Experimental Psychology: Human Learning and Memory, 1978, 4, 486-497.

Brooks, L. R. Spatial and verbal components of the act of recall. Canadian Journal of Psychology, 1968, 22, 349-368.

Brosey, M., & Shneiderman, B. Two experimental comparisons of relationaland hierarchical database models. International Journal of Man-Machine Studies, 1978, 10, 625-637.

Bruning, J. L., & Kintz, B.L. Computational Handbook of Statistics. Glenview, IL: Scott, Foresman and Company, 1977.

Calhoun, G. L. Control logic design criteria for multifunction switching devices. Proceedings of the Human Factors Society 22nd Annual Meeting, 1978, 383-387.

Collins, A. M., & Quillian, M. R. Retrieval time from semantic memory. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 240-247.

Crothers, E. J. Arbitrary CVC hierarchies learned by paired-component presentations. Journal of Experimental Psychology, 1969, 82, 285-289.

Cuff, R. N. On casual users. International Journal of Man-Machine Studies, 1980, 12, 163-187.

Dixon, W. J. (Ed.) BMDP Biomedical Computer Programs. Los Angeles, CA: University of California Press, 1979.

Durding, B. M., Becker, C. A., & Gould, J. D. Data organization. Human Factors, 1977, 19, 1-14.

Egan, D., Bowers, S., & Gomez, A. Learner characteristics that predict success in using a text editor. Proceedings of a Conference on Human Factors in Computer Systems, Gaithersburg, MD, March 1982, 337-340.

Ekstrom, R. B., French, J. W., Harman, H. H., & Derman, D. Kit of Factor-Referenced Cognitive Tests, 1976. Princeton, NJ: Educational Testing Service, 1976.

Engel, S. E., & Granda, R. E. Guidelines for Man/Display Interfaces (TR 00.2720). Poughkeepsie, NY: IBM, December 1975.

Fitter, M., & Green, T. R. G. When do diagrams make good computer languages? International Journal of Man-Machine Studies, 1979, 11, 235-261.

Furnas, G. W., Gomez, L. M., Landauer, T. K., & Dumais, S. T. Statistical semantics: How can a computer use what people name things to guess what people mean when they name things? Proceedings of a Conference on Human Factors in Computer Systems, Gaithersburg, MD, March, 1982, 251-253.

Gregg, L. W. Internal representations of sequential concepts. In B. Kleinmuntz (Ed.), Concepts and the Structure of Memory. New York, NY: John Wiley and Sons, Inc., 1966.

Hunt, E. B. Concept Learning. An Information Processing Problem. New York, NY: John Wiley and Sons, Inc., 1966.

Kernighan, B. W. UNIX for Beginnners. Murray Hill, NJ: Bell Laboratories, n. d.

Mandler, J. M., Seegmiller, D., & Day, J. On the coding of spatial information. Memory & Cognition, 1977, 5, 10-16.

McGee, W. C. On user criteria for data model evaluation. ACM Transactions on Database Systems, 1976, 1, 370-387.

Miller, D. P. The depth/breadth tradeoff in hierarchical computer menus. Proceedings of the Human Factors Society 25th Annual Meeting, 1981, 296-300.

Miller, R. B. Archetypes in man-computer problem-solving. Ergonomics, 1969, 12, 559-581.

Nie, N. H., Hull, C. H., Jenkins, J. G., Steinbrenner, K., & Bent, D. H. (Eds.) SPSS: Statistical Package for the Social Sciences. New York, NY: McGraw-Hill, 1970.

Rothkopf, E. Z. Incidental memory for location of information in text. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 608-613.

Scheerer, M. Problem-solving. Scientific American, 1963, 208(4), 118-128.

Schulman, A. I. Recognition memory and the recall of spatial location. Memory & Cognition, 1973, 1, 256-260.

Shneiderman, B. Software Psychology. Human Factors in Computer and Information Systems. Cambridge, MA: Winthrop Publishers, 1980.

Shneiderman, B. Improving the human factors aspects of database interaction. ACM Transactions on Database Systems, 1978, 3, 417-439.

Smith, S. L. Man-Machine Interface (MMI) Requirements Definition and Design Guidelines. A Progress Report (MTR-8134). Bedford, MA: The Mitre Corporation, February 1981.

Tombaugh, J. W., & McEwen, S. A. Comparison of two information retrieval methods on Videotex: Tree-structure versus alphabetical directory. Proceedings of a Conference on Human Factors in Computer Systems, Gaithersburg, MD, March 1982, 106-110.

van Ness, F. L., & Tromp, J. H. Is viewdata easy to use? IPO Annual Progress Report, 1979, 14, 120-123.

Winsbury, R. Electronic editing: Database and page design. In R. Winsbury (Ed.) Viewdata in action. London, UK: McGraw-Hill Book Company (UK) Ltd., 1981.

Zechmeister, E. B., McKillip, J., Pasko, S., & Bespalec, D. Visual memory for place on the page. Journal of General Psychology, 1975, 92, 43-52.

Zimmerman, J., & Underwood, B. J. Ordinal position knowledge within and across lists as a function of instructions in free-recall learning. Journal of General Psychology, 1968, 79, 301-307.

APPENDIX A

PRETESTS

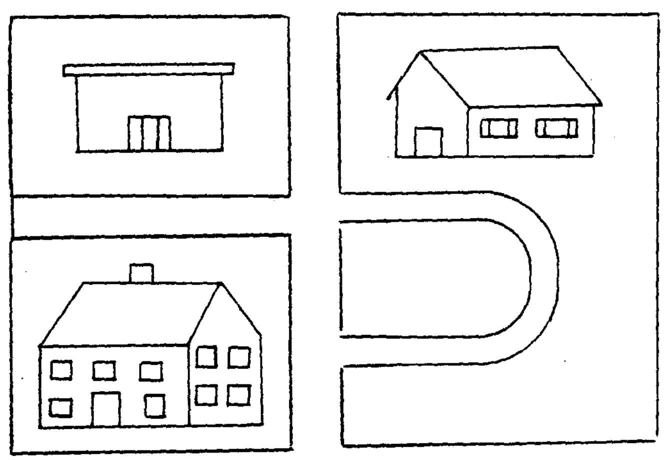
Name ______________________________

BUILDING MEMORY — MV-2

This is a test of your ability to remember the position of things on a street map.

You will be given a map with streets and buildings and other structures to study. After you have had some time to learn the street layout and the different kinds of structures, you will be asked to turn to a test page. On that page you will find the street map and numbered pictures of some of the structures. You will be asked to write in the number that shows where each of the structures was located on the study map.

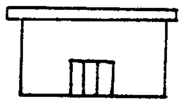
Now look at this simple and enlarged sample:



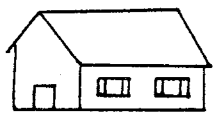
After you have studied the sample above for a minute, turn to the next page.

Look at the numbered houses on the left. Write the number of each structure on the map in the place that corresponds with where each house was located on the study map.

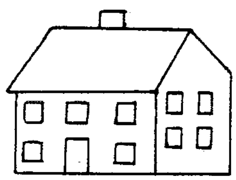
1.

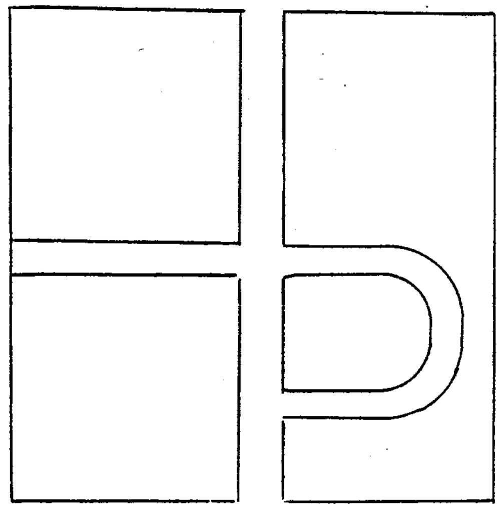


2.



3.





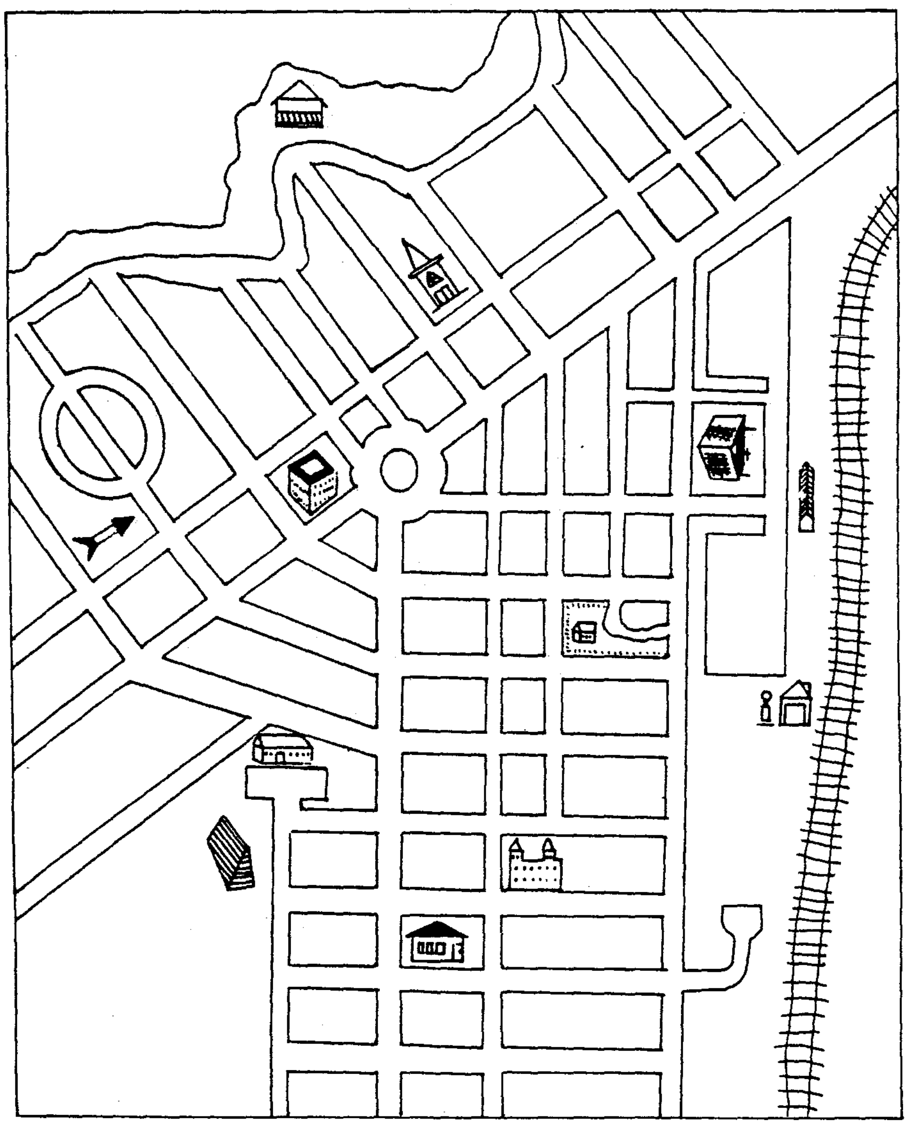
This test has two parts. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

STUDY PAGE

Part 1 (2 minutes)

Study this map so you can remember where each building is located.



DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

STOP

TEST PAGE

Part 1 (2 minutes)

INSTRUCTIONS: Write the number of each structure shown on the left in the place where it belongs on the map. Be as accurate as you can.

1. 

2. 

3. 

4. 

5. 

6. 

7. 

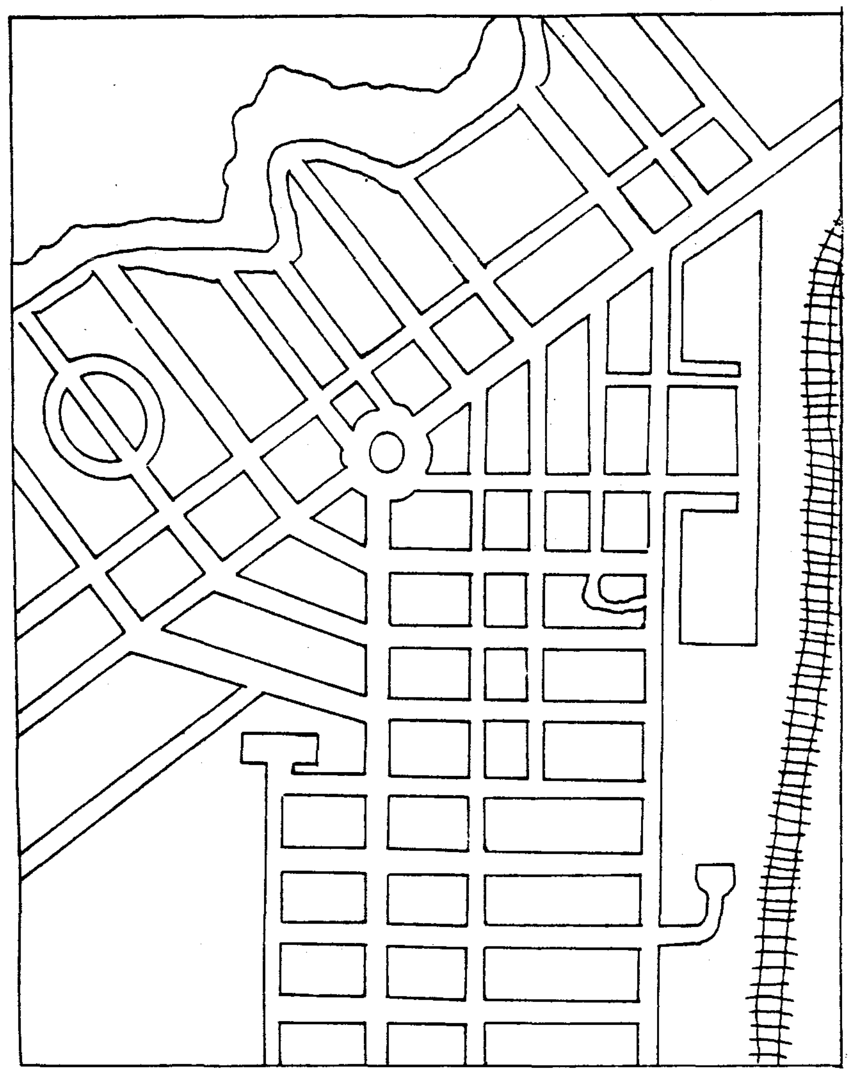
8. 

9. 

10. 

11. 

12. 



DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

STOP.

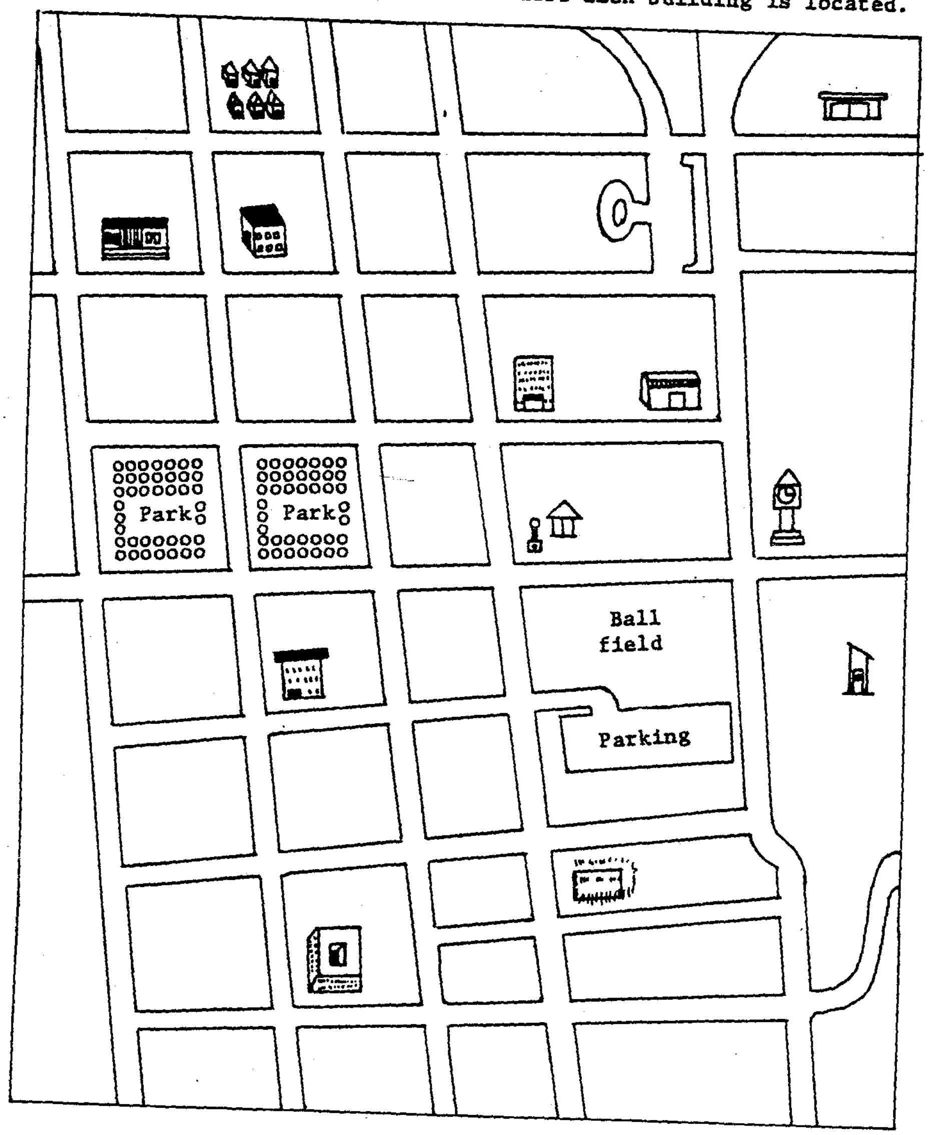
Page 5

MV-2

STUDY PAGE

Part 2 (2 minutes)

Study this map so you can remember where each building is located.



DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

STOP.

TEST PAGE

Part 2 (2 minutes)

INSTRUCTIONS: Write the number of each structure shown on the left in the place where it belongs on the map. Be as accurate as you can.

13. 

14. 

15. 

16. 

17. 

18. 

19. 

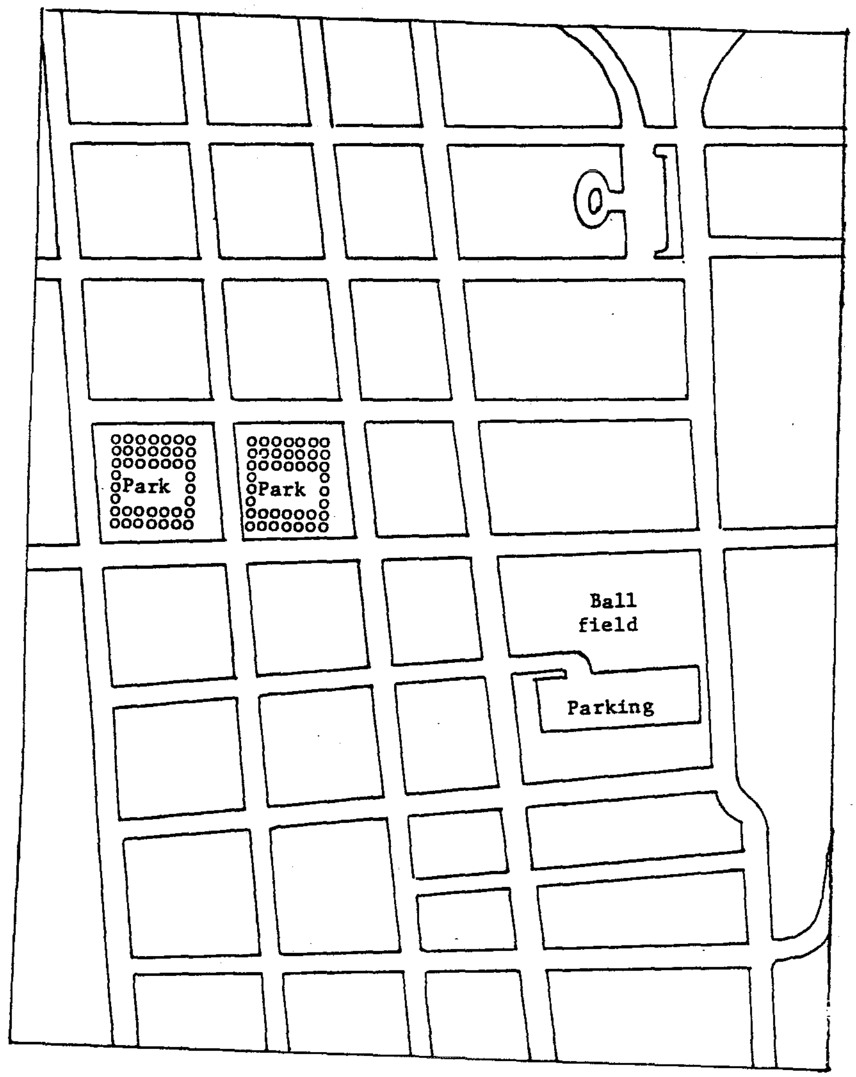
20. 

21. 

22. 

23. 

24. 



DO NOT GO BACK TO PART 1 AND DO NOT GO ON TO ANY OTHER TEST

STOP.

Name ____

FIRST AND LAST NAMES TEST — MA-3

This is a test of your ability to learn first and last names. In each part of the test you will study a page of 15 full names, first and last. After studying the page showing full names you will turn to a page showing a list of the <u>last</u> names in a different order. You will be asked to write the <u>first</u> names that go with each last name.

Here are some practice names. Study them until you are asked to turn to the next page (1 minute).

Janet Gregory

Thomas Adams

Roland Donaldson

Patricia Fletcher

Betty Bronson

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

PRACTICE TEST PAGE

The first name in the list below has been completed. Write all of the other first names that you can remember.

Patricia	Fletcher
	Bronson
	Donaldson
	Gregory
	Adams

Your score will be the number marked correctly. Even if you are not sure of the correct answer to a question, it will be to your advantage to guess.

There are two parts in this test. Each part has two pages:

The first of these is a memory page which you are to study for 3 minutes.

The second is a test page on which you are to write the first names that go with the last names. You will have 2 minutes to write.

When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

MEMORY PAGE FOR PART 1

Study this list. You will be allowed 3 minutes.

Claire Sullivan

Jack Thompson

Leon Chapin

John Reynolds

Joan White

Donald Lambert

Daniel Shaw

Kenneth Murray

Edward Nichols

Jean Wolfe

Carl Brown

Blanche Clark

Roger Lennon

Eloise Cooper

David Burgess

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

STOP.

TEST PAGE FOR PART 1

Complete the names below. You have 2 minutes.

_______________ Nichols
_______________ Cooper
_______________ Murray
_______________ Chapin
_______________ Brown
_______________ Reynolds
_______________ Sullivan
_______________ Lennon
_______________ Lambert
_______________ Wolfe
_______________ Burgess
_______________ Shaw
_______________ Thompson
_______________ Clark
_______________ White

DO NOT TURN TO PART 2 UNTIL ASKED TO DO SO.

STOP.

MEMORY PAGE FOR PART 2

Study this list. You will be allowed 3 minutes.

Walter Price

Robert Sweeney

Leo Wells

Shirley Watson

Barbara Lombard

Joseph Hall

Edith Manning

Bruce Green

James O'Donnell

Irene Buchanan

Stella Page

Judy Shea

Priscilla Bardon

Stanley Rhodes

Susan Tracy

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

STOP.

TEST PAGE FOR PART 2

Complete the names below. You have 2 minutes.

________________________ Sweeney

________________________ Lombard

________________________ O'Donnell

________________________ Rhodes

________________________ Buchanan

________________________ Price

________________________ Watson

________________________ Page

________________________ Green

________________________ Tracy

________________________ Wells

________________________ Bardon

________________________ Manning

________________________ Shea

________________________ Hall

DO NOT GO BACK TO PART 1 AND

DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO.

STOP.

APPENDIX B

COMPUTER PROGRAM

```
N\LIST

1  REM  BIGTREE2.1: LATEST PROGRAM VERSION AS OF APRIL 21, 1982

5  CLEAR : HOME
10 D$ =  CHR$ (4): REM   CONTOL-D
11  PRINT D$;"NOMON I,O,C"
12  GOSUB 10040:SLOT = C
15  PRINT "WELCOME TO THE ANIMAL HUNT."
20  PRINT : PRINT "TYPE IN YOUR FIRST AND LAST NAME,"
25  PRINT : PRINT "THEN PRESS THE RETURN KEY."
30  PRINT : INPUT N$
31  IF  LEN (N$) < 30 THEN 34
32  PRINT : PRINT "TOO LONG.  USE INITIAL FOR FIRST NAME."
33  GOTO 30
34  PRINT
35  PRINT : PRINT "TYPE IN TODAY'S DATE"
37  PRINT : PRINT "(EXAMPLE: APRIL 12, 1982)"
40  PRINT : PRINT "THEN PRESS THE RETURN KEY."
45  PRINT : INPUT DA$
100  HOME : PRINT "TIME FOR A SAMPLE ANIMAL HUNT.": PRINT
110  PRINT "YOU ARE LOOKING FOR THE OSTRICH."
120  VTAB (10): HTAB 13: PRINT "1. EUROPE"
130  PRINT : HTAB 13: PRINT "2. AFRICA"
140  PRINT : HTAB 13: PRINT "3. ANTARCTICA"
150  VTAB (22): PRINT "ENTER A NUMBER FROM 1 TO 3."
160  INPUT X
170  IF X <  > 2 THEN 160
180  HOME : PRINT "YOU ARE LOOKING FOR THE OSTRICH."
190  VTAB (10): HTAB 13: PRINT "1. REPTILE"
200  PRINT : HTAB 13: PRINT "2. FISH"
210  PRINT : HTAB 13: PRINT "3. BIRD"
220  VTAB (22): PRINT "ENTER A NUMBER FROM 1 TO 3."
230  INPUT X
240  IF X <  > 3 THEN 230
250  HOME : PRINT "CONGRATULATIONS!!!"
260  PRINT : PRINT "YOU'VE FOUND THE OSTRICH,"
270  PRINT : PRINT "AND YOU FOUND IT IN THE LEAST POSSIBLE"
280  PRINT : PRINT "NUMBER OF MOVES!!!"
290  VTAB (13): HTAB 13: PRINT "1. OSTRICH"
300  PRINT : HTAB 13: PRINT "2. SPARROW"
310  PRINT : HTAB 13: PRINT "3. SEAGULL"
320  VTAB (20): PRINT "THAT'S THE END OF THE SAMPLE."
321  PRINT
322  INPUT A$
```

```
325  IF A$ = "BEGIN" THEN 510
330  GOTO 322
510  REM   P IS THE ARRAY OF CHOICES.
515  DIM P(1000)
520  REM   T IS THE ARRAY OF NUMBER OF CHOICES.
525  DIM T(80)
530  REM   E IS THE ARRAY OF EFFICIENCY SCORES.
535  DIM E(80): REM  E IS THE ARRAY OF ERRORS
540  DIM A(9)
541  DIM TIME(80)
545  DIM TARG$(80)
546  DIM TB(80): REM  TB IS THE ARRAY OF TRIAL BLOCK NUMBERS
548 L = 1
550  FOR J = 1 TO 3
560  GOSUB 605
565  FOR I = 1 TO 9
570 S1 = 0:S2 = 0:STD = 0:H = 0:M = 0:S = 0: GOSUB 21650
575  ON A(I) GOTO 675,720,730,740,770,785,850,875,905
580  FOR J1 = 1 TO 2
584  GOSUB 605
585  FOR I = 1 TO 9
590 S1 = 0:S2 = 0:STD = 0:H = 0:M = 0:S = 0: GOSUB 21650
595  ON A(I) GOTO 650,680,705,755,805,820,830,860,890
605  FOR K = 1 TO 9
610 A(K) = K
615  NEXT K
620  FOR K = 9 TO 2 STEP  - 1
625 R = 1 +  INT (K *  RND (1))
630 T = A(K):A(K) = A(R):A(R) = T
635  NEXT K
638  RETURN
640  GOTO 7150
650 T$ = "SHEEP": GOTO 1000
655 T$ = "COW": GOTO 1000
660 T$ = "GOAT": GOTO 1000
665 T$ = "PIG": GOTO 1000
670 T$ = "CAT": GOTO 1000
675 T$ = "DUCK": GOTO 1000
680 T$ = "PONY": GOTO 1000
685 T$ = "DOG": GOTO 1000
690 T$ = "HORSE": GOTO 1000
700 T$ = "GUINEA PIG": GOTO 1000
705 T$ = "HAMSTER": GOTO 1000
710 T$ = "GERBIL": GOTO 1000
715 T$ = "CANARY": GOTO 1000
720 T$ = "PARROT": GOTO 1000
725 T$ = "ELEPHANT": GOTO 1000
730 T$ = "CAMEL": GOTO 1000
735 T$ = "MULE": GOTO 1000
740 T$ = "TROUT": GOTO 1000
745 T$ = "TUNA": GOTO 1000
```

```
750 T$ = "SHARK": GOTO 1000
755 T$ = "TURKEY": GOTO 1000
760 T$ = "CHICKEN": GOTO 1000
765 T$ = "GOOSE": GOTO 1000
770 T$ = "RABBIT": GOTO 1000
775 T$ = "MOUSE": GOTO 1000
780 T$ = "MONKEY": GOTO 1000
785 T$ = "FOX": GOTO 1000
790 T$ = "SEAL": GOTO 1000
795 T$ = "MINK": GOTO 1000
800 T$ = "DEER": GOTO 1000
805 T$ = "ALLIGATOR": GOTO 1000
810 T$ = "CALF": GOTO 1000
815 T$ = "PHEASANT": GOTO 1000
820 T$ = "DOVE": GOTO 1000
825 T$ = "TOUCAN": GOTO 1000
830 T$ = "ELK": GOTO 1000
835 T$ = "COUGAR": GOTO 1000
840 T$ = "MOOSE": GOTO 1000
845 T$ = "LION": GOTO 1000
850 T$ = "ZEBRA": GOTO 1000
855 T$ = "RHINOCEROS": GOTO 1000
860 T$ = "LEOPARD": GOTO 1000
865 T$ = "GORILLA": GOTO 1000
870 T$ = "PANTHER": GOTO 1000
875 T$ = "TIGER": GOTO 1000
880 T$ = "CHIMPANZEE": GOTO 1000
885 T$ = "BEAR": GOTO 1000
890 T$ = "OTTER": GOTO 1000
895 T$ = "BEAVER": GOTO 1000
900 T$ = "HIPPOPOTAMUS": GOTO 1000
905 T$ = "CROCODILE": GOTO 1000
910 T$ = "PENGUIN": GOTO 1000
915 T$ = "SALMON": GOTO 1000
1000 A$ = "DOMESTICATED":B$ = "COMMERCIAL/PRODUCT":C$ = "WILD"
1015  HOME : PRINT "YOU ARE LOOKING FOR THE ";T$;"."
1020  VTAB (10)
1021  HTAB 16: PRINT "MAIN MENU"
1025  VTAB (13)
1026  HTAB 13: PRINT "1. ";A$
1030  PRINT : HTAB 13: PRINT "2. ";B$
1035  PRINT : HTAB 13: PRINT "3. ";C$
1040  VTAB (21)
1041  PRINT "ENTER A NUMBER FROM 1 TO 3."
1045 N = N + 1:P(L) = 11:L = L + 1
1050  INPUT X
1055  IF X > 3 GOTO 1050
1060  ON X GOTO 1100.1200,1300
1100 A$ = "FARM":B$ = "PET":C$ = "TRANSPORT"
1110 P(L) = 21:L = L + 1
1120  GOSUB 5000
```

```
1130  ON X GOTO 1400,1500,1600,1000,1000
1200 A$ = "FOOD":B$ = "LABORATORY":C$ = "SKINS"
1210 P(L) = 22:L = L + 1
1220  GOSUB 5000
1230  ON X GOTO 1700,1800,1900,1000,1000
1300 A$ = "AIR":B$ = "LAND":C$ = "WATER"
1310 P(L) = 23:L = L + 1
1320  GOSUB 5000
1330  ON X GOTO 2000,2100,2200,1000,1000
1400 A$ = "PASTURE":B$ = "BARNYARD":C$ = ""
1410 P(L) = 31:L = L + 1
1420  GOSUB 5000
1430  ON X GOTO 2300,2400,1440,1100,1000
1440  PRINT
1500 A$ = "LARGE":B$ = "SMALL":C$ = ""
1510 P(L) = 32:L = L + 1
1520  GOSUB 5000
1530  ON X GOTO 2500,2600,1540,1100,1000
1540  PRINT
1600 A$ = "CAMEL":B$ = "ELEPHANT":C$ = "MULE"
1610 P(L) = 33:L = L + 1:IDEAL = 2
1620  IF A$ = T$ THEN 7000
1630  IF B$ = T$ THEN 7000
1640  IF C$ = T$ THEN 7000
1650  GOSUB 6000
1660  ON X GOTO 1670,1670,1670,1100,1000
1670  PRINT
1700 A$ = "FISH":B$ = "POULTRY":C$ = ""
1710 P(L) = 34:L = L + 1
1720  GOSUB 5000
1730  ON X GOTO 2700,2800,1740,1200,1000
1740  PRINT
1800 A$ = "RABBIT":B$ = "MOUSE":C$ = "MONKEY"
1810 P(L) = 35:L = L + 1:IDEAL = 2
1820  IF A$ = T$ THEN 7000
1821  IF B$ = T$ THEN 7000
1822  IF C$ = T$ THEN 7000
1830  GOSUB 6000
1840  ON X GOTO 1850,1850,1850,1200,1000
1850  PRINT
1900 A$ = "FUR":B$ = "LEATHER":C$ = ""
1910 P(L) = 36:L = L + 1
1920  GOSUB 5000
1930  ON X GOTO 2900,3000,1940,1200,1000
1940  PRINT
2000 A$ = "DOVE":B$ = "PHEASANT":C$ = "TOUCAN"
2010 P(L) = 37:L = L + 1
2015 IDEAL = 2
2020  IF A$ = T$ THEN 7000
2021  IF B$ = T$ THEN 7000
2022  IF C$ = T$ THEN 7000
```

```
2030  GOSUB 6000
2040  ON X GOTO 2050,2050,2050,1300,1000
2050  PRINT
2100 A$ = "BIG GAME":B$ = "CIRCUS":C$ = ""
2110 P(L) = 38:L = L + 1
2120  GOSUB 5000
2130  ON X GOTO 3100,3200,2140,1300,1000
2140  PRINT
2200 A$ = "MAMMAL":B$ = "NON-MAMMAL"
2205 C$ = ""
2210 P(L) = 39:L = L + 1
2220  GOSUB 5000
2230  ON X GOTO 3300,3400,2240,1300,1000
2240  PRINT
2300 A$ = "SHEEP":B$ = "COW":C$ = "GOAT"
2310 P(L) = 41:L = L + 1:IDEAL = 3
2320  IF A$ = T$ THEN 7000
2321  IF B$ = T$ THEN 7000
2322  IF C$ = T$ THEN 7000
2330  GOSUB 6000
2340  ON X GOTO 2350,2350,2350,1400,1000
2350  PRINT
2400 A$ = "DUCK":B$ = "PIG":C$ = "CAT"
2410 P(L) = 42:L = L + 1:IDEAL = 3
2420  IF A$ = T$ THEN 7000
2421  IF B$ = T$ THEN 7000
2422  IF C$ = T$ THEN 7000
2430  GOSUB 6000
2440  ON X GOTO 2450,2450,2450,1400,1000
2450  PRINT
2500 A$ = "PONY":B$ = "DOG":C$ = "HORSE"
2510 P(L) = 43:L = L + 1:IDEAL = 3
2520  IF A$ = T$ THEN 7000
2521  IF B$ = T$ THEN 7000
2522  IF C$ = T$ THEN 7000
2530  GOSUB 6000
2540  ON X GOTO 2550,2550,2550,1500,1000
2550  PRINT
2600 A$ = "FURRY":B$ = "FEATHERED":C$ = ""
2610 P(L) = 44:L = L + 1
2620  GOSUB 5000
2630  ON X GOTO 3500,3600,2640,1500,1000
2640  PRINT
2700 A$ = "TROUT":B$ = "TUNA":C$ = "SHARK"
2710 P(L) = 45:L = L + 1:IDEAL = 3
2720  IF A$ = T$ THEN 7000
2721  IF B$ = T$ THEN 7000
2722  IF C$ = T$ THEN 7000
2730  GOSUB 6000
2740  ON X GOTO 2750,2750,2750,1700,1000
2750  PRINT
```

```
2800 A$ = "TURKEY":B$ = "CHICKEN":C$ = "GOOSE"
2810 P(L) = 46:L = L + 1:IDEAL = 3
2820  IF A$ = T$ THEN 7000
2821  IF B$ = T$ THEN 7000
2822  IF C$ = T$ THEN 7000
2830  GOSUB 6000
2840  ON X GOTO 2850,2850,2850,1700,1000
2900 A$ = "FOX":B$ = "SEAL":C$ = "MINK"
2910 P(L) = 47:L = L + 1:IDEAL = 3
2920  IF A$ = T$ THEN 7000
2921  IF B$ = T$ THEN 7000
2922  IF C$ = T$ THEN 7000
2930  GOSUB 6000
2940  ON X GOTO 2950,2950,2950,1900,1000
2950  PRINT
3000 A$ = "ALLIGATOR":B$ = "DEER":C$ = "CALF"
3010 P(L) = 48:L = L + 1:IDEAL = 3
3020  IF A$ = T$ THEN 7000
3021  IF B$ = T$ THEN 7000
3022  IF C$ = T$ THEN 7000
3030  GOSUB 6000
3040  ON X GOTO 3050,3050,3050,1900,1000
3050  PRINT
3100 A$ = "FOREST":B$ = "PLAINS":C$ = "JUNGLE"
3110 P(L) = 49:L = L + 1
3120  GOSUB 5000
3130  ON X GOTO 3700,3800,3900,2100,1000
3200 A$ = "TIGER":B$ = "CHIMPANZEE":C$ = "BEAR"
3210 P(L) = 50:L = L + 1:IDEAL = 3
3220  IF A$ = T$ THEN 7000
3221  IF B$ = T$ THEN 7000
3222  IF C$ = T$ THEN 7000
3230  GOSUB 6000
3240  ON X GOTO 3250,3250,3250,2100,1000
3250  PRINT
3300 A$ = "OTTER":B$ = "BEAVER":C$ = "HIPPOPOTAMUS"
3310 P(L) = 51:L = L + 1:IDEAL = 3
3320  IF A$ = T$ THEN 7000
3321  IF B$ = T$ THEN 7000
3322  IF C$ = T$ THEN 7000
3330  GOSUB 6000
3340  ON X GOTO 3350,3350,3350,2200,1000
3350  PRINT
3400 A$ = "CROCODILE":B$ = "PENGUIN":C$ = "SALMON"
3410 P(L) = 52:L = L + 1:IDEAL = 3
3420  IF A$ = T$ THEN 7000
3421  IF B$ = T$ THEN 7000
3422  IF C$ = T$ THEN 7000
3430  GOSUB 6000
3440  ON X GOTO 3450,3450,3450,2200,1000
3450  PRINT
```

```
3500 A$ = "HAMSTER":B$ = "GUINEA PIG":C$ = "GERBIL"
3510 P(L) = 61:L = L + 1:IDEAL = 4
3520  IF A$ = T$ THEN 7000
3521  IF B$ = T$ THEN 7000
3522  IF C$ = T$ THEN 7000
3530  GOSUB 6000
3540  ON X GOTO 3550,3550,3550,2600,1000
3550  PRINT
3600 A$ = "PARROT":B$ = "PIGEON":C$ = "CANARY"
3610 P(L) = 62:L = L + 1:IDEAL = 4
3620  IF A$ = T$ THEN 7000
3621  IF B$ = T$ THEN 7000
3622  IF C$ = T$ THEN 7000
3630  GOSUB 6000
3640  ON X GOTO 3650,3650,3650,2600,1000
3650  PRINT
3700 A$ = "ELK":B$ = "COUGAR":C$ = "MOOSE"
3710 P(L) = 63:L = L + 1:IDEAL = 4
3720  IF A$ = T$ THEN 7000
3721  IF B$ = T$ THEN 7000
3722  IF C$ = T$ THEN 7000
3730  GOSUB 6000
3740  ON X GOTO 3750,3750,3750,3100,1000
3750  PRINT
3800 A$ = "ZEBRA":B$ = "LION":C$ = "RHINOCEROS"
3810 P(L) = 64:L = L + 1:IDEAL = 4
3820  IF A$ = T$ THEN 7000
3821  IF B$ = T$ THEN 7000
3822  IF C$ = T$ THEN 7000
3830  GOSUB 6000
3840  ON X GOTO 3850,3850,3850,3100,1000
3850  PRINT
3900 A$ = "LEOPARD":B$ = "GORILLA":C$ = "PANTHER"
3910 P(L) = 65:L = L + 1:IDEAL = 4
3920  IF A$ = T$ THEN 7000
3921  IF B$ = T$ THEN 7000
3922  IF C$ = T$ THEN 7000
3930  GOSUB 6000
3940  ON X GOTO 3950,3950,3950,3100,1000
3950  PRINT
5000  HOME : PRINT "YOU ARE LOOKING FOR THE ";T$;"."
5005  VTAB (10): HTAB 13: PRINT "1. ";A$
5010  PRINT : HTAB 13: PRINT "2. ";B$
5015  PRINT : HTAB 13: PRINT "3. ";C$
5020  PRINT : HTAB 13: PRINT "4. BACK ONE MENU."
5025  PRINT : HTAB 13: PRINT "5. BACK TO MAIN MENU."
5030 N = N + 1
5035  VTAB (22): PRINT "ENTER A NUMBER FROM 1 TO 5."
5040  INPUT X
5045  IF C$ <  > "" THEN 5055
5050  IF X = 3 THEN 5040
```

```
5055  IF X > 5 THEN 5040
5060  RETURN
6000  HOME : PRINT "THE ";T$;" ISN'T WITH THESE ANIMALS."
6005  PRINT : PRINT "TRY LOOKING IN A DIFFERENT PLACE."
6020  VTAB (10): HTAB 13: PRINT "1. ";A$
6025  PRINT : HTAB 13: PRINT "2. ";B$
6030  PRINT : HTAB 13: PRINT "3. ";C$
6035  PRINT : HTAB 13: PRINT "4. BACK ONE MENU."
6040  PRINT : HTAB 13: PRINT "5. BACK TO MAIN MENU."
6045  VTAB (22): PRINT "ENTER 4 OR 5 TO CONTINUE LOOKING."
6047 N = N + 1
6050  INPUT X
6055  IF X < 4 THEN 6050
6060  IF X > 5 THEN 6050
6070  RETURN
7000 Q = Q + 1: REM  Q IS THE TRIAL BLOCK COUNTER
7002 T(Q) = N
7003  GOSUB 21950
7004 TIME(Q) = ( INT (TIME(Q) * 100))
7005 E(Q) = N - IDEAL
7007 TARG$(Q) = T$
7008 TB(Q) = 1 +  INT ((Q - 1) / 9)
7010  IF IDEAL <  > N THEN 7040
7015  HOME : PRINT "CONGRATULATIONS!!!"
7020  PRINT : PRINT "YOU'VE FOUND THE ";T$;","
7025  PRINT : PRINT "AND YOU FOUND IT IN THE LEAST POSSIBLE"
7030  PRINT : PRINT "NUMBER OF MOVES!!!"
7035  GOTO 7045
7040  HOME : PRINT "YOU'VE FOUND THE ";T$;"."
7045  VTAB (13): HTAB (13): PRINT "1. ";A$
7050  PRINT : HTAB 13: PRINT "2. ";B$
7055  PRINT : HTAB 13: PRINT "3. ";C$
7060  VTAB (22): PRINT "ENTER 1 TO BEGIN THE NEXT SEARCH."
7075 N = 0: INPUT X
7080  IF X = 1 THEN 7095
7085  IF X = 9 THEN 7150
7086 X$ =  STR$ (X): IF X$ = "" THEN 7075
7090  GOTO 7075
7095 X = 1 +  INT (Q / 9)
7100  IF TB(Q) = X THEN 7120
7102  HOME
7105  PRINT "YOU'VE REACHED THE END OF TRIAL BLOCK ";TB(Q);"."
7106  IF TB(Q) <  > 5 THEN 7110
7107  PRINT : PRINT : PRINT "THE GAME IS OVER. THANKS FOR PLAYING."
7108  PRINT : PRINT "DATA IS BEING STORED ON THE DISK..."
7109  GOTO 7150
7110  PRINT "ENTER 1 TO CONTINUE."
7115  INPUT X
7117  IF X <  > 1 THEN 7115
7120  NEXT I
7125  IF J1 > 0 THEN 7132
```

```
7128  NEXT J
7130  IF J1 = 0 THEN 580
7132  NEXT J1
7150  REM   MAKE FILE WITH SUBJECT'S NAME
7160  PRINT D$;"OPEN ";N$
7170  PRINT D$;"WRITE ";N$
7180  PRINT N$
7185  PRINT DA$
7190  PRINT Q
7195  FOR I = 1 TO Q
7196  PRINT TB(I)
7197  NEXT I
7200  FOR I = 1 TO Q
7210  PRINT TARG$(I)
7215  NEXT I
7230  FOR I = 1 TO Q
7240  PRINT T(I)
7250  NEXT I
7260  FOR I = 1 TO Q
7270  PRINT E(I)
7280  NEXT I
7290  FOR I = 1 TO Q
7300  PRINT TIME(I)
7310  NEXT I
7320  PRINT L
7330  FOR I = 1 TO L
7340  PRINT P(I)
7350  NEXT I
7390  PRINT D$;"CLOSE ";N$
7500  END
10010  IF C =  - 1 THEN  GOTO 10030
10020  PRINT "THE APPLE CLOCK IS IN SLOT ";C
10030  END
10040  REM  APPLE CLOCK SLOT FINDER
10050  REM  ------SUBROUTINE-------
10060  REM  MOUNTAIN HARDWARE, INC
10070  REM  USES VARIABLES C1,C2,& C
10080  REM  RETURNS WITH C = THE
10090  REM  SLOT # THE CLOCK IS IN
10100  REM  IF NOT FOUNT C =-1
10110 C =  - 1
10120  FOR C2 = 1 TO 7
10130 C1 =  PEEK ( - 12289): REM  TURN OFF ALL ROMS
10140  IF  PEEK ( - 16384 + C2 * 256 + 19) = 3 OR  PEEK ( - 16384 + C2 *
     256 + 19) = 177 OR  PEEK ( - 16384 + C2 * 256 + 19) = 236 OR  PEEK (
      - 16384 + C2 * 256 + 19) = 44 THEN  GOTO 10170
10150  NEXT C2
10160  GOTO 10190
10170  IF  PEEK ( - 16384 + C2 * 256 + 21) = 248 OR  PEEK ( - 16384 + C2 *
     256 + 21) = 253 OR  PEEK ( - 16384 + C2 * 256 + 21) = 7 OR  PEEK ( -
     16384 + C2 * 256 + 21) = 104 THEN  GOTO 10220
```

```
10180  NEXT C2
10190  PRINT "APPLE CLOCK NOT FOUND"
10200 C1 =  PEEK ( - 12289): REM  KILL ALL ROMS
10210  RETURN
10220 C = C2
10230 C1 =  PEEK ( - 12289): REM  KILL ALL ROMS
10240  RETURN
21600  REM
```

INTERVAL TIMER

```
21650  REM
21700  GOSUB 24250: REM  GET THE TIME
21800  REM  FIND STD FOR T1$
21850  GOSUB 25200
21860 S1 = STD
21900  RETURN
21950  GOSUB 24250: REM  GET THE TIME NOW
22050  REM  FIND STD FOR T2$
22100  GOSUB 25200
22110 S2 = STD
22150 TIME(Q) = S2 - S1
22200  RETURN
24200  REM
```

SUBROUTINE--GET THE TIME

```
24250  PRINT D$;"IN#";SLOT
24300  PRINT D$;"PR#";SLOT
24350  INPUT "";Q$
24400  PRINT D$;"IN#0"
24450  PRINT D$;"PR#0"
24500  RETURN
25150  REM
```

SUBROUTINE--STD

```
25200 MT =  VAL ( MID$ (Q$,1,2))
25210 D =  VAL ( MID$ (Q$,4,2))
25220 H =  VAL ( MID$ (Q$,7,2))
25250 M =  VAL ( MID$ (Q$,10,2))
25300 S =  VAL ( MID$ (Q$,13,6))
25350 STD = H * 3600 + M * 60 + S
25400  RETURN
```

```
]LIST

10  REM        RETRIEVE N$
20  CLEAR
30  PRINT : PRINT "TYPE IN SUBJECT FILE NAME"
40  PRINT : INPUT N$
50  DIM TB(80)
60  DIM TARG$(80)
70  DIM T(80)
80  DIM E(80)
90  DIM TIME(80)
100  DIM P(1000)
110  DIM SEC(80)
120  DIM SEC$(80)
130  DIM TIME$(80)
140  DIM SCHOICE(80)
150  DIM STIME(80)
160  DIM DIAG(80)
170  DIM DIAG$(80)
180 D$ =  CHR$ (4)
190  PRINT D$;"OPEN ";N$
200  PRINT D$;"READ ";N$
210  INPUT N$
220  INPUT DA$
230  INPUT Q
240  FOR I = 1 TO Q
250  INPUT TB(I)
260  NEXT I
270  FOR I = 1 TO Q
280  INPUT TARG$(I)
290  NEXT I
300  FOR I = 1 TO Q
310  INPUT T(I)
320  NEXT I
330  FOR I = 1 TO Q
340  INPUT E(I)
350  NEXT I
360  FOR I = 1 TO Q
370  INPUT TIME(I)
380  NEXT I
390  INPUT L
400  FOR I = 1 TO L
410  INPUT P(I)
420  NEXT I
430  PRINT D$;"CLOSE ";N$
440  HOME : PRINT N$,DA$: PRINT : PRINT
450  PRINT "TB   TARGET   CHOICES   ERRORS   TIME   SEC/CHOICE   DIAGONAL
     "
460  PRINT "--   ------   -------   ------   ----   ----------   --------
```

```
470  PRINT : PRINT
480  FOR I = 1 TO Q
490 TARG$(I) =  LEFT$ (TARG$(I),10)
500 A =  LEN ( STR$ (T(I)))
510 B = (10 -  LEN (TARG$(I))) + 7 - A
520 C =  LEN ( STR$ (E(I)))
530 D = 7 - C
540 TIME$(I) =  STR$ (TIME(I)):Z =  LEN (TIME$(I))
550 E = 8 - Z:F = Z - 2
560 SEC(I) =  INT (TIME(I) / T(I))
570 SEC$(I) =  STR$ (SEC(I))
580  IF  LEN (SEC$(I)) = 2 THEN SEC$(I) = "0" + SEC$(I)
590 M =  LEN (SEC$(I))
600 N = 8 - M
610 O = M - 2
620 SCHOICE(I) = T(I) * T(I)
630 STIME(I) = (TIME(I) / 300) ^ 2
640 DIAG(I) =  INT ( SQR (SCHOICE(I) + STIME(I)) * 100)
650 DIAG$(I) =  STR$ (DIAG(I))
660  IF  LEN (DIAG$(I)) = 1 THEN DIAG$(I) = "00" + DIAG$(I)
670  IF  LEN (DIAG$(I)) = 2 THEN DIAG$(I) = "0" + DIAG$(I)
680 D1 =  LEN (DIAG$(I)):D2 = D1 - 2
690  PRINT  SPC( 1);TB(I); SPC( 2);TARG$(I);
700  PRINT  SPC( B);T(I); SPC( D);E(I);
710  PRINT  SPC( E); LEFT$ (TIME$(I),F);".";
720  PRINT  RIGHT$ (TIME$(I),2);
730  PRINT  SPC( N); LEFT$ (SEC$(I),O);".";
740  PRINT  RIGHT$ (SEC$(I),2);
750  PRINT  SPC( 12 - D1); LEFT$ (DIAG$(I),D2);".";
760  PRINT  RIGHT$ (DIAG$(I),2)
770 X = I + 1
780 TB(I) = 1 +  INT ((I - 1) / 9)
790  IF TB(I) = TB(X) THEN 810
800  PRINT
810  NEXT I
820  PRINT : PRINT
830  GOTO 940
840  PRINT "TOTAL NUMBER OF CHOICES = ";(L - 1)
850  PRINT
860 K = 1
870  FOR I = 1 TO Q
880  PRINT : PRINT
890  FOR J = 1 TO (T(I) + 1)
900  PRINT P(K); SPC( 3);
910 K = K + 1
920  NEXT J
930  NEXT I
940 X = 1:Y = 9
950  FOR J = 1 TO 5
960 ANIMAL(J) = 0
```

```
970  FOR K = X TO Y
980  IF T(K) > 52 THEN 1060
990 ANIMAL(J) = ANIMAL(J) + 1
1000 TCHOICE(J) = TCHOICE(J) + T(K)
1010 SUMERR(J) = SUMERR(J) + E(K)
1020 TTIME(J) = TTIME(J) + TIME(K)
1030 SEC(K) =  INT (TIME(K) / T(K))
1040 TSEC(J) = TSEC(J) + SEC(K)
1050 TDIAG(J) = TDIAG(J) + DIAG(K)
1060  NEXT K
1070 MCHOIC$(J) =  STR$ ( INT (TCHOICE(J) / ANIMAL(J) * 100))
1080 MERR$(J) =  STR$ ( INT (SUMERR(J) / ANIMAL(J) * 100))
1090 MTIME$(J) =  STR$ ( INT (TTIME(J) / ANIMAL(J)))
1100 AVSEC$(J) =  STR$ ( INT (TSEC(J) / ANIMAL(J)))
1110 MDIAG$(J) =  STR$ ( INT (TDIAG(J) / ANIMAL(J)))
1130 X = X + 9:Y = Y + 9
1140  NEXT J
1150  PRINT : PRINT
1160  PRINT "TB   VAL  TOTAL     TOTAL     TOTAL     AVERAGE   AVERAGE
     AVERAGE   AVERAGE"
1170  PRINT "     SRCH CHOICES   ERRORS    TIME      CHOICES   ERRORS
     TIME      SEC/CHOC"
1180  PRINT "---- ---- --------  --------  -------   -------   -------
     -------   -------"
1190  PRINT : PRINT
1200  FOR J = 1 TO 5
1210 A1 = 8 -  LEN ( STR$ (TCHOICE(J)))
1220 A2 = 10 -  LEN ( STR$ (SUMERR(J)))
1230 TTIME$(J) =  STR$ (TTIME(J))
1240 A3 = 9 -  LEN (TTIME$(J))
1250 A4 =  LEN (TTIME$(J)) - 2
1260  IF  LEN (MCHOIC$(J)) = 1 THEN MCHOIC$(J) = "00" + MCHOIC$(J)
1270  IF  LEN (MCHOIC$(J)) = 2 THEN MCHOIC$(J) = "0" + MCHOIC$(J)
1280  IF  LEN (MERR$(J)) = 1 THEN MERR$(J) = "00" + MERR$(J)
1290  IF  LEN (MERR$(J)) = 2 THEN MERR$(J) = "0" + MERR$(J)
1300  IF  LEN (AVSEC$(J)) = 1 THEN AVSEC$(J) = "00" + AVSEC$(J)
1310  IF  LEN (AVSEC$(J)) = 2 THEN AVSEC$(J) = "0" + AVSEC$(J)
1320 A5 =  LEN (MCHOIC$(J)):A6 = A5 - 2
1330 A7 =  LEN (MERR$(J)):A8 = A7 - 2
1340 B1 =  LEN (MTIME$(J)):B2 = B1 - 2
1350 B3 =  LEN (AVSEC$(J)):B4 = B3 - 2
1360  PRINT J; SPC( 5);ANIMAL(J); SPC( A1);
1370  PRINT TCHOICE(J); SPC( A2);SUMERR(J);
1380  PRINT  SPC( A3); LEFT$ (TTIME$(J),A4);"."; RIGHT$ (TTIME$(J),2);
1390  PRINT  SPC( 9 - A5); LEFT$ (MCHOIC$(J),A6);"."; RIGHT$ (MCHOIC$(J),
     2);
1400  PRINT  SPC( 9 - A7); LEFT$ (MERR$(J),A8);"."; RIGHT$ (MERR$(J),2);
1410  PRINT  SPC( 9 - B1); LEFT$ (MTIME$(J),B2);"."; RIGHT$ (MTIME$(J),2)
     ;
1420  PRINT  SPC( 9 - B3); LEFT$ (AVSEC$(J),B4);"."; RIGHT$ (AVSEC$(J),2)
     ;
```

```
1430  PRINT : PRINT
1440  NEXT J
1450  FOR J = 1 TO 5
1452 MCHOICE(J) =  VAL (MCHOIC$(J))
1453 MTIME(J) =  VAL (MTIME$(J))
1455 B5 =  LEN (MDIAG$(J)):B6 = B5 - 2
1457 M2DIAG(J) =  INT ( SQR ((MCHOICE(J) ^ 2) + ((MTIME(J) / 3) ^ 2)))
1458 M2DIAG$(J) =  STR$ (M2DIAG(J))
1459 B7 =  LEN (M2DIAG$(J)):B8 = B7 - 2
1460  PRINT  SPC( 8 - B5); LEFT$ (MDIAG$(J),B6);".";
1470  PRINT  RIGHT$ (MDIAG$(J),2);
1475  PRINT  SPC( 8 - B7); LEFT$ (M2DIAG$(J),B8);".";
1477  PRINT  RIGHT$ (M2DIAG$(J),2)
1480  NEXT J
1490  END
```

APPENDIX C

FINAL QUESTIONNAIRE

FINAL QUESTIONNAIRE

NAME: ______________________________

AGE: ______________ SEX: ______________

HAND YOU WRITE WITH: ______________________________

NUMBER OF COMPUTER COURSES: ______________________________

PROGRAMMING EXPERIENCE/LANGUAGES LEARNED: ______________________________

____

NUMBER OF MATH COURSES, INCLUDING STATISTICS: ______________________________

WORD PROCESSING EXPERIENCE: ______________________________

MAJOR: ______________________________

Try to describe the strategy you used to remember how to find target animals. Make an "X" next to any of the statements below that match your own strategy, then explain it in as much detail as you can.

____ I remembered the order of numbers to enter, not specific words.

____ I remembered the sequence of word choices from the menus.

____ I tried to visualize the overall structure of the file system.

____ I remembered the list or map that I used during the first trial block (if applicable).

____ I used a different strategy, or a combination of some of these.

Please explain: ______________________________

____

____

____

____

Try to draw a picture of how you think the whole file system was organized. Fill in as many of the animal names and menu choices that you can.

APPENDIX D

INSTRUCTIONS TO SUBJECTS

WELCOME TO THE ANIMAL HUNT!

You are a veterinarian and a friend of the millionaire animal collector and breeder, John Smith. While he is away on safari, Mr. Smith has asked you to take care of the health of his animals. Mr. Smith uses his personal computer to keep track of the medical records of all the animals living on his estate. Unfortunately, he cannot be reached to tell you how he categorized the animals, and you need to find the files of some of your animal "patients". You must learn to use the information in the computer to locate their files quickly and without making mistakes, since an animal's life could be at stake. Mr. Smith's method for assigning animals to categories might not always be the one you would choose yourself, but you must use his file system anyway.

The Animal Hunt is a game that Mr. Smith invented to help him practice finding individual animal's files in the computer, and now you can use it to help you learn his system. In the game, you are asked to search for 18 different animals in all. To complete each search, you must make the right choices from a series of "menus" that will appear on the screen in front of you. In this case, a menu is a numbered list of words that describe different features or characteristics that an animal might have. To pick one of the choices from any menu, all you have to do is type in the number that appears beside it, and then press the RETURN key. Before the actual game begins, let's run through an example...

As you might imagine, finding the animals in the actual game is a little more difficult. You may have to make the correct choice from as many as four menus in a row in order to reach the animal you are looking for. If you don't find an animal where you expect to, try other possibilities. This system was designed by someone else, and their ideas about animals may be very different from your own.

There a couple of special features of the game that you should know about:

- You don't have to remember which animal you're looking for as you play the game. It will always be displayed at the top of the screen.

- There may be blank choices on some menus. If you accidentally choose one of them, the computer will just ask you to reenter a number. The key with an arrow pointing to the left lets you delete anything you've typed in by mistake.

- On every menu there are choices that let you go back one step to the menu you just came from (CHOICE 4), or go all the back to the starting point, called the Main Menu (CHOICE 5). These choices allow you to continue searching if you accidentally reach the wrong group of animals. (The computer always lets you know when that happens.) Animals are always found in groups of three, but you will only have to remember how to find the first one in each group.

- As you go through the menus, the computer counts the number of choices you make. If you find an animal using the fewest possible number of choices, the computer will congratulate you. Otherwise, it will just tell you that you found the animal you were searching for.

- The computer also keeps track of the time that you take to complete each search, so work as quickly as possible.

- You should try to remember how you find each animal, because the game requires you to search for every target animal more than time. At the end of every nine searches, the computer will notify you that you've reached the end of a trial block. Please tell the experimenter when you reach the end of each trial block, and then follow the instructions displayed on the screen. You will go through five trial blocks in all.

WORK AS QUICKLY AND EFFICIENTLY AS YOU CAN.

While you are working on the first set of nine searches, you will have an ANIMAL MAP to use. This map shows you the exact sequence of choices that you must make to reach any animal in the file system. All you have to do is locate the name of the animal you are searching for in one of the boxes in the lower part of the map, and then follow the correct sequence of menu choices from the top of the map to the target animal.

You should use this map for every search in the first trial block since it can help you find animals more quickly. Remember, however, to pay attention to the way that you locate each animal, because the ANIMAL MAP will be taken away at the end of the first trial block.