AGE-RELATED EFFECTS OF ACTION VERSUS CONCEPT TRAINING ON DEVELOPING SYSTEM REPRESENTATION

A Thesis

Presented to

The Academic Faculty

By

Jamye M. Hickman

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science in Psychology

Georgia Institute of Technology

April 2004

Age-Related Effects of Action versus Concept Training on

Developing a System Representation

Approved:

Dr. Wendy A. Rogers, Chair

Dr. Arthur D. Fisk

Dr. Richard Catrambone

Date Approved: 04/09/04

DEDICATION

To my parents,

James and Ollie Hickman,

for all their love and support.

ACKNOWLEDGEMENTS

I would like to acknowledge my committee members for their comments and suggestions that helped me improve the finished product. I would especially like to thank, my committee chair and advisor, Dr. Wendy A. Rogers for her guidance in the completion of this work. Finally, I would like to thank the members of the Human Factors and Aging Lab for their support.

TABLE OF CONTENTS

LIST OF TABLES

Appendix A

LIST OF FIGURES

SUMMARY

While living and working in today's high-tech world, the ability to perform tasks and understand the system structure of technology may affect our lives in many ways. For example, calibrating a medical device such as a blood glucose meter may be infrequently performed but adequate knowledge of the system structure may be critical for doing it correctly. This and other forms of technology vary in complexity and require training for proper use. Due to age-related differences in skill acquisition, the design of proper training may be especially important for older adults when learning to use new technology. One factor to consider when developing age-specific training is the type of information presented during training. In general, little research has addressed the effect of information type on the development of an understanding of the system structure and fewer have examined the influence of age. The current study compared the effects of emphasizing actions or concepts during training on performance on multiple measures of learning. Participants completed one of two tutorials for operating a computer-simulated hydroponic garden control. One tutorial presented participants with instructions that focused specific actions to operate the system. The other tutorial displayed instructions that focused on generalized system concepts. At test, overall participants in the concept training condition were faster and more accurate than those in the action training condition for both novel and familiar tasks. Concept training also reduced age-related differences in performance. Results suggest that concept training may lead to the development of a better understanding of the system structure.

CHAPTER 1

INTRODUCTION

The population of the United States is getting older. People are living longer than ever before. In 2000, 13 percent of the population (approximately 35 million) was age 65 and older. Also, during that year, approximately 4 million individuals age 85 and older accounted for 2 percent of the population. The population of older adults is steadily increasing and by 2011 one out of five people will be age 65 and older (Federal Interagency Forum on Aging-Related Statistics, 2000). Within this aging population, the number of older adults engaging in computer use is also increasing. In 1997, approximately 20 percent of individuals age 65 and older reported using computers and in 2001 the amount increased to approximately 40 percent with projections of future increases (U.S. Department of Commerce, 2002). Yet human-computer interaction researchers rarely include older adults in their sample when designing new technologies. Human-computer interaction textbooks state that individual differences, such as age, need to be taken into account in the designing process. However, textbooks do not give specific suggestions on how to enhance the design such that older individuals can benefit from the advancements (Dix, Finlay, Abowd, & Beale, 1998). How is our society to age productively if limitations due to aging are not considered in the design or redesign of products?

The present study focused on the design of training materials to facilitate both the acquisition of skills and the development of an adequate representation of the system structure of a complex task. To support the assertion that age affects skill acquisition the next section will present a discussion of patterns of age-related differences in skill acquisition explored through previous aging research. The following section will address, in depth, two studies that provided training design implications to reduce these age-related differences in skill acquisition. Then a brief discussion of mental models will be presented followed by a discussion of the theoretical framework of procedural and conceptual knowledge will be presented followed by. The section will conclude with a discussion of the rationale for the present study.

Patterns of Age-Related Skill Acquisition

Previous research has demonstrated a number of performance differences in the abilities of older adults compared to younger adults during skill acquisition. These finding are summarized in Table 1.

Table 1. *Age-related Performance Differences and Supporting Research*

Performance Difference	**Supporting Research**
Older adults took longer to complete tasks	Charness, Kelley, Bosman, & Mottram, (1996) Czaja, Hammond, Blascovich, & Swede (1989) Fisk, McGee, & Giambra (1988) Fisk, Rogers, & Giambra (1990) Freudenthal (2001) Mead & Fisk (1998)
Older adults completed fewer tasks than younger adults	Czaja, Hammond, Blascovich, & Swede (1989) Mead, Sit, Rogers, Jamieson, & Rousseau (2000)
Older adults made more errors than younger adults	Charness, Kelley, Bosman, & Mottram (2001) Czaja, Hammond, Blascovich, & Swede (1989) Jamieson, & Rogers (2000) Mead & Fisk (1998) Mead, Sit, Rogers, Jamieson, & Rousseau (2000)
Older adults had longer learning times than younger adults	Charness, Kelley, Bosman, & Mottram (2001) Charness, Schuman, & Boritz (1992) Elias, Elias, Robbins, & Gage (1987) Hartley, Hartley, & Johnson (1984) Zandri & Charness (1989)
Older adults required more help than younger adults	Charness, Schuman, & Boritz (1992) Elias, Elias, Robbins, & Gage (1987) Hartley, Hartley, & Johnson (1984) Zandri & Charness (1989)

In short, for older adults, there is an increase in the amount of time to complete a task compared to younger adults. This results in older adults taking longer to complete tasks, completing fewer tasks, and making more errors than younger adults. In addition, older adults have longer learning times and require more help than younger adults; therefore older participants spend more time per task than younger participants. All these findings suggest that older participants are at a disadvantage compared to younger adults during skill acquisition.

Other differences in skill acquisition between older and younger adults may be an inability to engage in mental computations involving the location of objects and the spatial relationship among them. Within the context of skill acquisition, spatial ability is essential in learning a task in which the components have specific functions and the relationship among these components are the backbone of the task (Egan & Gomez, 1985). Bruce and Herman (1986) assessed the spatial memory of older and younger adults using buildings in model towns. The study presented convincing evidence that older adults have more difficulty than younger adults engaging in mental computations involving the location of objects and the spatial relationship among them. Older adults were found to be less accurate in distinguishing between buildings and building locations than younger adults. While learning computer tasks, these declines may contribute to older adults' need for longer training and poorer performance, in that, older adults may have trouble understanding the spatial structure of the system.

The age-related slowing of cognition, perception, and movement control may further explain the aforementioned differences in skill acquisition (Fisk & Fisher, 1994; Fisk, Fisher, & Rogers, 1992; Salthouse, 1993; 1996). Consequently, Park (1992) stated that when acquiring a skill, older adults have a more restricted amount of time in which appropriate actions can be successfully implemented than younger adults. As processing continues through a task, the products of early processing may no longer be available when later processing is complete. As a result, cognitive processes, perception, and movement control take longer and are more prone to errors for older adults compared to younger adults.

Age-related differences in skill acquisition increase as task complexity increases (Park, 1992) and task complexity increases as levels of depth and breadth of a system structure increase (Sanderson, 1990). Therefore, understanding the differences in performance between older and younger adults is essential to a more complete understanding of where and why the patterns of age-related differences in skill acquisition occur. Skill acquisition can be supported through training, therefore designing training materials that reflect these patterns are important to reduce the differences in performance between older and younger adults. The next section will describe some findings related to training both older and younger adults.

Age and Training

Previous research studies have been conducted to determine whether and how training might reduce age-related performance differences. The notion that practice schedules may have an effect on skill acquisition during training was explored by Jamieson and Rogers (2000). They studied the effects of practice schedules on the performance of older adults (60-80 years old) and younger adults (18-25 years old) on a computerized Automatic Teller Machine (ATM) simulator. Practice schedules were defined in terms of the presentation format of the practice trials during training. The trials were either presented in a blocked format (all items focusing on the same feature were practiced at the same time) or random format (different features practiced in different orders). Participants were trained on an ATM simulator and then tested on the same simulator during a near transfer task. A near transfer task is a task that is similar to tasks a participant has previously performed. To measure the generalizability of skills attained in training, participants then completed tasks on a novel ATM simulator (i.e., far transfer task). Accuracy was measured by correct completion four steps: selecting the correct menu item, taking their card, taking their receipt, and taking their cash. Overall, younger adults performed better than older adults. The results also indicated a benefit of random practice schedules for both younger and older adults during acquisition and transfer.

An the discussion of results, Jamieson and Rogers (2000) state that the random practice schedule initially exposed participants to all paths of the ATM structure, thereby improving their overall knowledge of the menu hierarchy. "Participants in the random practice schedule may have been able to extract the structure of the menu hierarchy and use that structure to develop a schema for the ATM task" (p. 351), although not directly measured. This research and that of Kraiger, Salas, & Cannon-Bowers (1995) support the notion that providing the framework of organization for a menu hierarchy enhances performance. In relation to the current research, the framework of organization for a menu hierarchy is synonymous with what we are defining as a system representation; therefore random practice schedules may improve the development of a system representation.

In addition to practice schedules, the method by which training materials are presented to participants may also effect skill acquisition. Mead and Fisk (1998) examined the effect of training material presentation for a computerized ATM simulator on performance. Older adults (64-80 years old) and younger adults (18-30 years old) were randomly assigned to training conditions of concept or action training. In the concept training condition participants received instructions on what to do to complete a task, but were not instructed on how to complete the task. For example participants were told “To begin a transaction, you must insert your ATM card”. In the action training condition, participants received instructions on how to do an action, but they were not told why they were doing the action. For example, participants were told, “Move the pointer over the picture of the ATM card and click the left mouse button.” Participants were measured on the percentage of correctly completed transactions, transaction time, correct path, dollar amount correct, taking the card correctly, taking the cash correctly, and taking the receipt. Performance was assessed immediately after training and one month later.

The results from Mead and Fisk (1998) demonstrated overall, that younger adults performed better than older adults. Within the sample of older adults, participants in the action training condition performed better than those in the concept training condition on number of correct transactions, transaction time, dollar amount correct, and number of times they took card, cash, and receipt. These assessment measures focused on speed and accuracy, in which the participants in the action training condition performed better. However, compared to older participants in the action training condition, those in the concept training condition performed better on measures of the correct path during menu navigation and had better retention in that skill after one month. Although not explicitly stated in Mead and Fisk (1998), the ability to navigate through menu hierarchy may be a reflection of knowledge of the system structure. Therefore, the ability to navigation efficiently through the menu hierarchy, demonstrated by the correct path measure, may indicate that participants in the concept training condition developed a more accurate system representation than participants in the action training condition. These findings suggest that developing training methods that facilitate development of a system representation may improve performance and system knowledge. The development of a system representation can be assessed by examining the user's mental model of the system structure.

Mental Models

"Mental model" is a broad term used throughout psychology. Norman (1983) defined mental models with four meanings 1) as the actual model of the target system; 2) the conceptual model of that target system; 3) the user's mental model of that target system; and 4) the scientist's conceptualization of the user's model. The model of interest to the current research study was the user's mental model, which is the mental understanding the user or operator has developed of the target system.

Mental models can also refer to the notion of knowledge representation; knowing how a system works and what to do in various situations (Moray, 1999). Therefore, a user's mental model of a system (e.g., power plant or ATM) can be referred to as knowledge representation of a system structure. This terminology was used in the current study, with the user's mental model of a knowledge representation of a system structure operationally defined as a system representation.

Previous research on the acquisition of complex skills or expertise refers to the notion of a system representation as a knowledge structure or a memory organization (Day, Winfred, & Gettman, 2001; Wyman & Randel, 1998; Zeitz & Spoehr, 1989). Zeitz and Spoehr (1989) argues that knowledge organization consists of both declarative memory, the part of long-term memory where factual information is stored, and procedural memory, the part of memory where knowledge of skills or procedures is stored. "Before efficient procedures can be formed, declarative knowledge must be organized according to level of abstraction." (p. 316). Factual information pertaining to the connections of system components and their relation to each other can be classified as declarative knowledge. In contrast, knowledge of how to perform the steps necessary to achieve specific system functions is procedural knowledge. Tulving's memory-classification scheme, arranged in a monohierarchical fashion, consists of procedural memory, which supports semantic memory, which supports episodic memory; each memory type is dependent on one below it (Tulving, 1985). Semantic memory and episodic memory are both components of declarative memory. Zeitz and Spoehr (1989) concluded that declarative and procedural knowledge together result in the development of a system representation, while procedural knowledge alone does not.

Procedural and Declarative Distinction

The action and concept training investigated in Mead and Fisk (1998) is grounded in the theoretical concept of procedural and declarative knowledge. Action training presents task information in a sequence of "how to" steps or procedures. These procedures are specific goals and subgoals necessary to complete the given task, therefore instilling procedural knowledge. However, concept training presents factual task information at each system state, which is analogous to declarative knowledge. Training presented in declarative form consists of general facts that do not directly translate into procedures. These instructions must be interpreted into productions. Both training methods have their advantages where action training is less error prone and faster but concept training is more flexible. Anderson's Adaptive Control of Thought (ACT*), Information Processing theory (Shiffrin and Schneider, 1977), and the Subgoal Learning Model (Catrambone, 1998) can be used to understand the difference between procedural and declarative knowledge and how the development of training can utilize these differences to improve task performance (Anderson, 1983).

Anderson's general ACT* framework consists of three memories: working, declarative, and production (Anderson, 1983). Working memory refers to permanent or temporary declarative memory that is in an active state. Information from the outside world is first encoded in working memory (i.e., encoding processes) and at that point is currently accessible. Working memory also consists of information retrieved from long-term declarative memory as well as temporary structures deposited by encoding processes and the action of productions. The progression of information into declarative memory involves two processes: storage and retrieval. In the storage process, permanent records of information can be created in declarative memory and the strength of existing records can be increased. The retrieval process obtains the records of information from declarative memory. The progression of information into production memory also involves two processes: match and execution. The match process involves taking information from working memory and matching them with conditions of productions. The execution process then deposits the actions of the matched productions into working memory where the actions become behaviors. This production process is also referred to as production application because new productions are learned from existing productions (i.e., learning by doing).

Although minimally described in the previous section, the ACT* model is complex and can be used to understand skill acquisition. When the encoding processes deposit information in working memory, it is active declarative knowledge that is either permanent or temporary. Permanent information has cognitive units in declarative memory, however temporary structures do not. Information in declarative memory is stored as declarative facts and when the information in working memory is presented as declarative facts the processes of storage and retrieval begins to strengthen the cognitive units in declarative memory. During this process, information is stored in the declarative network, which contains an interconnected set of facts in the form of propositions, visual images, and the order of events. Information interpreted in declarative form is more flexible, but the process is slower and involves more working-memory space. Increasing working memory demands results in more errors and longer processing time. The shift from the declarative stage to the procedural stage occurs next and is known as knowledge compilation, which has two sub processes, proceduralization and composition. Once the facts have been interpreted in working memory, proceduralization begins with the production memory process matching the facts to conditions of productions. Composition condenses these produced facts into a single production, which makes them faster to process. The execution process deposits the actions of the matched productions into working memory where they become actions.

The ACT* model can be applied to the development and design of training materials, which will be explored in the current study. Information presented by training that focuses on facts, or concepts, is encoded, stored and retrieved from declarative memory. Once the information is retrieved from declarative memory, working memory continuously interprets the information to convert it into a production. This involves an increased amount of cognitive processing on behalf of the trainee because the training instructions are maintained internally. Internal maintenance results in a lower level of activation which slows pattern matching (Anderson, 1989). Therefore, individuals who are trained in this manner may take longer to complete the task and make more errors during training. However, slower, more effortful processing of information may allow these individuals to develop a better system representation.

Information presented during training that focuses on procedures, or actions, is encoded through the declarative processing stage, but the time needed to interpret facts and working memory load is decreased. Anderson (1982) stated that a speedup in performing procedures may be due to the individual no longer bringing a declarative representation of the task into working memory, therefore increasing speed and reducing working memory load. Therefore, knowledge compilation and production processing occurs more rapidly which allows the task information to be applied quickly and accurately. In addition, Anderson (1989) stated that continuously visible productions are maintained at a high level of activation unless the information has to be maintained internally. Individuals presented information as procedures do not have to maintain the information internally because the step by step instructions are visually interpreted. However, the information presented as declarative facts has to be maintained internally in the individual's working memory because the information is not yet actions of productions. This internal maintenance of declarative facts in working memory may increase working memory demands resulting in longer processing times and more errors. Also, higher levels of activation result in faster pattern matching. Therefore, individuals trained with productions (i.e., action training) may be faster at completing the task and may make fewer errors, but at the cost of not performing more involved processing, which may be necessary for the development of a system representation.

The strengthening of cognitive nodes, as stated in Anderson (1983), is further supported by Shiffrin and Schneider's framework for information processing (Shiffrin & Schneider, 1977). They described memory as a "large and permanent collection of nodes, which become complexly and increasingly interassociated and interrelated through learning" (p. 155). Similar to the associative net, Shiffrin and Schneider's information processing theory includes both short-term and long-term stores. Nodes within learned sequences of information processing are located in permanent long-term store (LTS). They are in an inactive state until initiated by a control process, environmental input, or an internal information input by nodes in the temporary short-term store (STS). The strengthening of cognitive nodes that occurs during the proceduralization stage of ACT* may also be increasing the number of nodes in the learned sequence of information processing. Therefore, individuals trained with declarative knowledge (i.e., concept training) may develop more cognitive nodes than those trained with productions (i.e., action training). This increase in cognitive nodes may increase the number of possible pathways to retrieve the sequence of steps that accurately executes procedure after training, resulting is higher accuracy and faster task completion times.

Catrambone's Subgoal Learning Model may also help explain the performance benefits of concept training (Catrambone, 1998). This model suggests that the organization of one's problem-solving knowledge, in some way, ties the steps to a meaningful hierarchical structure may be helpful in improving performance. A hierarchical structure that consists of a "higher level of conceptual aspects of the solution procedure form the skeleton of the solution approach" (p. 356). "Learners who form a hierarchical representation are typically able to solve novel problems more successfully than learners who are led to form a step by step organization of the problem-solving procedure" (p. 356). Participants in the concept training condition were presented the hierarchical structure during training where as participants in the action training condition were presented a step by step organization. As a result, the Subgoal Learning Model predicts increased accuracy and task completion time by participants in the concept training condition on novel tasks which is due to their increased knowledge of the system structure.

Present Study Rationale

The current study was aimed at answering questions pertaining to the development of system representation, age-related differences in skill acquisition, and the effect of training on learning. The results of Mead and Fisk (1998) indicated that older participants who received concept training performed better at tasks measuring the use of the correct paths during menu navigation compared to older participants trained with the action instructions. This suggests that participants in concept training may have developed a more accurate system representation than participants in action training, therefore improving menu navigation. However, system representation was not directly measured in the Mead and Fisk study. The current study was designed to measure the development of a system representation, and to investigate the age-related differences in skill acquisition and more specifically, the influence of proper training on reducing these age-related differences. Finally, the current study was interested in impact of training on learning. Some types of training may yield better system representations than other types of training.

There were two questions to be answered by the current study: What is the differential effect of training that emphasizes learning facts (i.e., concepts) verses training that emphasizes learning procedures (i.e., actions) on learning to use a complex system and developing an adequate system representation? Do these effects differ with age?

To investigate learning to use a complex system and developing a system representation, a computer simulated Hydroponic Garden Control (HGC) was designed to emulate a complex system. The HGC was structured with a number of variables and states that the user must take into account to produce a result. Sanderson (1990) identified a complex structure by the number of variables and states the user must take into account to produce a result. The more variables and states needed to produce a result, the more complex the system. A complex structure also included problems or tasks that incorporate multiple variables or states that require the human to integrate them to understand the whole structure. In an effort to reduce the effect of previous experience, the HGC was a fabricated complex system. Although hydroponic gardening does exist, results from pilot data suggest that participants have not encountered similar systems before. Therefore, the novelty, complexity, and unique nature of the HGC made it an appropriate system for answering the previously stated research questions.

The present study was in part a replication of Mead and Fisk (1998), and also incorporated some important findings of Jamieson and Rogers (2000). Based on the results of Jamieson and Rogers in which a random practice schedule yielded better performance than a blocked practice schedule, participants in both sets of training in the present study received a random practice schedule. The questions remaining from Mead and Fisk (1998) lead to investigating the effects of training on learning and the development of a system representation.

By definition, a system representation is not directly observable. However, this representation is assumed to contain the user's understanding of the causal structure of the system they operate. While the user operates the system, the investigator can then observe the sequence of responses made by the user which reflects the structure of the system representation (Moray, 1999). However, Sanderson (1990) and Zeitz and Spoehr (1989) investigated system representation through examining participants' responses to system failures or abnormal event scenarios. Zeitz and Spoehr (1989) concluded that knowledge organization of a system structure improved performance on troubleshooting tasks. Therefore, it may be possible to assess system representation through the observation of task procedures and performance with system failures.

Subgoal learning research suggests that learners form a type of system representation (Catrambone, 1998). Subgoals represent the task structure to be learned and are a set of steps under a meaningful task or purpose (Catrambone, 1995). Catrambone (1998) stated that "a subgoal represents a meaningful conceptual piece of an overall solution procedure" (p. 357). This explanation of a subgoal is similar to the instructions in the concept training condition. In the concept training condition, participants were given meaningful subgoals to accomplish a system goal. However, in the action training condition, instructions were presented as step by step actions needed to accomplish the subgoals. When trained with subgoals, a learner can then solve novel problems of a similar domain because they usually share the same subgoals. Now that the learner's representation contains subgoals he/she has some direction about what prior knowledge might be necessary for accomplishing a system procedure. However, a learner trained with a series of steps (i.e., action training) is less likely to identify what prior knowledge is necessary for accomplishing a system procedure. Therefore, individuals trained with productions (i.e., action training) may be less accurate than individuals trained with declarative knowledge (i.e., concept training) when performing novel tasks.

To explore the notion of system representation, the current study included multiple measures of learning through performance on familiar tasks, performance on unfamiliar tasks, and the ability to combine system subgoals, to troubleshoot system failures, and to remember the layout of the system.

Overview of Experiment

Figure 1 presents the overview of the experimental procedure used in the current study. Half of the participants in each age group received action training and half received concept training in a random practice schedule. Participants began with abilities testing and mouse training. They then began the training phase of either action or concept training after which, participants moved into the assessment phase of the experiment. System performance was assessed using performance on tasks participants received during training and tasks they were not trained on, the ability to incorporate system subgoals, the ability to troubleshoot, and memory for system surface features.

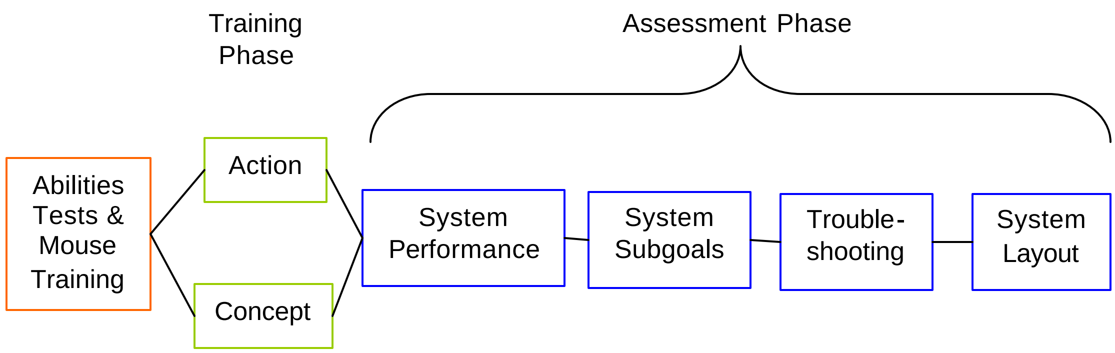


Figure 1. Illustration of the experimental procedure used in the current study.

Hypothesis: Performance during Training - Training Condition Differences

When information is presented in declarative form it is continuously stored and retrieved, which creates and strengthens cognitive units. However, this information has to be maintained internally, causing an increase in working memory demand to interpret the declarative knowledge into actions and procedures (Anderson, 1989; Catrambone, 1998; Shiffrin & Schneider, 1997). Concept trainees may be slower and more prone to errors compared to action trainees during training (Anderson, 1983; Mead & Fisk, 1998). Participants in action training condition were expected to complete the training faster, with fewer errors and navigate the through the system with fewer steps (i.e., navigational efficiency) than those in the concept training condition (see Table 2).

Table 2. *Hypotheses: Training Condition Differences*

Dependent Variable	During Training	At Test: Trained	At Test: Untrained
Accuracy	Action better	No Difference	Concept better
Speed	Action better	No Difference	Concept better
Navigational Efficiency	Action better	No Difference	Concept better

Hypothesis: Performance during Training - Age Group Differences

As demonstrated in previous aging research, younger adults should maintain a performance advantage over older adults (see Table 1). Specifically, younger adults were expected to complete tasks faster due to their ability to perform faster choice and simple reaction times (Cerella, 1985), with greater accuracy because they were not as restricted as older adults when processing information (Park, 1992), and with greater navigational efficiency because younger adults may have a better understanding of the system structure than older adults (Mead & Fisk, 1998).

Hypothesis: Performance during Training - Age x Training Interaction

Previous research as indicated that during training, action training results in higher accuracy and fast task completion times compared to concept training (Mead & Fisk, 1998). This benefit of action training may be explained by Anderson's ACT* theory, where the speedup in performing procedures (e.g., action training) may be due to the individual no longer bringing a declarative representation of the task into working memory, therefore increasing speed and reducing working memory load (Anderson, 1982). Therefore, knowledge compilation and production processing occurs more rapidly which allows the task information to be applied quickly and accurately. In addition to ACT*, Shiffrin and Schneider's Information Processing theory may also provide support for the benefits of action training during training due to the presentation of the exact procedures (Shiffrin & Schneider, 1977). The exact procedures provided in action training form specific cognitive pathways with fewer cognitive nodes than in concept training. This may result in higher accuracy and shorter task completion times for participants in the action training condition compared to those in the concept training condition. Because working memory deficits occur for older adults, a reduction in working memory load may increase performance of speed and accuracy measures for older adults. As a result, the difference between older and younger adults may be smaller for the action training condition compared to the performance of the concept training condition (see Table 3).

Table 3. *Hypotheses: Age x Training Interaction*

Dependent Variable	During Training	At Test: Trained	At Test: Untrained
Accuracy	Action reduces age differences	No interaction	Concept reduces age differences
Speed	Action reduces age differences	No interaction	Concept reduces age differences
Navigational Efficiency	Action reduces age differences	No interaction	Concept reduces age differences

Hypothesis: Performance at Test - Training Condition Differences

Performance at test consisted of four assessment tools: system performance, system sub-goals, troubleshooting, and system layout. The system performance, system sub-goals, and troubleshooting tools each contained tasks divided into trained and untrained tasks. Because participants were exposed to all screens in the system, the system layout tool was not divided into trained or untrained components and was therefore measured as an entire task. Each of these tools contained an accuracy measure.

The system performance task and the system sub-goals tasks contained additional measures of task time and navigational efficiency.

Trained Tasks. Trained tasks received at test consisted of tasks participants received during training. Because participants in the action training condition may perform the tasks faster and more accurate during training (Anderson, 1982; Mead & Fisk, 1998, Shiffrin & Schneider, 1977), they may also perform with greater accuracy and speed at test compared to participants in the concept training condition. However, participants in the concept training condition may perform with greater accuracy and speed at test because the increase on working memory demands resulted in a deeper level of processing, the development of hierarchical levels, and an increase in the number of cognitive nodes compared to participants in the action training condition (Anderson, 1982; Catrambone, 1998; Shiffrin & Schneider, 1977). Because participants in both training conditions were exposed to the trained tasks, and there may be benefits of training for both training conditions, accuracy, the time to complete those tasks, and navigational efficiency were not expected to be significantly different (see Table 2).

Untrained Tasks. Untrained tasks received at test consisted of tasks participants did not receive during training and did not perform previously. Participants in the concept training condition may have better performance on untrained tasks compared to participants in the action training condition due to the process involved when storing declarative facts in memory. This process is described in detail an earlier section on the procedural/declarative distinction. The strengthening of cognitive units and the internal maintenance of information (Anderson, 1983, 1989), along with the increase in cognitive nodes (Shiffrin & Schneider, 1997) and the development of hierarchical levels

(Catrambone, 1998) may result in the concept trainees performing better on untrained tasks because the slower more effortful process of information and the flexibility of declarative knowledge may allow these individuals to develop a better system representation. Concept trainees may also perform better on untrained tasks because concept training instructions provided meaningful subgoals to accomplish major system goals. As a result, concept trainees may be able to generalize the trained meaningful subgoals to untrained tasks more effectively than action trainees (Catrambone, 1995, 1998). Therefore, on untrained tasks, participants in the concept training condition should perform the tasks faster, with greater accuracy, and with more navigational efficiency than participants in the action training condition (see Table 2).

System Layout Task. The strengthening of cognitive units, the internal maintenance of information, and the use of subgoals may aid concept trainees in developing a better system representation (Anderson, 1982, 1983, 1989; Catrambone, 1995, 1998). Supporting this notion, Zeitz and Spoehr (1989) concluded that participants who receive instructions that focus on declarative knowledge develop a better understanding of the system structure than participants who receive instructions that focus on procedural knowledge. Having a better understanding of the system structure may aid in remembering or identifying the layout of the system. Therefore, training group differences were expected to occur such that concept trainees would perform with greater accuracy on labeling system layout features than the action trainees.

Hypotheses: Performance at Test - Age Group Differences

In addition to previous statements on aging differences, computer usage questionnaires administered in previous research indicate that younger adults have an experience advantage over older adults in that they have more experience with using computers and use computers more regularly than older adults (Mead & Fisk, 1998). Based on ACT* and the Information Processing theory, cognitive units are made stronger (Anderson, 1983) and the number of cognitive nodes increase (Shiffrin & Schneider, 1977) when new information adds to existing information. Therefore, if younger adults have more experience (i.e., existing information) about computers than older adults, they may have a greater number of existing cognitive nodes and units to be made stronger with the storage of new information. This strengthening of cognitive units may account for the development of an adequate system representation. Therefore, younger adults may have a better system representation than older adults, resulting in better performance at test than older adults.

Hypotheses: Performance at Test - Age x Training Interaction

It has been suggested that participants who receive instructions that focus on declarative knowledge develop a better understanding of the system structure than participants who receive instructions that focus on procedural knowledge (Zeitz & Spoehr, 1989). Also, when examining the effects of age on system learning, Mead & Fisk (1998) found that older adults in a concept training condition navigated the system structure better than those in the action training condition. This finding may be an indication that for older adults, concept training facilitates the development a better system representation than action training. Therefore, there was an expected Age x Training group interaction for measures assessing system representation. Older participants in concept training should produce higher scores on the identification of system layout features, troubleshooting system failures, incorporating system subgoals and take fewer navigation steps for both trained tasks and untrained tasks than older participants in action training. Because previous research did not directly assess system representation it is conceivable that the measures used in the current study will show similar benefits for younger and older adults. Therefore, younger adult concept trainees may perform better than younger adult action trainees for measures assessing system representation (see Table 3).

CHAPTER 2

METHOD

Participants

The younger adults were 32 undergraduates attending Georgia Institute of Technology, ranging in age from 18 to 29 years of age (SD = 1.8). The older adults were 32 residents of Metro Atlanta contacted through a independent living facility and a community center, ranging in age from 65 to 79 years of age (SD = 4.2). Older adults received $100 for their participation lasting approximately 10 hours. Younger adults received course credit, monetary compensation, or a combination of the two for their participation. All participants were screened to eliminate participants who participated in previous studies involving a simulator similar to the Hydroponic Garden Control.

The current study was conducted through the Center for Research and Education on Aging and Technology Enhancement (CREATE). Participants in this study completed several questionnaires and ability tests (Czaja, Sharit, Charness, Fisk, & Rogers, 2001). Participants were pre-screened via the telephone then mailed a home questionnaire. These measures included demographic and health questionnaires and technology and computer experience questionnaires (see Appendix A). The demographic and health/medication questionnaires consist of items pertaining to age, gender, education, income, and health/medication issues. The technology and computer experience questionnaires consists of items relating to daily computer use and device familiarity.

Participants also completed a 6-hour battery of ability measures in a 5-hour group-testing environment and a 1-hour individual testing environment. The ability measures assessed semantic knowledge, associative memory, perceptual speed, working memory, reading comprehension and rate, induction, short and long-term memory, spatial ability, inferencing ability, emotional state, and depressive state (see Appendix B). In addition to those measures, both near and far visual acuity were assessed using a Snellen eye chart, with the criterion set at 20/40 (corrected or uncorrected). Hearing was also assessed using an audiometer, there was no criterion set, all participants were able to hear conversation between themselves and the experimenter with or without the assistance of a hearing device. A portion of the abilities measures collected are reported in Table 4. There was no difference in demographic data or ability between the training conditions for the older adults. The only difference for the younger adults was in the Reverse Digit Span, where participants in the concept training condition recalled more numbers than those in action training condition.

Table 4. *Ability Test Data and Demographic Information*

	Action		Concept		
Younger Adults	*M*	SD	*M*	SD	*t*-value*
Males/Females	10M / 6F	-----	11M / 5F	-----	-----
Age	20.06	2.17	19.19	1.22	1.40
Education [a]γ	2.56	0.51	2.63	0.50	-0.35
Health [b]γ	4.06	0.93	3.63	1.20	1.15
Digit Symbol Substitution [c]γ	68.69	13.57	70.63	12.98	-0.41
Reverse Digit Span [d]γ	8.00	2.37	9.94	1.98	-2.51*
Vocabulary [e]	30.88	4.21	32.06	3.26	-0.89
Simple Reaction Time [f]γ	286.13	32.22	286.63	36.70	-0.04
Choice Reaction Time [g]γ	322.88	35.95	317.38	42.23	0.40
Near Vision [h]γ	20.31	1.25	20.31	1.25	0.00
Far Vision [h]γ	23.44	8.70	20.63	1.71	1.27
Older Adults	*M*	SD	*M*	SD	*t*-value*
Males/Females	3M / 13F	-----	6M / 10F	-----	-----
Age	71.13	4.46	72.38	4.03	-0.83
Education [a]	3.40	1.24	3.31	1.35	0.19
Health [b]	3.33	0.90	3.31	0.70	0.07
Digit Symbol Substitution [c]	46.27	13.18	43.06	9.30	0.79
Reverse Digit Span [d]	6.60	2.13	7.13	2.03	-0.70
Vocabulary [e]	31.13	7.81	33.56	4.75	-1.05
Simple Reaction Time [f]	388.33	90.18	451.50	113.98	-1.70
Choice Reaction Time [g]	456.07	85.19	498.13	89.11	-1.34
Near Vision [h]	22.67	2.58	24.06	5.23	-0.93
Far Vision [h]	26.00	6.87	25.63	7.93	0.14

Note: *p<.05, [a] Range: 1 = less than high school, 2=High School, 3=some college, 4=Bachelor's degree; [b]Self-rating: 1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent; [c] Perceptual Speed (Wechsler, 1997); [d] Memory Span (Wechsler, 1997); [e]Vocabulary (Shipley, 1986); [f]Simple RT: time to press one key, in ms (locally developed); [g]Choice RT: time to select respond to one of two keys, in ms (locally developed); [h]The distance from which a person with normal eyesight can read the same line on the eye chart, 20 = normal; γ represents difference found between younger and older adults.

Materials

Hydroponic Garden Control. A computer simulated Hydroponic Garden Control (HGC) was designed as a training apparatus with a complex menu structure. Hydroponic gardening is gardening without soil. These types of gardens use nutrient enriched water based medium, which flows under the roots of the plants in reservoirs causing them to grow quicker and larger.

By design, the system's main screens were seeds, medium, and climate and the sub-screens were advance growth controls, settings, and message history. Each main screen was designed with three primary functions that were necessary for proper system operation. The seeds screen's primary functions were to plant a seed, adjust the amount, and view the seed information, shown below in Figure 2.

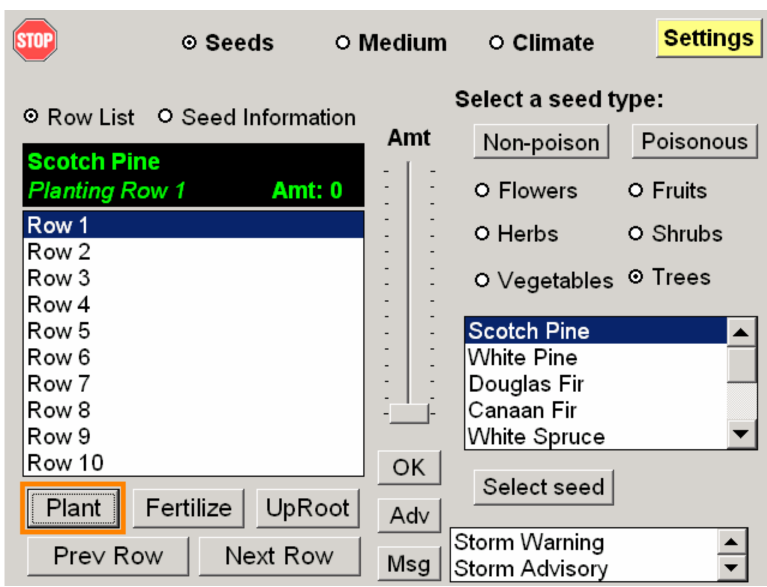


Figure 2. Illustration of the screen of the HGC once the Seed tool and Seed Type option has been selected.

The medium screen's primary functions were to adjust the gel medium, adjust the liquid medium, and adjust the amount, which are visible below in Figure 3.

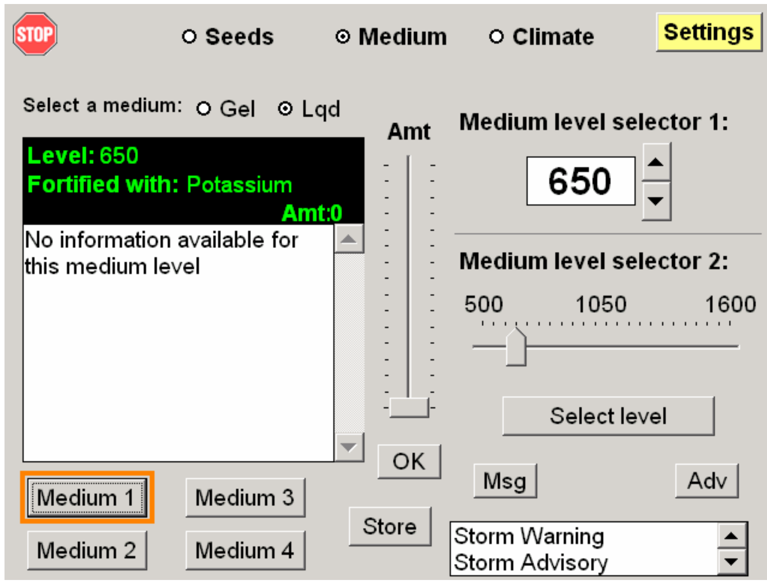


Figure 3. Illustration of the screen of the HGC once the Medium tool has been selected.

The climate screen's primary functions were to set the climate months, set the altitude, and set both the climate and altitude simultaneously, shown in Figure 4.

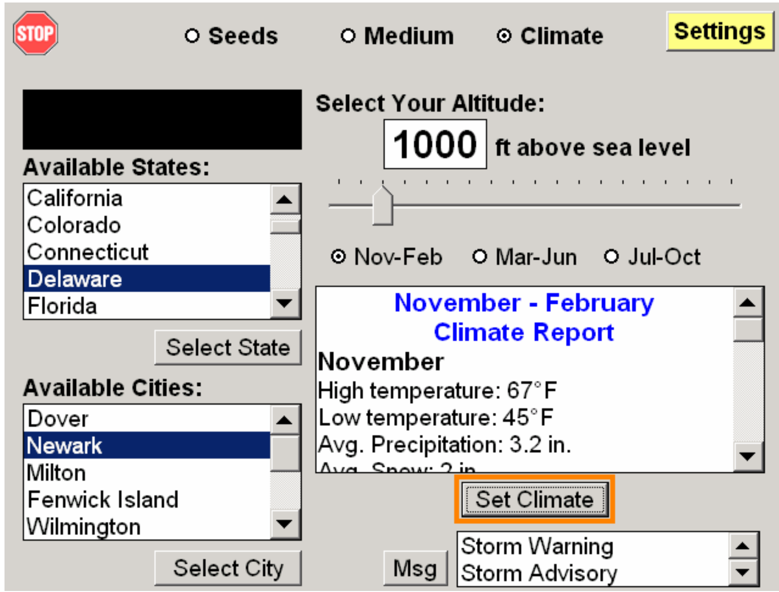


Figure 4. Illustration of the screen of the HGC once the Climate option has been selected.

In addition to functions of the three main screens, the HGC had three secondary screens that contained the advanced controls (i.e., calcium levels), the settings (i.e., set alarm), and the message histories (i.e., loss of power). By design, the sub-screens had supplemental functions that were not necessary for proper system operation, but enhanced system operation. The advance growth control screen was accessible from the medium and seeds screens and consisted of functions that improved the growth of the plants. The message history screen was accessible from all main screens and displayed details and the date of the occurrence for messages that the system had previously displayed. The settings screen was accessible from all main screens and consisted of systems functions operating with time and/or date properties. Because there were no primary functions in sub-screens, these tasks were selected from each sub-screen based position of the control.

Task Environment. During the study, the HGC was displayed on a 15" laptop monitor to the right of a presentation notebook, which displayed the directions for each task on 8 ½ x 11" paper in Times New Roman, font size 24. An external computer mouse was used in this study and a hand pointer with an extended index finger was used as a point and click aid in the navigation of the device. This task environment is shown below in Figure 5.

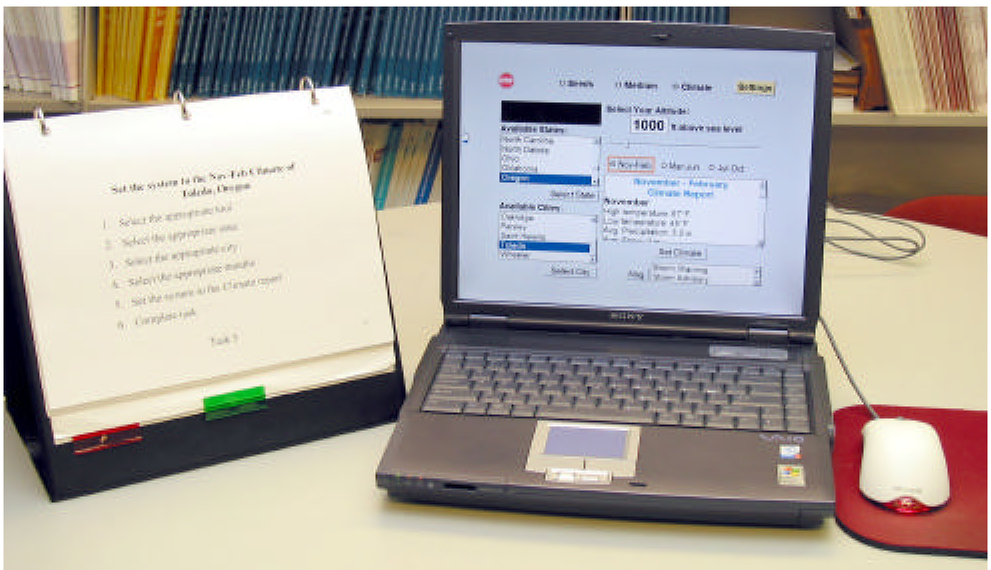


Figure 5. Picture of the physical setting of the laptop and presentation notebook used during the study.

Mouse and Control Training. A task analysis of the general process and skills needed to complete task objective and pilot testing identified that basic computer skills (mouse skills, button/slider activation) were necessary to perform tasks of the HGC. The mouse training apparatus was a Microsoft Visual Basic 6.0 © program that recorded task time and accuracy. The purpose of mouse and control training was to establish a base level of knowledge of operating controls that were used in the HGC in addition to increasing familiarity with primary functions of mouse usage, such as following/moving the pointer and clicking the left mouse button. Figure 6 shows a control in the HGC and how that control was represented during mouse and control training.

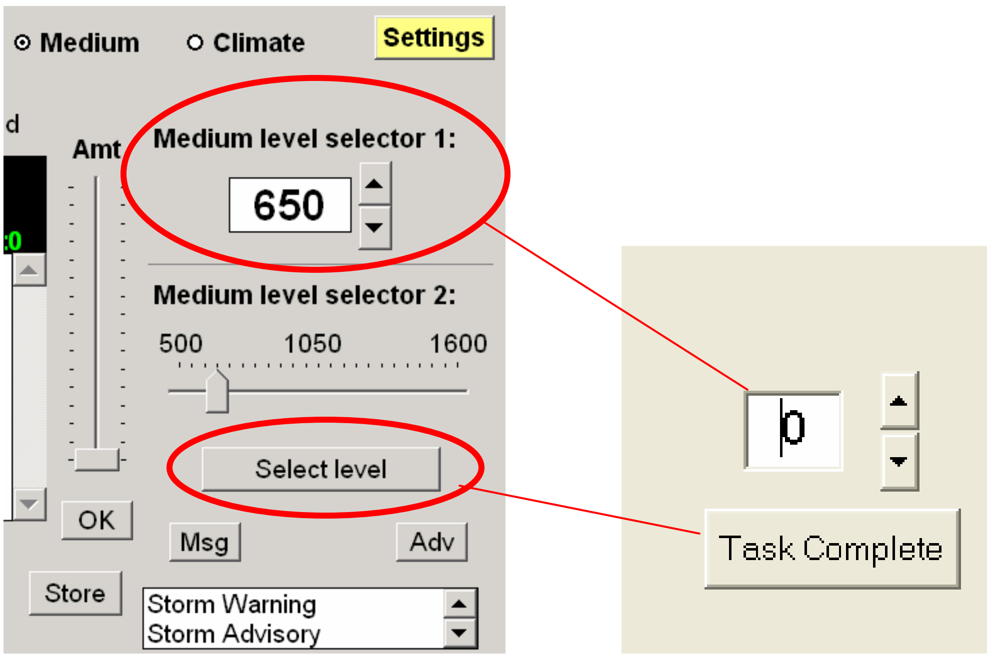


Figure 6. Image of a screen HGC control (left) and a similar control used during mouse and control training (right).

Mouse and control training also served as a technique to reduce individual differences because older participants reported different levels of computer experience.

The training program consisted of nine controls that were used in the HGC. Eight of the nine were each paired with a "Task Complete" button, which resulted in a total of nine controls. During training, a word or number was presented in the middle of the screen. Participants then selected that word or number in the control to complete the task successfully. Only one control pair was displayed at a time, so that participants did not have to decide what control to use, but were trained on how to use the control. The controls were positioned around the screen in one of eight places and were presented in the same place each time they were presented. The position of the control and the order of presentation were randomized and each participant then received the same order of presentation.

Mouse and Control training was divided into two sessions because the study occurred over two days. The first session of mouse and control training consisted of at least 10 blocks of the eight controls. Because the controls were all paired with a "Task Complete" button, participants completed at least 160 control activations. Successful mouse and control training was determined by a 90% accuracy criterion. This criterion was determined to ensure the successful activation of every type of control at least once. A criterion set any lower could result in a participant not successfully activating one type of control, but still successfully completing mouse and control training. If a participant did not meet the 90% accuracy criteria this process was repeated again. Participants were given three attempts to complete mouse and control training with a minimum 90% accuracy. Participants who did not successfully complete mouse and control training were not called back for the Day 2 session. One participant from the older adult action training condition did not reach criterion in the first session.

The second session of mouse and control training occurred at the beginning of the Day 2 session. This was a refresher mouse and control training session that consisted of at least five blocks of eight controls, which had at least 80 activations. Successful mouse and control training was determined again by a 90% criterion. If a participant did not reach the criterion during refresher mouse and control training, the participant was unaware that he or she did not successfully complete the refresher session and was then informed that the study was over and was paid the full compensation amount for completing the study. One older adult participant from the concept training condition did not reach criterion in the second session.

Development of Training Programs

Two computerized training tutorials were designed to present the structure of the Hydroponic Garden Control. Based on suggestions from previous research, a system analysis was performed for the simulator to understand the structural design of the system (Mead & Fisk, 1998; Moray, 1999) (see Appendix C for complete system analysis). From the system analysis, a task decomposition was performed for each task to identify the subtasks and the order in which they must be performed for the task to be accomplished on the HGC. Table 5 gives several examples of task decompositions performed. Both training programs were then developed from the decomposed tasks.

Table 5. *Examples of Task Decompositions Used to Develop Training*

Task	Subtasks
To plant a non-poisonous seed of roses	Seed > Non-poisonous > Flower > Rose > Select Seed > Plant
To adjust the Seed Amount	Seed > Amt vertical slider > OK button Medium > Amt vertical slider > OK button
To set the current date to March 9, 2004	Settings > (Month) March > (Day) 9 > (Year) 2004
To set the current time to 1:45 PM on the 12 hr clock	Settings > 12-hour > (Hour) 1 >(Minutes) 45 > (AM/PM) PM
To set the Alarm Clock to 2:45pm with a audio alert, weekly	Settings > (Under Current time) 12-hour > (Under Alarm Clock) (Hour) 2 > (Minutes) 45> (AM/PM) PM > Audio Alert > Weekly

System training was designed to train participants on the primary operational functions of the system established in the task decompositions. The system consisted of three main screens and three sub-screens. Through the training trials, participants were exposed to all six screens of the HGC; however they were not trained to operate all functions of each screen.

During training, participants received 35 tasks that exposed them to each screen of the system. To give participants the opportunity to successfully complete that type of task, the training included three tasks for each of the three primary functions resulting in nine tasks per main screen. The number of training tasks from the three sub-screens was determined by the number of main screens they were accessible from. For example, the advanced growth screen is only accessible from the Seeds screen and the Medium screen; therefore, there were two tasks from the advance growth screen. From the remaining sub-screens, there were three tasks from the message history screen and three from the settings screen.

After selecting the 35 training tasks, the task presentation order was distributed in a random presentation across the six screens, such that tasks from the same screen were intermingled with tasks from the other five screens (Jamieson & Rogers, 2000). An initial presentation order was first randomized then checked against the following decision rule: two tasks of the same screen type could not be in subsequent trials. This procedure was followed twice to develop two presentation orders. Half of the participants received presentation order 1 and half received presentation order 2. This process was completed to check on whether the order of training affected performance, which helped control for extraneous variables and allowed the exclusion of the alternative hypothesis that type of training, not training presentation, affected performance.

Action Training. The general process to complete a specific task was identified in the task decomposition (see Table 5). Action training instructions included minimum step-by-step directions to operate the Hydroponic Garden Control, but did not give information on what was to be completed in each step. Shown in Table 6, action training instructions only emphasized procedural information for the current system state and task, therefore provided minimal conceptual information. During training, participants were given the goal and instructions on exactly what button to select; they were required to only follow the steps to complete the task. To complete the task, participants had to read the problem statement to identify the appropriate tool, identify the value, and change the value. In action training participants were given the exact button selections needed to complete the task.

Concept Training. Just as in action training, the general process to complete a specific task was identified in the task decomposition (see Table 5). Concepts are defined as an abstract or generic ideas generalized from particular instances, they are task-independent procedures. Concept training instructions consisted of generalized directions necessary to complete a task used in the Hydroponic Garden Control. Participants were given instructions on what to do to complete a task but not how to complete a task, the precise function selection was not provided. Shown in Table 6, concept training instructions only emphasized general system information, therefore provided minimal procedural (i.e. step-by-step) information. During training, participants were given the goal and general instructions on what is being performed during each step. They were required to extrapolate the exact button presses from the goal based on the given general instructions to complete the task. Just as with action training, to complete the task, participants had to read the problem statement to identify the appropriate tool, identify the value, and change the value. However, in concept training participants were given the generalized hierarchical labels, identified through a system analysis, needed to complete the task.

Table 6. *Example of One Task Illustrating Action and Concept Training*

Task: Plant a Sunflower flower seed	
Action Training	Concept Training
Click ‘Seeds’	Select the appropriate tool
Click ‘Non-poison’	Select the appropriate seed type
Click ‘Flowers’	Select the appropriate seed category
Click ‘Sunflower’	Choose the appropriate seed
Click ‘Select seed’	Select the appropriate seed
Click ‘Plant’	Plant the Seed
Click ‘Stop’ sign	Complete task

Development of Assessment Tools

System Performance Measure. The System Performance measure consisted of 17 trained and 17 untrained tasks. During training, participants were given the task and the steps to complete the task. Shown below in Figure 7, during the system performance measure, participants were given the task but not the steps to accomplish the task.

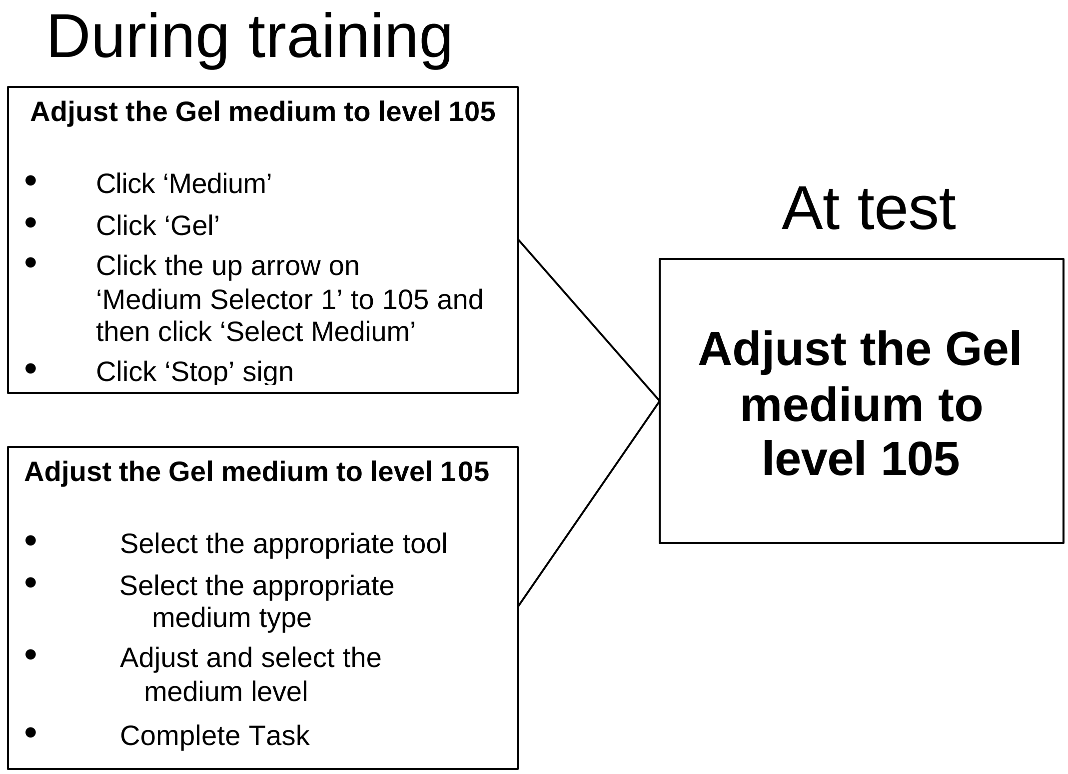


Figure 7. Diagram illustrating the difference between tasks during training and those during the system performance measure.

In general, the system performance measure was designed to assess participants' ability to perform system functions of both trained and untrained tasks. The trained tasks were chosen to assess participants' ability to perform the three primary functions of each of the three main screens and the supplemental functions of the sub-screens. These tasks were identical to those used during training. Trained tasks are analogous to near transfer tasks because participants performed these tasks during training with the steps provided, however at test, the steps were not available. From each of the three primary functions of the three main screens one trained tasks was randomly selected from each, resulting in nine trained tasks. Because there were fewer training tasks from the sub-screens compared to the main screen, the same tasks that participants performed during training were used during performance assessment; therefore no random selection was necessary. The untrained tasks were chosen to assess participants' ability to perform secondary functions of the main screens and supplemental functions not trained on in the sub-screens. Shown in Figure 8, the untrained tasks were of similar difficulty to the trained tasks because they were from the same screens and had equal number of steps. Untrained tasks are analogous to medium transfer tasks because participants were exposed to the screen during training, but were not specifically presented the task to complete during training.

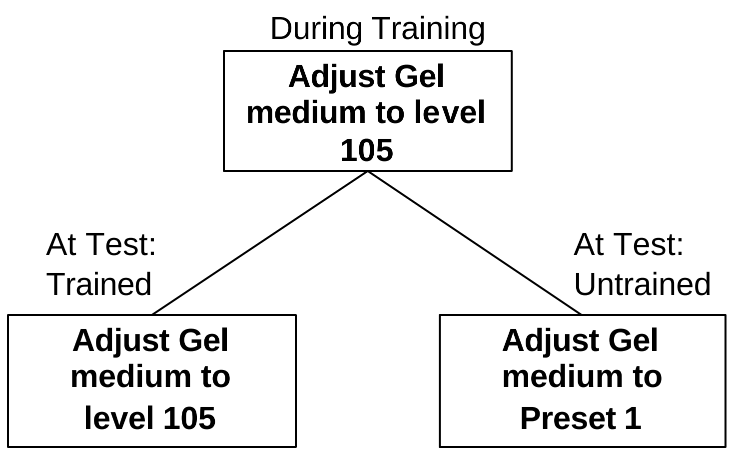


Figure 8. Diagram illustrating the difference between tasks shown at training and those shown at test

The untrained tasks in the main screen consisted of one of each of the three secondary functions. From the remaining tasks of each of the sub-screens, two untrained tasks were randomly selected from the advance growth control screen, three from the settings screen, and three from the message history screen.

The order of the 34 system performance tasks was determined as follows. An initial presentation order was first randomized then checked against the following decision rules: 1) no more than two trials in a row were trained or untrained; 2) tasks of the same screen type were not in subsequent trials. This procedure was followed twice to develop two presentation orders. Half of the participants who received training order 1 received assessment order 1 and half received assessment order 2; half of the participants who received training order 2 received assessment order 1 and half received assessment order

System Sub-goals Assessment. The system sub-goals measure consisted of two scenarios that illustrate the overall purpose of the HGC, shown below in Table 7. Two sub-goal tasks consisted of one trained task and one untrained task. Both tasks consisted of four sub-goals from the same screens, except the trained task consisted of sub-goals performed during training and the untrained tasks consists of sub-goals not performed during training.

Table 7. *System Subgoals Measure*

Type	Number of Subgoals	System Purpose
Trained	4	You decide to plant rose flower seeds in your greenhouse. After you plant the roses you read the back of the seed pack which stated the seed must be planted in temperatures mimicking the climate of Southport, NC, and a gel medium at level 105. The package also states you must monitor the growth rate for gel medium level 104 on February 1, 2003. Complete the steps to accomplish this task.
Untrained	4	You decide to plant thyme herb seeds in your greenhouse. After you plant the thyme you read the back of the seed pack which stated the seed must be planted in temperatures mimicking the Mar-Jun climate of Fairfax, Virginia and a gel medium at Preset 3. To ensure the setting are correct, the package states you must set daily audio alert alarm for 10 am. Complete the steps to accomplish this task.

These tasks were counterbalanced, such that half of the participants received the trained task first and half received the untrained task first.

Troubleshooting Assessment. The true/false troubleshooting measure consisted of vignettes describing an individual using the HGC incorrectly. Each vignette followed the same order of events: a description of the desired task to complete including the name of the individual using the HGC, followed by an incorrect action resulting in the task not being completed, and then concluding with a statement providing a solution. This task was completed by pencil and paper. Participants were instructed to decide if the provided solution was either true or false. Performance on the troubleshooting task was based on the percentage of correct answers.

Based on pilot testing, 12 troubleshooting tasks were chosen, consisting of six trained and six untrained tasks (two from each of the six screens), several examples are shown in Table 8. Tasks that were selected fell between 40%-60% accuracy in the pilot study for participants who had not received any training on the system. After selection, the presentation order of the 12 tasks was randomized and all participants received the same order.

Table 8. *Examples of True/False Troubleshooting Measure*

Troubleshooting measure	**Answer**	**Screen**	**Task Type**
Andrew is planting some trees native to Aspen area of Colorado, so he wants to adjust the altitude to mimic that of the area. After selecting Colorado, Andrew tries to adjust the altitude but the altitude control is "grayed out". The control is "grayed out" because he did not select the appropriate city.	TRUE	Climate	Untrained
Henry wanted to select Gel Medium level 101 but the medium selector controls were not visible. The controls were hidden because Henry did not select a Medium type.	TRUE	Medium	Trained
Adam is trying to plant a SEED but he keeps getting the message "NO Poisonous plants available!" Adam is having a problem planting a SEED because he selected the Poisonous Type instead of the Non-poisonous Type.	TRUE	Seed	Untrained

System Layout Assessment. The system layout assessment measure consisted of images of the six screens used in the HGC, but the names of the screen features were not visible. This measure followed a "fill-in-the-blank" paradigm, where participants were instructed to write in the name of the label in the space provided. The system layout measure consisted of two sections, each section had 113 blanks. The first section instructed participants to fill-in-the-blank with the correct feature name without an alphabetized word list below the image, demonstrated in Figure 9. The second section provided an alphabetized word list below the image with a 1:1 word to blank ratio and included only words from that screen image.

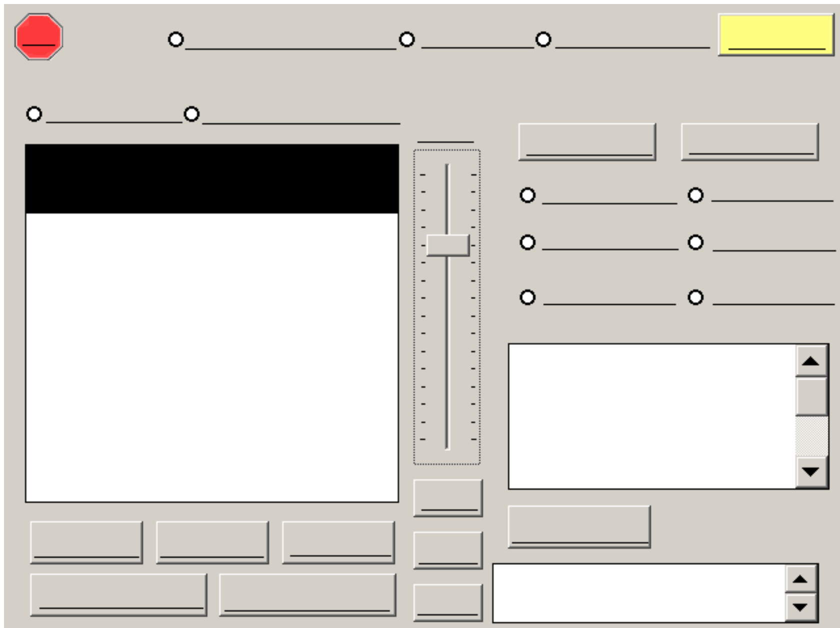


Figure 9. HGC image used in the System Layout measure.

Performance on the system layout measure was measured in two ways: stringent and lenient. In stringent scoring, a response was correct if the label name was written in the exact blank. In lenient scoring, a response was correct if the label name was located within a cluster of similar labels identified in the system analysis (see Appendix C). For example, in stringent scoring, the six seed category features must have been in the exact blank to be counted correct, but in lenient scoring the six features could have been in any of the six blanks.

The presentation order of the screen images was randomized and all participants received the same order of images. The section without the word list was always presented before the section with the word list because we wanted to examine a participant's ability to complete the screen layout from memory without the word prompts.

Procedure

The current study was performed in three sessions; the first session lasted approximately 5 hours, the second session lasted approximately 2 hours, the third session required approximately 3 hours to complete. During the first session, after understanding and signing consent forms, participants were administered the 5-hour CREATE ability tests in a group setting (see Appendix B).

In the second session participants were administered another set of CREATE ability tests (see Appendix B) including vision/hearing tests in an individual testing environment, followed by mouse training.

The third session started with a brief refresher session of mouse training. Participants were then randomly assigned to one of two training conditions, action or concept. Before beginning the training, participants received an orientation of the HCG and three practice trials.

After the training session, participants were given a 10-minute break. After reconvening, participants moved into the assessment phase of the study. The assessment phase consisted of four tasks: System Performance task, System Sub-goals task, True/False Troubleshooting task, and System Layout task. Each participant received the assessment tasks in the same order, however, within each task there were two counterbalances.

The assessment phase was followed by an exit interview and debriefing. The exit interview consisted of two parts: a structured interview and a questionnaire. The structured interview questioned participants' understanding of the tasks completed during the study. The questionnaire was focused on obtaining personal performance evaluations, improvement suggestions, and previous experience with similar systems.

Design

This experiment was a 2(age) x 2 (training method) x 2 (trial type) mixed design. The between-participant independent variable was training method (concept or action). Age group (younger or older) was a quasi-independent variable. Trial Type (trained or untrained) was a within participant variable. Dependent variables for the System Performance task set and the System Sub-goals task were percent of tasks completed correctly (Accuracy), mean time to complete each correct task (Task Time), the number of mouse clicks minus the minimal mouse clicks necessary to complete the task for each correct task (Navigational Efficiency); for the Troubleshooting task, percent of tasks completed correctly (Accuracy); and for the System Layout task, stringent and lenient scores based on percent correct.

CHAPTER 3

RESULTS

Because there were many measures of performance during training and at test, the results chapter of the current study is first separated by performance interval, during training and at test. The performance at test section is then arranged by each assessment measure. Each section is structured with a brief summary of the measure, followed by the findings and a discussion of the impact of the results of that specific measure. Within the performance during training section, ANOVAs performed were Age (younger, older) x Training condition (action, concept). Within each performance at test section, ANOVAs performed were Age (younger, older) x Training condition (action, concept) x Trial type (trained, untrained). Also, the following results are from data of 63 participants, because one older adult in the action training condition was not included in the analysis as his/her scores were more than two standard deviations from the mean.

Performance during Training

During training, participants received 35 tasks presented as either action training or concept training. These tasks contained the goal and the steps necessary for accomplishing that goal. While performing these tasks on the HGC, the computer was recording every button selection and the amount of time participants spent completing each button selection. From those data, percent of tasks completed correctly (Accuracy), mean time to complete each correct task (Task Time), and the number of mouse clicks minus the minimal mouse clicks necessary to complete the task for each correct task (Navigational Efficiency) was computed. For navigational efficiency, the closer the score is to zero the better the performance. The tasks were counterbalanced and ANOVAs were performed for each variable and found that there was no significant difference between the counterbalance groups. Means and standard deviations for performance during training are reported in Table 9.

Table 9. *Descriptive Statistics: Performance during Training*

	Action		Concept	
Age Group	*M*	*SD*	*M*	*SD*
	Accuracy (percent correct)			
Older Adults	87.81	13.20	79.46	15.62
Younger Adults	97.86	3.54	93.39	4.86
Total Sample	93.00	10.66	86.43	13.40
	Mean Task Time in seconds			
Older Adults	57.16	22.51	93.69	28.26
Younger Adults	19.68	5.45	21.33	6.14
Total Sample	37.82	24.78	57.51	41.90
	Mean Navigational Efficiency			
Older Adults	2.16	2.68	4.07	1.92
Younger Adults	1.27	.65	1.48	1.07
Total Sample	1.70	1.94	2.78	2.02

For performance during training, the ANOVA revealed a main effect of training condition, in that participants in the action training condition completed tasks more accurately, $F(1, 59) = 5.733$, $p < .05$, faster, $F(1, 59) = 18.801$, $p < .01$, and with greater navigational efficiency, $F(1, 59) = 5.860$, $p < .05$, than those receiving concept training. But, an Age (younger, older) x Training condition (action, concept) ANOVA was performed on the dependent variables (accuracy, task time, and navigational efficiency) for performance during training. There was a significant Age x Training condition interaction for task time, $F(1, 59) = 15.833$, $p < .01$ and marginally significant for navigational efficiency, $F(1, 59) = 3.706$, $p = .059$, but not for accuracy, $F(1, 59) = .526$, $p > .05$. Follow-up analysis revealed that, for task time, the difference between training conditions was significant for older adults ($p < .01$), not for younger adults ($p = .466$). A similar trend was found for navigational efficiency; the difference between training conditions was significant for older adults ($p < .01$), but not for younger adults ($p = .491$). These data represent how long it took participants to perform the training tasks, how efficient there were, and how accurate they were during training. The results from the training data support the findings of Mead and Fisk (1998) and the hypotheses that action training has training benefits of faster training times, greater accuracy, and more efficient at navigating the system during training compared to concept training.

As found in previous research, younger adults performed the training tasks with greater accuracy, $F(1, 59) = 20.087$, $p < .01$, faster task completion times, $F(1, 59) = 146.908$, $p < .01$, and greater navigational efficiency, $F(1, 59) = 15.650$, $p < .01$, than older adults. This difference between younger and older adults was reduced for participants receiving action training, for percent correct, the amount of time spent during training and the number of mouse clicks used to navigate the system (see Table 9).

Performance at Test: System Performance Measure

During the system performance measure, participants were assessed on their ability to perform system tasks without aid of step-by-step instructions. Participants received 34 tasks in which they were presented the goal, but not the steps to accomplish the goal. Seventeen tasks were tasks participants had previous experience performing (i.e., trained tasks) and 17 were novel tasks (1.e., untrained tasks). Just as during training, the computer was recording every button selection and the amount of time participants spent completing each button selection during the system performance measure. From those data, percent of tasks completed correctly (Accuracy), mean time to complete each correct task (Task Time), and the number of mouse clicks minus the minimal mouse clicks necessary to complete the task for each correct task (Navigational Efficiency) was computed. For navigational efficiency, the closer the score is to zero the better the performance.

An Age (younger, older) x Training condition (action, concept) x Trial type (trained, untrained) ANOVA was performed on the dependent variables (accuracy, task time, and navigational efficiency) for the system performance task. There was no 3-way interaction for accuracy (p = .227), task time (p = 1.04), or navigational efficiency (p = .142). Although the 3-way interactions were not significant, an age x training condition ANOVA within each trial type was performed in line with the a priori hypotheses for the dependent variables in the system performance measure. First, the results from the trained tasks ANOVA are reported, followed by the results from the untrained tasks.

Trained Tasks. The means and standard deviations for performance on the trained tasks in the system performance measure are presented below in Table 10.

Table 10. *Descriptive Statistics: System Performance, Trained Tasks*

	Action		Concept	
Age Group	*M*	*SD*	*M*	*SD*
	Accuracy (percent correct)			
Older Adults	49.41	26.94	75.00	17.38
Younger Adults	94.49	6.25	96.69	4.28
Total Sample	72.68	29.71	85.85	16.63
	Mean Time in seconds			
Older Adults	58.86	27.62	53.13	16.69
Younger Adults	18.19	5.48	13.99	3.47
Total Sample	37.87	28.24	33.56	23.15
	Mean Navigational Efficiency			
Older Adults	2.10	1.84	2.40	1.61
Younger Adults	1.56	.69	1.01	.76
Total Sample	1.82	1.38	1.70	1.43

For accuracy of the trained tasks, there was a main effect of age, $F(1, 59) = 66.530$, $p < .01$, and training condition, $F(1, 59) = 11.530$, $p < .01$, and there was a significant interaction between age and training condition, $F(1, 59) = 8.160$, $p < .05$. Follow-up analyses revealed that difference in training conditions was significant for older adults ($p = .004$), but not for younger adults ($p > .05$). The difference between the younger and older adults was smaller for participants in the concept training condition compared to those in the action training condition (see Table 10). For task completion time of trained tasks, there was also a main effect of age, $F(1, 59) = 95.457$, $p < .01$, but not training condition, $p > .05$ and the interaction was also not significant, $p > .05$. Because of the hypothesis stated earlier, follow-up analyses were performed and revealed that the differences between the training conditions were not significant for either age group ($p > .05$). For navigational efficiency of trained tasks, there was a main effect of age, $F(1, 59)$

= 8.445, $p < .01$, but not training condition, $p > .05$ and the interaction was also not significant, $p > .05$. Again, follow-up analyses were performed, they revealed that the differences between the training conditions were significant for younger adults (p = .038), but not for older adults (p > .05).

The improved performance of older adult participants for task time and navigational efficiency and younger adults for navigational efficiency in the concept training condition indicates that there may be benefits of this training method for trained tasks. This may be explained by the declarative/procedural distinction. Training materials presented in declarative form results in slow, error prone training. However, there is a trade-off at test where the increased working memory demands may have cause deeper levels of processing, which improved performance on tasks at test regardless of trial type. Also, during training concept training instructions provided participants with generalized steps to complete each task. Participants in the concept training condition were not able to rely on specific procedural instructions; therefore they may have developed a different schema for completing each task. Concept trainees may have relied on the task goal itself to guide their actions for successful completion of the task during training.

Untrained Tasks. The means and standard deviations for performance on the untrained tasks in the system performance measure are presented below in Table 11.

Table 11. *Descriptive Statistics: System Performance, Untrained Tasks*

	Action		Concept	
Age Group	*M*	*SD*	*M*	*SD*
	Accuracy (percent correct)			
Older Adults	48.24	26.23	69.49	19.71
Younger Adults	88.97	6.40	92.65	5.88
Total Sample	69.26	27.75	81.07	18.53
	Mean Time in seconds			
Older Adults	95.02	47.44	64.51	20.82
Younger Adults	21.79	7.55	16.66	3.58
Total Sample	57.22	49.62	40.59	28.41
	Mean Navigational Efficiency			
Older Adults	5.18	4.48	3.64	3.11
Younger Adults	1.50	.74	1.16	.90
Total Sample	3.28	3.62	2.40	2.58

For accuracy of the untrained tasks, there was a main effect of age, $F(1, 59) = 57.112$, $p < .01$, and training condition $F(1, 59) = 8.691$, $p < .01$, and there was a significant interaction between age and training condition, $F(1, 59) = 4.320$, $p < .05$. Follow-up analyses revealed that the difference in training condition was significant for older adults ($p = .016$), but not for younger adults ($p > .05$). The difference between the younger and older adults was smaller for those in the concept training condition compared to those in the action training condition (see Table 11). For task completion time of untrained tasks, there was also a main effect of age, $F(1, 59) = 87.123$, $p < .01$, and training condition $F(1, 59) = 7.547$, $p < .01$, and there was a significant interaction between age and training condition, $F(1, 59) = 3.824$, $p < .05$. Follow-up analyses revealed that the difference between the training conditions was significant for both younger adults ($p = .020$) and older adults (*p* = .026). For navigational efficiency of the untrained tasks, there was a main effect of age, $F(1, 59) = 19.771$, $p < .01$, but not training condition, p > .05, and the interaction was also not significant, $p > .05$. Follow-up analyses were performed; they revealed that the differences between the training conditions were not significant for either age group, $p > .05$.

The improved performance of older adult participants for accuracy and task completion time and younger adults for task time indicates that these results pertaining to accuracy and task time where in accordance with the hypothesis that concept training results in better performance on untrained tasks compared to performance of participants in the action training condition. This supports the notion that concept training results in performance benefits in speed and accuracy for novel tasks, which may be due to a better understanding of the system structure. However, the navigational efficiency results were not as hypothesized. Several conclusions can be drawn from these findings. Examining one measure by itself gives an incomplete picture of effects of training on learning. There was no speed-accuracy trade-off, participants in the concept training condition performed untrained tasks faster and with greater accuracy than participants in the action training condition. However, participants in both training conditions navigated the HGC with similar efficiency. This may indicate that participants in the concept training condition developed a better understanding of the system structure which allowed them to navigate the system faster and perform the tasks with greater accuracy. The non-significance of the navigational efficiency may be due to the manner in which it was calculated. The mean and standard deviation was gathered from only the tasks performed correctly. Action participants performed significantly fewer tasks successfully resulting in fewer tasks used to determine the navigational efficiency.

Performance at Test: System Subgoals Measure

The system subgoals measure focused on participants' ability to combine smaller system subgoals to achieve an overall system purpose. Participants also completed this measure on the computer, just as in training and in the system performance measure. From the system subgoals data collected, accuracy, task time, and navigational efficiency were computed.

Because the original purpose of this measure was to assess participants' ability to combine system subgoals into an overall system purpose, the measure was intended to be analyzed as two complete tasks, one containing four subgoals that consisted of trained components and one containing four subgoals that consisted of untrained components. Accuracy was determined by successfully completing each of the four subgoals, all four subgoals had to be successfully completed for the task to be scored correct. However, the "all or none" method of determining accuracy did not provide a complete understanding of participants' performance. Accuracy was then computed using percent correct of events. An event is an essential step needed to perform the task correctly. For the task with the untrained components there were 11 events and for the task with the trained components there were 12 events. Percent correct was then calculated (e.g. 10 events out of 12 correct results in an accuracy score of 83.33%). Due to the manner in which the data were recorded by the computer, decomposing the data to compute task time and navigational efficiency for each of the four subgoals was not possible. It is impossible to accurately indicate when a participant stopped or started working on a subgoal because initial or final button selection may not be correct. For this reason, task time was computed using the total time to complete each task type and navigational efficiency was computed using the total number of mouse clicks made by the participant to complete each task type.

An Age (younger, older) x Training condition (action, concept) x Trial type (trained, untrained) ANOVA was performed on the dependent variables (accuracy, task time, and navigational efficiency) for the system subgoals measure. There was no 3-way interaction for accuracy (p = .293), task time (p = .458), or navigational efficiency (p = .482). Although the 3-way interactions were not significant, an age x training condition ANOVA within each trial type was performed in line with a priori hypotheses the dependent variables in the system subgoals measure. First, the results from the trained tasks ANOVA are reported, followed by the results from the untrained tasks.

Trained Tasks. The means and standard deviations for performance on the task with the trained components in the system subgoals measure are presented below in Table 12.

Table 12. *Descriptive Statistics: System Subgoals, Trained Tasks*

	Action		Concept	
Age Group	*M*	*SD*	*M*	*SD*
	Accuracy (percent correct)			
Older Adults	55.76	27.89	56.25	25.55
Younger Adults	88.69	14.66	92.61	16.67
Total Sample	72.73	27.37	74.43	28.13
	Mean Time in Seconds			
Older Adults	229.77	130.85	259.14	213.70
Younger Adults	106.66	30.18	99.00	38.59
Total Sample	166.23	111.16	179.07	171.57
	Mean Navigational Efficiency			
Older Adults	36.60	22.86	38.81	25.48
Younger Adults	53.06	8.47	44.00	9.81
Total Sample	45.10	18.70	41.41	19.18

For the trained tasks, the interaction between age and training condition was not significant for accuracy (p = .752), task time (p = .567), and navigational efficiency (p = .224). The pattern was also the same for untrained tasks for accuracy (p = .490), task time (p = .111), and navigational efficiency (p = .608). These findings indicate that regardless of trial type (trained versus untrained tasks), there was no reduction of age-related differences between the two training conditions. This finding may also be an indication that the learning that occurred during the system performance measure reduced the effects of the training condition as well as the effects of the trial type.

For the trained tasks, there was no difference found between the performance of participants in the concept and action training conditions for accuracy (p = .686), task time (p = .737), or navigational efficiency (p = .459). Due to order effects, participants in both training conditions may have learned the untrained tasks during exposure from the system performance task. The order of the assessment measures was not counterbalanced; therefore we cannot test this conclusion. However, in the system performance measure there was a difference between the trained and untrained tasks. The tasks were the same in both measure, this supports the notion that assessment order may have reduced learning effects.

The younger adults performed the system subgoals task with greater accuracy, $F(1, 59) = 39.654$, $p < .05$, faster, $F(1, 59) = 19.387$, $p < .05$, and with greater navigational efficiency, $F(1, 59) = 5.557$, $p < .05$ than the older adults for trained tasks. These findings are consistent with the hypothesis and with previous findings in training and aging research.

Untrained Tasks. The means and standard deviations for performance on the task with untrained components in the system subgoals measure are presented below in Table 13.

Table 13. *Descriptive Statistics: System Subgoals, Untrained Tasks*

	Action		Concept	
Age Group	*M*	*SD*	*M*	*SD*
	Accuracy (percent correct)			
Older Adults	55.56	35.53	64.58	26.09
Younger Adults	94.79	5.99	96.35	9.11
Total Sample	75.81	30.15	80.47	25.10
	Mean Time in seconds			
Older Adults	185.02	158.82	269.46	161.22
Younger Adults	88.54	24.82	80.38	19.87
Total Sample	135.23	120.34	174.92	148.30
	Mean Navigational Efficiency			
Older Adults	31.67	29.08	36.00	17.44
Younger Adults	38.06	4.09	38.00	3.71
Total Sample	34.97	20.34	37.00	12.44

For the untrained tasks, the interaction between age and training condition was not significant for accuracy ($p = .490$), task time ($p = .111$), and navigational efficiency ($p = .608$). These findings indicate that regardless of trial type (trained versus untrained tasks), there was no reduction of age-related differences between the two training conditions. This finding may also be an indication that the learning that occurred during the system performance measure reduced the effects of the training condition as well as the effects of the trial type.

For the untrained tasks, there was also no difference found in the performance of participants in the concept and action training conditions for accuracy, $F(1, 59) = .971$, $p > .05$, task time, $F(1, 59) = 1.781$, $p > .05$, or navigational efficiency, $F(1, 59) = .251$, $p > .05$. These findings are contrary to the hypothesis that participants in the concept training condition would perform the system subgoals with faster speed, greater accuracy, and navigational efficiency than participants in the action training condition. These findings also support previous conclusions that the order of the assessment measure may have influenced learning. Exposure to both trained and untrained tasks during the system performance measure may have made the untrained tasks similar to the trained tasks.

The younger adults performed with greater accuracy, $F(1, 59) = 43.660$, $p < .05$, and faster times, $F(1, 59) = 24.965$, $p < .05$ on the task with untrained components in the system subgoals measure compared to older adults. However, there was no difference found between the performance of older and younger adults on the untrained task for navigational efficiency ($p = .329$). This finding was contrary to the hypothesis. Although there was no difference found between the navigational efficiency performance of the younger and older adults, the standard deviations, reported in Table 13, show more variance in the performance of the older adults compared to younger adults. The younger adults had greater consistency in their performance as a whole; therefore they may have had a better understanding of the system structure than the older adults and may be better at combining system subgoals to achieve an overall system purpose more efficiently than the older adults.

Follow-up analyses were performed to determine if the training condition differences were significant for each age group within each trial type for accuracy, task time, and navigational efficiency. Benefits of concept training were only demonstrated by younger adult participants in the concept training condition who performed with greater navigational efficiency on trained tasks than those in the action training condition, $F(1, 30) = 7.825$, $p < .05$.

In an effort to compare performance on the trained portion of the system subgoal task at test to performance on those 4 task components during training, two Brinley plots were computed for task completion time. Performance on those 4 task components during training was calculated by summing the task time for each of the four tasks when they were performed during training. Performance on the trained portion of the system subgoal task calculated when the data were collected at test. In a Brinley plot, the performance on the system subgoal task is on one axis, while the performance on the components during training is on the other. If the relationship is perfectly linear (draw on the diagonal), it can be concluded that there is a one to one relationship between performance on system subgoal task and performance on components during training. If the line of best fit is above the diagonal, it can be concluded that performance on the system subgoal task is slower than that of performance on the components during training; if the line of best fit is below the diagonal, performance on the components during training is slower. For older adults, the equation of the best fit line is $y = .0735x + 217.24$, $R^2 = .0042$. The slope of the line of best fit (shown in Figure J) is below the diagonal revealing that performance on components during training is faster than performance on the system subgoal task at test. This is an indication that, for older adults, it may be faster to combine system subgoals into a major system function than to perform those components independently during training. For the younger adults, the equation of the best fit line is $y = .3273x + 61.882$, $R^2 = .2267$. The slope of the line of best fit (shown in Figure K) is again below the diagonal revealing that performance on components during training is faster than performance on the system subgoal task at test. Just as with older adults, younger adults may be faster at combining system subgoals into a major system function than performing those components independently during training. For both age groups this is an indication that some learning has occurred resulting in an increase in task completion time at test.

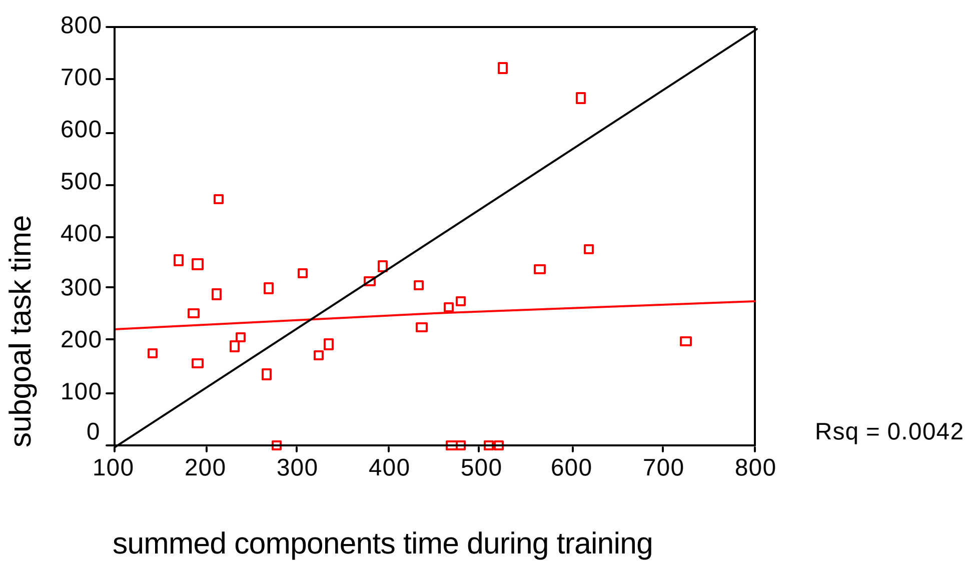


Figure J. Troubleshooting task Brinley plot for older adults, task time (sec)

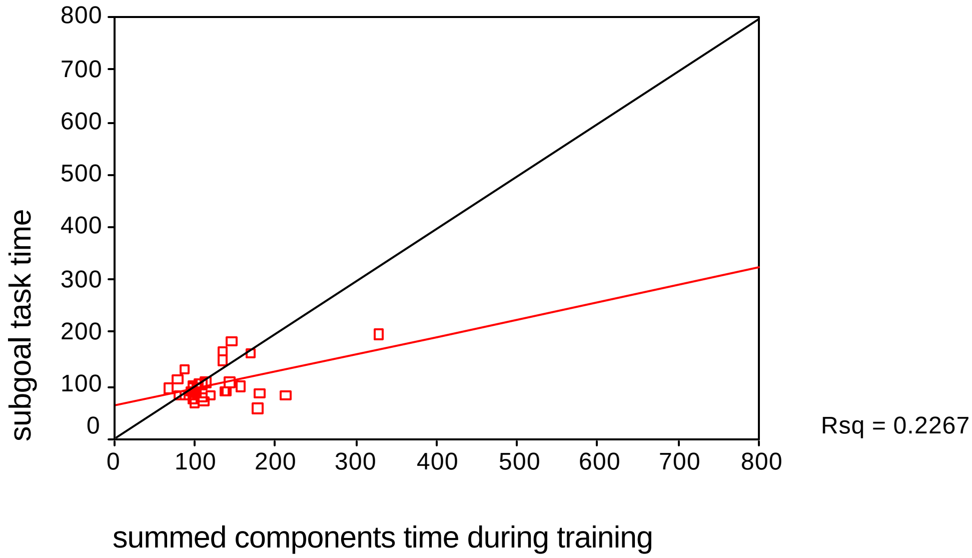


Figure K. Troubleshooting task Brinley plot for younger adults, task time (s)

Performance at Test: Troubleshooting Measure

The true/false troubleshooting measure consisted of vignettes describing an individual using the HGC incorrectly. Participants were instructed to decide if the provided solution was either true or false. This pencil-paper measure consisted of 12 vignettes, six vignettes contained system components that were trained and six vignettes contained system components that were untrained. Performance on the troubleshooting measure was based on the percentage of correct answers.

An Age (younger, older) x Training condition (action, concept) x Trial type (trained, untrained) ANOVA was performed on accuracy for the troubleshooting measure, however it was not significant (p = .862). Although the 3-way interaction was not significant, an age x training condition ANOVA within each trial type was performed in line with an a priori hypothesis for accuracy in the troubleshooting measure. First, the results from the ANOVA of the vignettes containing trained system components will be reported, followed by the results from the vignettes containing untrained system components.

Trained Tasks. The means and standard deviations for the troubleshooting task on trained tasks are reported in Table 14.

Table 14. *Descriptive Statistics: Troubleshooting, Trained Tasks*

	Action		Concept	
Age Group	*M*	*SD*	*M*	*SD*
	Accuracy (percent correct)			
Older Adults	66.67	20.89	68.75	14.75
Younger Adults	82.29	16.63	87.50	9.62
Total Sample	74.73	20.13	78.13	15.52

There was not a significant interaction between age and training condition for accuracy for trained tasks (p = .689). This finding indicates that there was no reduction in age-related differences between the training conditions. This may be attributed to learning that occurred due to previous exposure to the system and other tasks, but cannot be directly assessed because the order of the assessment measures was not counterbalanced. Also, there was no difference found between the performance of participants in the concept and action training conditions for accuracy (p = .367). However, younger adults performed the tasks with greater accuracy, than the older adults for trained tasks, $F(1, 59) = 18.393$, $p < .05$. Younger adults demonstrate better troubleshooting skills than older adults. This may be an indication that younger adults may have developed a better system representation than the older adults (Zeitz & Spoehr, 1989).

Untrained Tasks. The means and standard deviations for troubleshooting on untrained tasks are reported in Table 15.

Table 15. *Descriptive Statistics: Troubleshooting, Untrained Tasks*

	Action		Concept	
Age Group	*M*	*SD*	*M*	*SD*
	Accuracy (percent correct)			
Older Adults	55.56	17.44	56.25	13.48
Younger Adults	71.88	13.22	73.96	12.12
Total Sample	63.98	17.27	65.10	15.47

There was not a significant interaction between age and training condition for accuracy for untrained tasks (p = .846). This finding indicates that there was no reduction in age-related differences between the training conditions. This may be attributed to learning that occurred due to previous exposure to the system and other tasks, but cannot be directly assessed because the order of the assessment measures was not counterbalanced. Similar to the findings of the trained tasks, for the untrained tasks, there was no difference found between the performance of participants in the concept and action training conditions for accuracy (p = .698). Again, younger adults performed the tasks with greater accuracy, than the older adults for untrained tasks, $F(1, 59) = 22.790$, $p < .05$.

For both the trained and the untrained tasks, the findings were contrary to the hypothesis. Based on Sanderson (1990) and Zeitz and Spoehr (1989), understanding the system structure may increase participants' responses to system failures or abnormal events, participants in the concept training condition were expected to complete the task with greater accuracy than the participants in the action training condition. However, this did not occur. The means and standard deviations reported for the troubleshooting measure (see Table 14 and Table 15) showed that no group of participants performed at ceiling and there was a moderate amount of variance present. This may be an indication that the measure has low validity; it may not assess participants' ability to troubleshoot system errors, but may in fact assess their ability to draw conclusions from event scenarios.

A follow-up analysis was performed to determine if the training condition differences were significant for each age group within each trial type for accuracy, however, there were no significant differences found.

Because the Troubleshooting task consisted of true/false responses, several t-tests were performed for each age group within each training condition to determine if the mean scores were significantly differently from chance (50%). The older participants in both the action and concept training conditions performed the trained tasks significantly better than chance ($p < .05$, $p = .01$), there was not a significant difference in the performance of the untrained tasks ($p > .05$). However, for the younger participants in both training conditions performance on the trained and untrained tasks was significantly different from chance ($p < .01$ for all groups). These findings suggests that learning did occur for both older and younger adults.

Performance at Test: System Layout

The system layout measure consisted of images of the six screens used in the HGC, but the names of the screen features were not visible. This measure followed a "fill-in-the-blank" paradigm, where participants were instructed to write in the name of screen feature in the space provided. The system layout measure consisted of two sections, one without a word list and one with a word list, each section had 113 blanks. Performance on the system layout measure was calculated using percent correct and was computed in two ways: stringent and lenient. In stringent scoring, a response was correct if the label name was written in the exact blank. In lenient scoring, a response was correct if the label name was located within a cluster of similar labels identified in the system analysis (see Appendix C). Unlike the previous assessment measures, the system layout measure was not divided into trained components and untrained components, therefore the results of the system layout measure without the word list will be reported first, followed by the results with the word list.

For the system layout measure without the word list, an age (younger, older) x training condition (action, concept) ANOVA was performed. There was no significant difference found between the performance of participants in the action or concept training conditions, in stringent scoring ($p = .215$), or lenient scoring ($p = .471$). The means and standard deviations are reported in Table 16. Regardless of training conditions, participants performed below 50% accuracy on this section of the system layout measure. Although it was hypothesized that participants in the concept training condition would perform with greater accuracy than participants in the action training condition, remembering the location of 113 labels may be too difficult of a task.

Table 16. *Descriptive Statistics: System Layout, without word list*

	Action		Concept	
Age Group	*M*	*SD*	*M*	*SD*
	Stringent Scoring (percent correct)			
Older Adults	14.00	10.58	12.00	9.86
Younger Adults	50.81	13.48	60.75	15.36
Total Sample	33.00	22.20	36.38	27.83
	Lenient Scoring (percent correct)			
Older Adults	17.73	13.65	13.56	10.31
Younger Adults	62.94	16.19	72.56	18.22
Total Sample	41.06	27.30	43.06	33.33

The pattern was the same for the measure with the word list for both stringent scoring ($p = .608$), and lenient scoring ($p = .846$). The means and standard deviations are reported in Table 17. When given the word list, participants performed with greater accuracy than when they were not given the word list. However, the training condition again did not result in a significant performance difference.

Table 17. *Descriptive Statistics: System Layout, with word list*

	Action		Concept	
Age Group	*M*	*SD*	*M*	*SD*
	Stringent Scoring (percent correct)			
Older Adults	43.73	22.93	37.13	16.99
Younger Adults	80.75	12.99	91.63	10.63
Total Sample	62.84	26.14	64.38	31.00
	Lenient Scoring (percent correct)			
Older Adults	51.00	24.45	44.06	19.22
Younger Adults	89.81	12.32	95.06	8.97
Total Sample	71.03	27.27	69.56	29.81

Younger adults performed with greater accuracy than older adults on the system layout measure without the word list for both stringent scoring, $F(1, 59) = 182.902$, $p < .05$, and lenient scoring, $F(1, 59) = 192.093$, $p < .05$. The pattern was the same for the system layout measure with the word list for both stringent scoring, $F(1, 59) = 122.141$, $p < .05$, and lenient scoring, $F(1, 59) = 107.634$, $p < .05$.

The difference between younger and older adults was smaller for participants in the action training condition compared to those in the concept training condition on the system layout measure both stringent scoring, $F(1, 59) = 3.560$, $p = .064$ and lenient scoring, $F(1, 59) = 3.367$, $p = .072$ (marginally significant). These findings are contrary to the hypothesis that participants in the concept training condition would perform with greater accuracy than those in the action training condition. A similar pattern was also found for the system layout measure with the word list for stringent scoring, $F(1, 59) = 4.458$, $p = .039$. However, this interaction was not found for the system layout measure with the word list for lenient scoring ($p = .164$). The easier of the two sections of this measure, system layout with the word list, scored leniently resulted in a non-significant interaction. It has also been determined that the section of the system layout task without the word list may be too difficult to be a valid measure. Therefore, it can be concluded that performance on this measure may be best indicated by the system layout measure with the word list. Therefore, lack of a performance difference may be attributed to learning that occurred due to previous exposure to the system layout from the first two assessment measures (system performance and system subgoals). After continuous exposure to the system, training effects may diminish.

Several follow-up analyses were performed to determine if the training condition differences were significant for each age group for accuracy of both stringent and lenient scoring of the system layout task with words. When stringently scored, younger adult participants in the concept training condition performed marginally better than those in the action training condition, $F(1, 30) = 6.715$, $p < .05$. However, these analyses did not reveal significant training group differences for leniently scored younger adults ($p > .05$), stringently scored older adults ($p > .05$), and leniently scored older adults ($p > .05$). Another set of follow-up analyses were performed after an arc sine transformation was applied to the data in an effort to normalize the distribution. The analyses revealed no significant difference in training conditions for the older adults for both stringent scoring ($p > .05$) and lenient scoring ($p > .05$). For younger adults, there was a significant difference for the stringent scoring ($p < .05$), but not for the lenient scoring ($p > .05$). These findings are consistent with the findings prior to the arc since transformation.

Exit Interview

The assessment phase was followed by an exit interview which consisted of two parts: a structured interview and a questionnaire. The structured interview questioned participants' understanding of the tasks completed during the study. The purpose of this interview was to identify any participants who felt they did not understand the instructions and the tasks during the assessment phase and to identify problems in the study such as confusing instructions. However, all participants indicated that they understood the instructions and the tasks.

The questionnaire was focused on obtaining personal performance evaluations, improvement suggestions, and previous experience with similar systems (see Appendix E for questions, coding scheme and results).

CHAPTER 4

GENERAL DISCUSSION AND DESIGN IMPLICATIONS

The current study examined two questions 1) does the type of training received affect the development of a system representation? and 2) were there age-related differences in the training effects? Results from the current study indicate that type of training and age both affect the development of a system representation. Although the additional measures of system representation were exploratory and did not behave as expected, participants in the concept training condition performed novel tasks in the system performance measure faster and with greater accuracy than those in the action training condition. The following sections explore the impact of the results and design issues from each assessment tool.

System Performance Assessment Measure

The results from the system performance assessment measure gives insight into what participants have learned from the training they received based on their ability to perform novel tasks, as well as tasks that they have experience completing. During training, participants were given the goal and the steps to complete the goal. However, at test, participants were only given the goal and they had to complete the task without any instructions. Participants who received action training were given specific steps during training, therefore at test; participants had to generalize specific trained procedures to complete the tasks successfully. Conversely, participants who received concept training were trained with generalized system procedures and therefore did not have to convert trained procedures. Participants who received concept training performed with greater accuracy when completing tasks they had previous experience with during training. However, there was no difference in how long participants took completing the tasks or the number of mouse clicks they made while completing the tasks. The result of higher accuracy from participants who received concept training was contrary to the hypothesis. As stated before, both training groups received the same tasks during training and therefore similar accuracy scores of participants from the two training conditions was expected. It is possible that training presented as conceptual information has benefit at recall over information presented as procedural information for performing tasks in which the user has previous experience. Processing conceptual information is more taxing on working memory leading to errors and slower processing speeds during encoding (Anderson, 1983). Although previously thought to decrease performance (Zacks, Hasher, & Li, 2000), increasing working memory demands may be beneficial for strengthening connections in memory (Anderson, 1983), making them easier to recall at test.

These implications are further supported by the findings that performance for novel tasks was faster and more accurate for participants who received the concept training those who received the action training, but for those tasks they completed correctly, there was no difference in their ability to navigate the system structure. Participants who were trained with concept training did not demonstrate a speed-accuracy trade-off (Pachella, 1974), in which their performance would have suffered due to either increased time spent completing the task and higher accuracy or a decrease in time and lower accuracy. Participants trained with action training were slower and less accurate compared to those who received concept training. The results from the system performance data indicate that concept training showed benefits of increasing performance on novel tasks without sacrificing speed or accuracy. Concept training also reduced the difference in accuracy and task completion time between younger and older adults, but not for navigating the system structure.

System Subgoals Assessment Measure

The system subgoals assessment measure did not behave as expected and had several weak points. It did not pass the manipulation check where the performance on the trained tasks was greater than the performance on the untrained tasks. For accuracy, younger adults were at ceiling, older adults were around 55% for both trained and untrained tasks. Also, for older adults, there was an abundance of variability of accuracy scores. Standard deviations of the accuracy scores ranged from 26 to 36, demonstrating that the performance of older adults spanned from very bad to very good regardless of training condition. This is an indication that the tasks were too easy for the younger adults and too difficult for the older adults.

Although the measure had several weak points, as stated above, it served as a beginning model to be improved upon for future studies exploring the problem solving abilities. In its current state, this measure may have high validity, but low reliability. The task does assess participants' ability (based on accuracy, task time, and navigational efficiency) to combine system subgoals into a major system function. However, due to manner in which the data were recorded by the computer, this measure may give different results each time it is applied to the same person. Initially there were two items in this measure, one task that contained trained system components and one task that contained untrained system components and was scored as completely correct or completely incorrect. Each task was then divided into their four sub-tasks, which allowed for partial credit. This division then allowed for the analysis for four trained tasks and four untrained tasks. The four tasks were again divided, this time into events, which were even smaller than sub goals. By decreasing the size of each task to two subgoals instead of four and increase the number of tasks from two to 20 or more may help in several ways. First, clarity, the larger 4-sugoal task was a small paragraph which may have been difficult for the older adults to divide into smaller tasks, so by reducing the number of subtask the clarity of the entire task may increase. There is a consequence to this reduction; younger adults performed the 4-subgoal task at ceiling therefore it can be expected that a 2-subgoal task will be performed at ceiling as well. Second, by increasing the number of tasks performed the possibility of statistical significance increases. Twenty tasks may seem like a huge increase from two, but this measure consisted of two task types, trained and untrained. Ten tasks is still a small number to analyze, therefore several pilot tests are necessary to determine the number of tasks necessary to improve this measure.

Troubleshooting Assessment Measure

The troubleshooting assessment measure was also exploratory and did not behave as expected. The measure did pass the manipulation check where performance on the trained tasks was better than that on the untrained tasks, but participants from both training conditions had similar performance. Therefore, in its present state, the training appears to have no affect on the performance of this measure. An alternative choice than to dismiss this measure is to improve it so that it can be used in later studies assessing troubleshooting abilities. Although performance on this measure is similar across training conditions, it is not at ceiling, younger adults were at maximum 88% for tasks they had been previously trained on.

This measure as a whole may have been too difficult for its purpose of accessing troubleshooting abilities. Merriam-Webster defines a troubleshooter as a person skilled at solving or anticipating problems or difficulties in machinery and technical equipment. The vignettes used in this measure were aimed at just that, participants were to place themselves in the position of a troubleshooter and decided if the solution provided was either true or false. However, this may have increased the difficulty of the measure through the use of the word "troubleshoot". Participants may have seen themselves as novices, not as a person skilled in the technical background of hydroponic gardening. Participants may have perceived the task as more difficult than it actually was. This is also supported by the results of pilot studies using an Entertainment System simulator which contained a CD player, radio, and a weather tool. Participants were given a brief description of the system and then given the pencil-paper measure, they never interacted with the actual system. Participants in the pilot study were at ceiling when performing a similar troubleshooting task for the Entertainment System. It is possible, but not examined, that participants in the pilot study perceived themselves as skilled persons and thus behaved in that manner. To resolve this problem, the name and description of the task may need to be changed to take the emphasis of skill level.

The number of vignettes used in the troubleshooting measure may have also contributed to the small F-values. There were 12 vignettes used, six were trained and six were untrained. This problem is similar to that of the system subgoals measure. Increasing the number of vignettes increased the possibility of statistical significance. To improve the measure, the number of vignettes may need to be increased to 20 or more, so that each trial type contains 10 tasks.

System Layout Assessment Measure

The system layout measure performed contrary to what was expected. There was no difference found between the performance of participants in the action and concept training conditions. The system layout measure without the word list, which was presented first, resulted in the worst performance of this measure. Older participants averaged accuracy scores of 16%, while younger participants averaged 68%. Consequently, the system layout measure without words should not be used as an assessment tool again. However, performance on the system layout measure with the word list was higher, older adults averaged 47%, younger adults averaged 92%. The variability for the measure with the word list was high for the older adults. Several changes can be made to the measure with the word list to increase its reliability, so that the measure consistently gives the same result every time it is applied to the same person. In the previous assessment measures one problem was too few tasks, however in this measure 113 is too many. Participants appeared overwhelmed at having to remember where to write the feature labels, which may result in different scores for the same person. Also, the measure may also have low validity, participants may have believed the measure assessed memory for exact locations. The purpose of this measure was not to test participants ability to identify the exact location each feature, hence the reason for two scoring methods. Unbeknownst to the participants, this measure was aimed at testing participants' ability to structure the HGC into groupings, similar to card sorting. The initial measure was a card sorting task, but after pilot testing it was apparent that the

HGC was too complex to sort into piles. However, to improve the reliability and validity of this measure, reduce the number of system features and either keep the measure as a "fill-in-the-blank" task or change it to a card sorting task. However, both versions should be pilot tested.

Theoretical Implications

Age-related Skill Acquisition. The findings from this study further support previous research on age-related performance differences presented in Table 1. In the current study, older adults took longer to complete tasks and performed them with less accuracy and less navigational efficiency than younger adults. The findings suggest that regardless of training type, older participants are at a disadvantage compared to younger adults during skill acquisition. The age-related slowing of cognition, perception, and movement control may further explain the differences in skill acquisition (Fisk & Fisher, 1994; Fisk, Fisher, & Rogers, 1992; Salthouse, 1993; 1996). Older adults have a more restricted amount of time in which appropriate actions can be successfully implemented than younger adults (Park, 1992). As processing continues through a task, the products of early processing may no longer be available when later processing is complete. As a result, cognitive processes, perception, and movement control take longer and are more prone to errors for older adults compared to younger adults, which is consistent to the findings.

Age and Training. Although older adults are at a disadvantage compared to younger adults during skill acquisition, previous research suggests that training reduces age-related performance differences (Jamieson & Rogers, 2000; Mead & Fisk, 1998). The current study supports these findings. In several of the measures used throughout this study, concept training reduced the age-related performance differences for accuracy and speed compared to action training. Therefore, not only is the use of training important in skill acquisition, but the type of training also influences the level of learning acquired by the individual.

Procedural and Declarative Knowledge. Anderson's Adaptive Control of Thought (ACT*) model (Anderson, 1983), Shiffrin and Schneider's Information Processing theory (Shiffrin & Schneider, 1977), and Catrambone's Subgoal Learning model (Catrambone, 1998) can be used to understand the difference between procedural and declarative knowledge and how the development of training can utilize these differences to improve task performance. Anderson's general ACT* framework consists of three memories: working, declarative, and production. In the knowledge compilation phase of the ACT* model, the demand on working memory is increased, leading to more errors and longer processing times. Based on theories of cognitive aging, working memory declines for older adults, therefore knowledge compilation further exacerbates older adults' working memory demands. However, the continuous demands on working memory increases the strength of existing information in long-term memory through connecting information and possibly an increase understanding of the structure of the information being presented.

The benefits of training with declarative knowledge as explained previously with ACT * may also be further supported by the Information Processing theory. Shiffrin and Schneider (1977) describe memory as a "large and permanent collection of nodes, which become complexly and increasingly interassociated and interrelated through learning" (p. 155). ACT* consists of procedural and declarative memory, while Information Process consists of long-term store (LTS), both of which involves similar processes of maintaining information in memory for later use. Nodes within learned sequences of information processing are located in LTS. During the proceduralization stage of ACT*, cognitive nodes are strengthened, consistent with this strengthening, there is an increase the number of nodes. Individuals trained with declarative knowledge may develop more cognitive nodes than those trained with procedural, therefore increasing associations and relatedness.

Another benefit of training with declarative knowledge may be explained by Catrambone's Subgoal Learning model, in which the organization of one's problem-solving knowledge into a meaningful hierarchical structure may improve performance (Catrambone, 1998). Participants in the concept training condition were presented the hierarchical structure during training where as participants in the action training condition were presented a step by step organization. As a result, the Subgoal Learning Model predicts increased accuracy and task completion time by participants in the concept training condition on novel tasks which is due to their increased knowledge of the system structure.

Findings from the current study support the implications from these three theories. During training participants in the action training condition performed training tasks faster and with greater accuracy than participants in the concept training condition. Information presented in the form of declarative knowledge increased working memory demands thereby producing more errors and slower reaction times than information presented in the form of procedural knowledge. However, increasing working memory demands through the concept training resulted in better performance on the system performance assessment tool for measures of speed and accuracy. It is possible that concept training involves more effortful processing of information in working memory, an increase in the development of cognitive node, and the development of a hierarchical structure than action training. It was previously thought that increasing the working memory load for older adults resulted in a decrease in performance (Zacks, Hasher, & Li, 2000). However, the current study suggests that there may be benefits of increasing working memory demands for both older and younger adults, provided that the working memory demands do not exceed capacity.

Practical Implications

Practically, applying this research to the development of training materials may increase proper product usage of complex technological systems for both older and younger. Each training condition had its benefits. Overall, action training resulted in shorter completion times and greater accuracy during training.

At test, the findings were in favor of the concept training condition. For tasks participants were trained on, overall, the participants receiving concept training were more accurate than those receiving action training, but there was no difference in task time or navigational efficiency. Concept training also reduced age-related performance differences for accuracy but not for task time or navigational efficiency. For the untrained tasks, overall, participants receiving concept training were faster and more accurate than those receiving action training.

In addition to concept training reducing the age-related performance differences for accuracy, there was also a reduction in age-related performance difference for task time. Although concept training takes longer during training and is prone to training errors, this style of training helped increase performance on familiar tasks in terms of accuracy and novel or infrequent tasks in terms of both speed and accuracy.

The findings in the current study are important to consider when making design decisions for training materials. Action training is faster and more accurate during training compared to concept training, but at test the benefits of greater speed and accuracy are demonstrated from individuals who received concept training.

Future Research

Further research is needed to explore the benefits of increasing working memory load to improve performance subsequent tasks. A proposed follow-up study should consist of a similar methodology as the current study. The number or amount of assessment measures used in the current study needs to be decreased to reduce the learning effects that occur over time and fatigue demonstrated by participants in the current study. To explore the benefits of increasing working memory demand, the procedure of the current study should be reduced to include only two assessment measures, the system performance measure and an extended version of either the system subgoals assessment measure or the troubleshooting assessment measure. Pilot testing is necessary in decided which of the two tasks may yield the most informative and valid results.

In addition to the future studies involving the assessment measures, the training phase of the study also needs to be modified and tested. Results from the current study indicated age-related differences in performance during training and throughout the assessment phase. Older adult participants may not have received enough training which may account for some of the age-related differences in performance. To explore this notion, a proposed future study should consist of training to criterion of 90% accuracy. Participants will continue training until they have completed the tasks with 90% accuracy, regardless of the time to complete the tasks. This may also lead to other studies in which criterion reached is a between subjects independent variable and performance is assessed for each criterion level.

The current study explored transfer, but did not explore retention. Performance after a retention phase is used to determine if knowledge can be retained over time and to reveal if performance differences between training conditions will be decreased or increased. A future study will include a retention phase of one week. Participants will complete training and the assessment phase and in one week complete the assessment phase again. Results from this study will help conclude if the benefits of concept training are sustained over time.

In addition to training, the design of the system structure may influence the development of a system representation. Design issues, for example descriptive label or button names, may lead the development of inaccurate hierarchical levels. Therefore, another future study may involve redesigning the hydroponic garden control or creating a new original system. The structure of the system needs to be evaluated and user tested to identify any problems that could result in an inadequate development of a system representation.

In conclusion, future research will provide support for the current study's findings of increasing working memory load to increase performance and will help in proving a solid methodology for assessing system representation and working memory capacity. Applying this research to the development of training materials may increase proper product usage of complex technological systems for both older and younger. With the development of these types of systems occurring everyday in domains such as medical care, communication, transportation, and entertainment, understanding the system structure may result in a better quality of life.

APPENDIX A

Table 1. Pre-screening and Home Questionnaires

Measure	Description
Pre-Screening Questionnaire	
Demographic questions	Demographic information
SPMSQ – Short Portable Mental Status Questionnaire	Mental status questionnaire/Memory screening
Wechsler Memory Scale III (WMS-III) - (Logical Memory I, Story A)	Memory test
Home Questionnaire	
Demographic and Health Questionnaire	Questionnaire for demographic and health history
Self-Efficacy Questionnaire	Measure of self-efficacy
Technology and Computer Experience	Assess experience with computers and other technology (e.g., web)
Computer Attitude Questionnaire	Assess typical attitude toward computers
Computer Anxiety Questionnaire	Assess anxiety toward computers and technology

APPENDIX B

Table 1. CREATE Testing: Description of Tests and Abilities Measured

Test Name	**Reference**	**Administration Time**	**Testing Environment**	**Medium**	**Description (Ability Measured)**
Shipley Vocabulary	Shipley, 1986	10 minutes	5-hour Group testing	Paper/Pencil	Participants were instructed to choose the synonym for each of the words given, from four available choices. Score was the total number correct from 40 items. (Semantic Knowledge)
Meaningful Memory	Hakstian & Cattell, 1982	5 minutes	5-hour Group testing	Paper/Pencil	Participants were presented with 20 pairs (object and descriptive word, e.g., table-sturdy). Following a distractor task, participants selected the synonym of the descriptor from the original list (from five options). Score was the total number correct. (Associative Memory)
Number Comparison	Ekstrom et al., 1976	3 minutes	5-hour Group testing	Paper/Pencil	Participants presented with two numbers and told to determine if they differed. Numbers ranged in length from 3 to 13 numbers. Score was the total number marked correctly, marked incorrectly, or incomplete for two 48-item parts each with a 1.5 minute time limit. (Perceptual Speed)
Alphabet Span	Craik, 1986	25 minutes	5-hour Group testing	Paper/Pencil	Two to nine words were presented orally (three trials were presented at each level). Task was to recall the words in alphabetical order. Span score was the total number of words recalled for trials that were recalled perfectly (absolute span, LaPointe & Engle, 1990). (Working Memory)
Nelson-Denney Reading Comprehension	Brown et al., 1993	20 minutes	5-hour Group testing	Paper/Pencil	Participants read a series of seven text passages and answered a total of 38 items that pertained to the passages. After one minute, participants marked the sentence that they were reading and this provided a measure of reading rate. Score was the total number of correct answers from the 38 items. (Reading Comprehension and Rate)

Test Name	Reference	Administration Time	Testing Environment	Medium	Description (Ability) Measured)
Multidimensional Aptitude Battery (MAB) Information	Jackson, 1998	10 minutes	5-hour Group testing	Paper/Pencil	Participants were instructed to choose the correct answer, from the five available choices, for each of 40 items designed to measure general world knowledge. Score was the total number correct. (Semantic Knowledge)
Letter Sets	Ekstrom et al., 1976	14 minutes	5-hour Group testing	Paper/Pencil	Participants were presented with four sets of five letters. The task was to determine which set did not follow the rule that related the other sets. Score was the total number correct, number incorrect, and incomplete for two 15-item parts each with a 7 minute time limit. (Induction)
California Verbal Learning	Delis et al., 1987	25 minutes	5-hour Group testing	Paper/Pencil	Participants were presented with a list of 16 items that might appear on a shopping list (i.e., Mondays List). The shopping list was presented six times and participants immediately free recalled the items after each presentation. Another shopping list (i.e., Tuesdays List) was presented and participants immediately free recalled those items after presentation. Participants were then asked to free recall the items on the Monday List after a short-delay and later to complete a cued recall test of the same items. Following a 20-minute filler task, participants free recalled the Monday List items after a long-delay before completing a long-delay cued recall test and a recognition test of the same items. Score used by CREATE was the total number of Monday List items free recalled immediately during all six free recall tests and the number of items free recalled after the 20-minute long delay. (Short and Long-term Memory)
Computation Span	Salthouse & Babcock, 1991	20 minutes	5-hour Group testing	Paper/Pencil	Participants were required to solve simple arithmetic problems presented orally and at the same time remember the last digit of each problem. Following presentation of all the problems within a trial (one to seven), participants recalled the final numbers. Span score was the total of the number recalled for trials that were recalled perfectly (absolute span, LaPointe & Engle, 1990). (Working Memory)

Test Name	Reference	Administration Time	Testing Environment	Medium	Description (Ability Measured)
Paper Folding	Ekstrom et al., 1976	6 minutes	5-hour Group testing	Paper/Pencil	Participants completed two 10-item parts, each with a 3-minute time limit. For each item, participants were asked to visualize a piece of paper being folded and using a pencil to punch a hole through a specified section. Participants were required to choose, from 5 available options, the correct pattern of holes if the paper were unfolded. Score was the total number correct, incorrect, and incomplete from the 20 items. (Spatial Ability)
Inference Test	Ekstrom et al., 1976	12 minutes	5-hour Group testing	Paper/Pencil	Participants completed two 10-item parts, each with a 6-minute time limit. For each item, participants read one or two statements before choosing a valid conclusion, from five available choices, drawn from the previous statements. Score was the total number of valid conclusions inferred from the 20 items. (Inferencing Ability)
Cube Comparison	Ekstrom et al., 1976	6 minutes	5-hour Group testing	Paper/Pencil	Participants completed two 21-item parts, each with a 3-minute time limit. For each item, participants determined whether or not two six-sided cubes could be the same if they were spatially manipulated by the turning each cube in a specified manner. Score was the total number correct, the number incorrect, and the number incomplete from the 42 items. (Spatial Ability)
Digit Symbol	Wechsler, 1997	3 minutes	5-hour Group testing	Paper/Pencil	Participants presented with a digit-symbol key (e.g., 1=X), followed by 100 digits for which they had to fill in the appropriate symbol. Score was the total number correct. (Perceptual Speed)
Information (WAIS III)	Wechsler, 1997	7 minutes	5-hour Group testing	Paper/Pencil	Participants answered 28 short answer questions designed to measure general world knowledge. Score was the total number correct. (Semantic Knowledge)
Brief Symptom Inventory	Derogatis, 1994	7 minutes	5-hour Group testing	Paper/Pencil	Participants answered 53 five-point Likert scale questions concerning various distressing situations that they may or may not have encountered in the last 7-day period. Score was the sum of the weighted questions. (Emotional State)

Test Name	Reference	Administration Time	Testing Environment	Medium	Description (Ability Measured)
CES-D	Radloff, 1977	5 minutes	5-hour Group testing	Paper/Pencil	Participants answered 20 four-point Likert scale questions designed to index their depressive state. Score was the sum of the weighted questions. (Depressive State)
Mini Mental State Examination	Folstein et al., 1975	7 minutes	5-hour Group testing	Paper/Pencil	Participants answered a series of questions designed to screen for dementia. Score was total number of correct answers out of 30. (Dementia)
Trailmaking	Reitan, 1992	5 minutes	1-hour Individual testing	Paper/Pencil	Participants were presented with a series of sequential circles labeled numerically, in part one, and alternating between numerical and alphabetical labels, in part two. Participants used a pencil to trace the sequential pattern in each part of the test as quickly as possible. Number of errors and time to completion were recorded. (Perceptual Speed)
Simple RT	Locally Developed	10 minutes	1-hour Individual testing	Computer	Participants were presented with the digit 5 in the center of the computer screen and required to respond as quickly as possible by pressing the '5' key on the number keypad. Random foreperiods of 500, 800, 1100, 1400, or 1700 ms and variable intertrial intervals (1000 ms or 2000 ms) were used. There were 10 practice trials, and 60 trials. Trials on which RT was below 100 ms or above 1000 ms were not included. The task was given twice; on the first day of computer testing and again on the last day of computer testing after all of the criterion tasks had been completed. (Simple Reaction Time)

Test Name	Reference	Administration Time	Testing Environment	Medium	Description (Ability) Measured)
Choice RT	Locally Developed	10 minutes	1-hour Individual testing	Computer	The task was to respond to the location of the extended ascii character 219 (¯) on a 3 x 3 grid spatially compatible with the layout of the numeric keypad. For 2-choice trials, the ¯ appeared in the '8' or '2' location; for 4-choice trials, the Ü appeared in the '8', '2', '4', or '6' location; for 8-choice trials, the ¯ appeared in the '8', '2', '4', '6', '7', '9', '1', or '3' location. The center location (the '5' key) was used as the home key and the target never appeared in this location. Practice consisted of four 2-choice trials, eight 4-choice trials, and sixteen 8-choice trials (two practice trials for each potential location for each choice task). There were 45 trials each for the 2-, 4-, and 8-choice tasks. The task was given twice; on the first day of computer testing and again on the last day of computer testing after all of the criterion tasks had been completed. (Choice Reaction Time)
Stroop	Golden, 1978	5 minutes	1-hour Individual testing	Paper/Pencil	Participants were given 45 seconds to complete each of three parts. Participants read the words presented in part one and read the colors presented in part two. Part three was a measure of inhibition such that participants read the color of the ink that words were presented in rather than the word itself (e.g., the word "blue" presented in green ink). Time to completion was measured for each of the three parts. (Inhibition)
Digit Span (Forward)	Wechsler, 1997	5 minutes	1-hour Individual testing	Paper/Pencil	Participants were asked to remember numbers that were presented orally, then write them in order. Digit list length varied from two to nine digits. Score was total correct for the 16 sets of digits presented. (Memory Span)
Digit Span (Reverse)	Wechsler, 1997	5 minutes	1-hour Individual testing	Paper/Pencil	Participants were asked to remember numbers that were presented orally, then write them in reverse order. Digit list length varied from two to eight digits. Score was total correct for the 14 sets of digits presented. (Memory Span)

APPENDIX C

SYSTEM ANALYSIS DISPLAYING FUNCTION AVAILABILITY FOR THE HYDROPONIC GARDEN CONTROL

Figure A. Overall General System Structure.

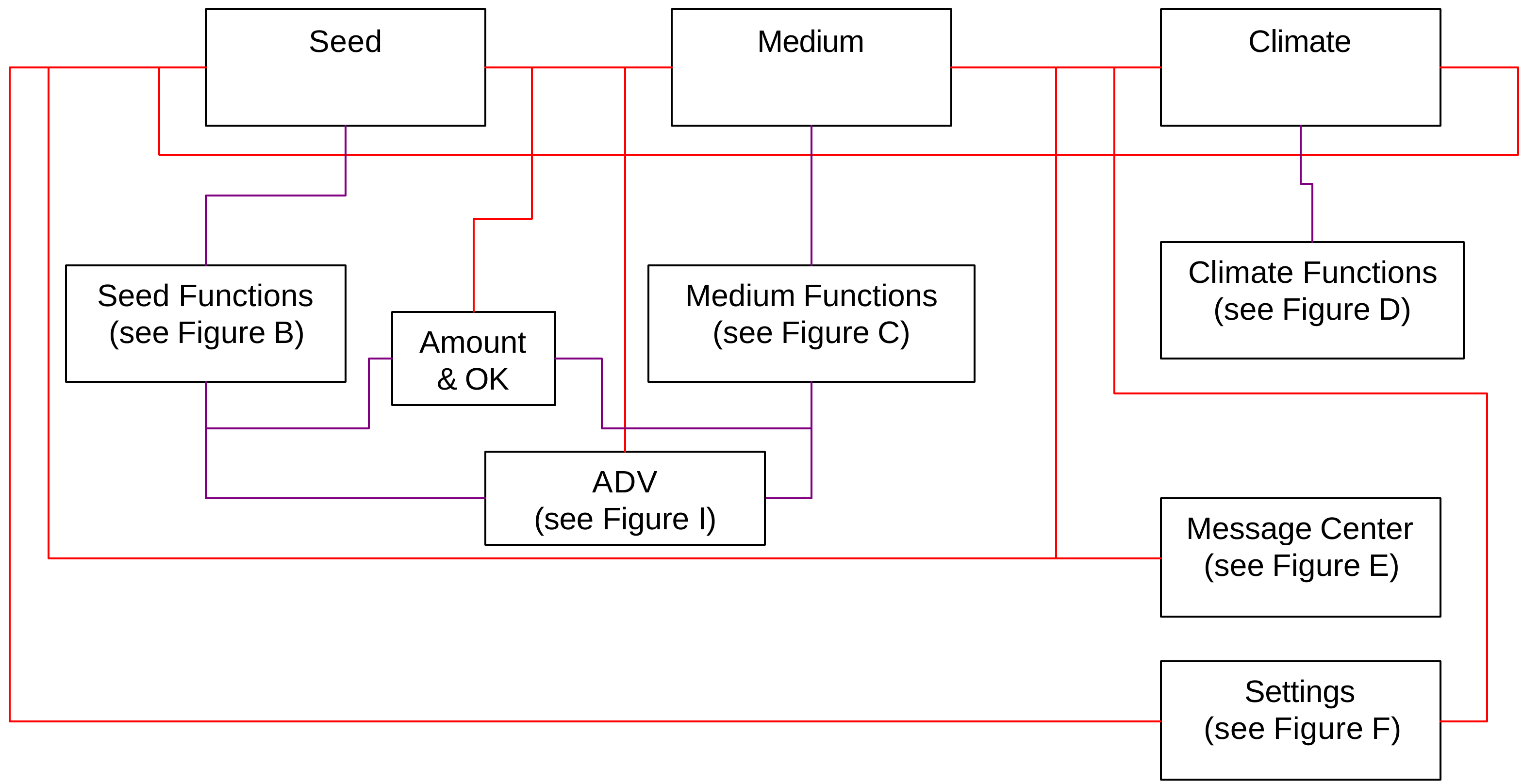


Figure B. Seed Screen Functions

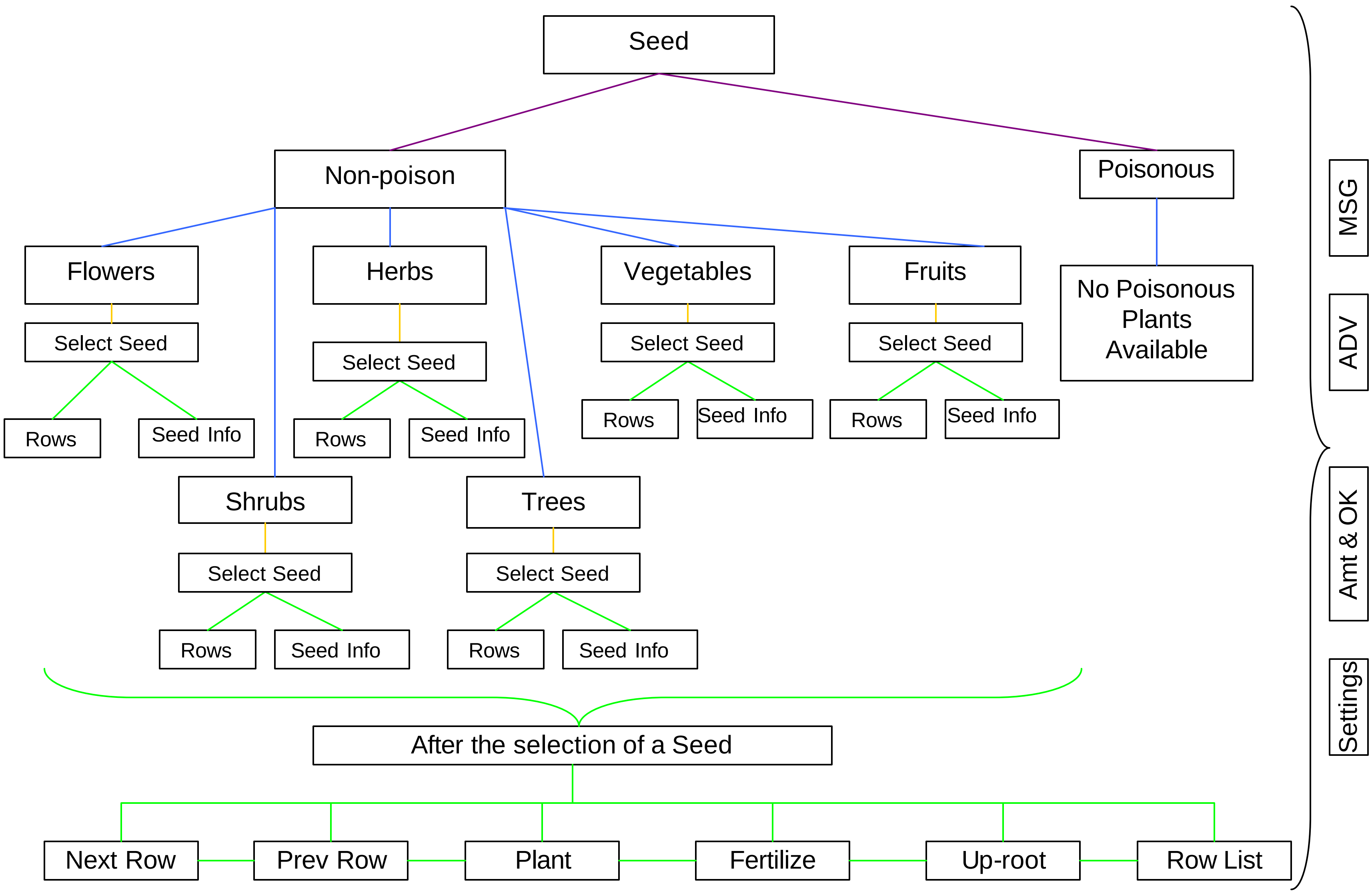


Figure C. Medium Screen Functions

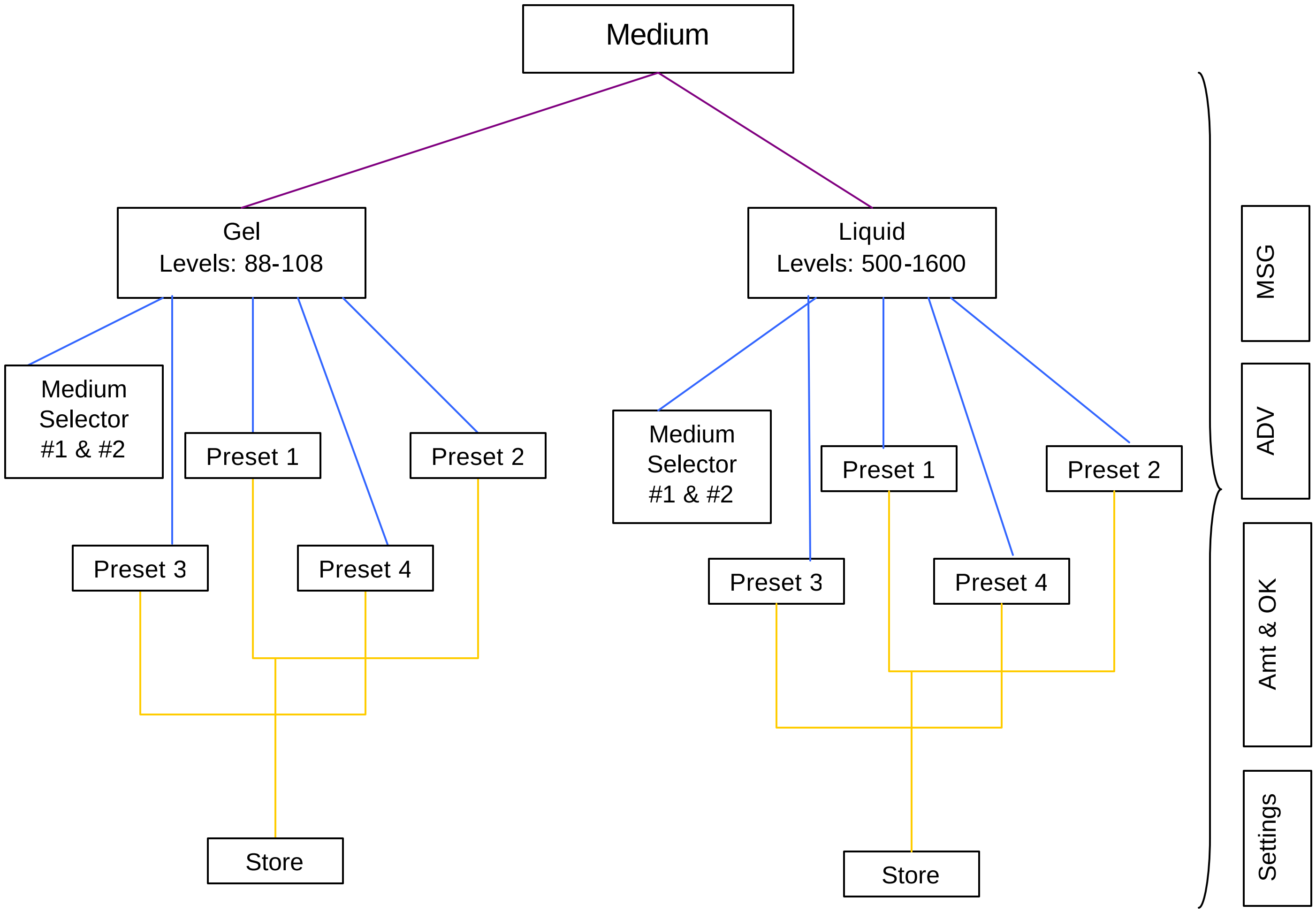


Figure D. Climate Screen Functions

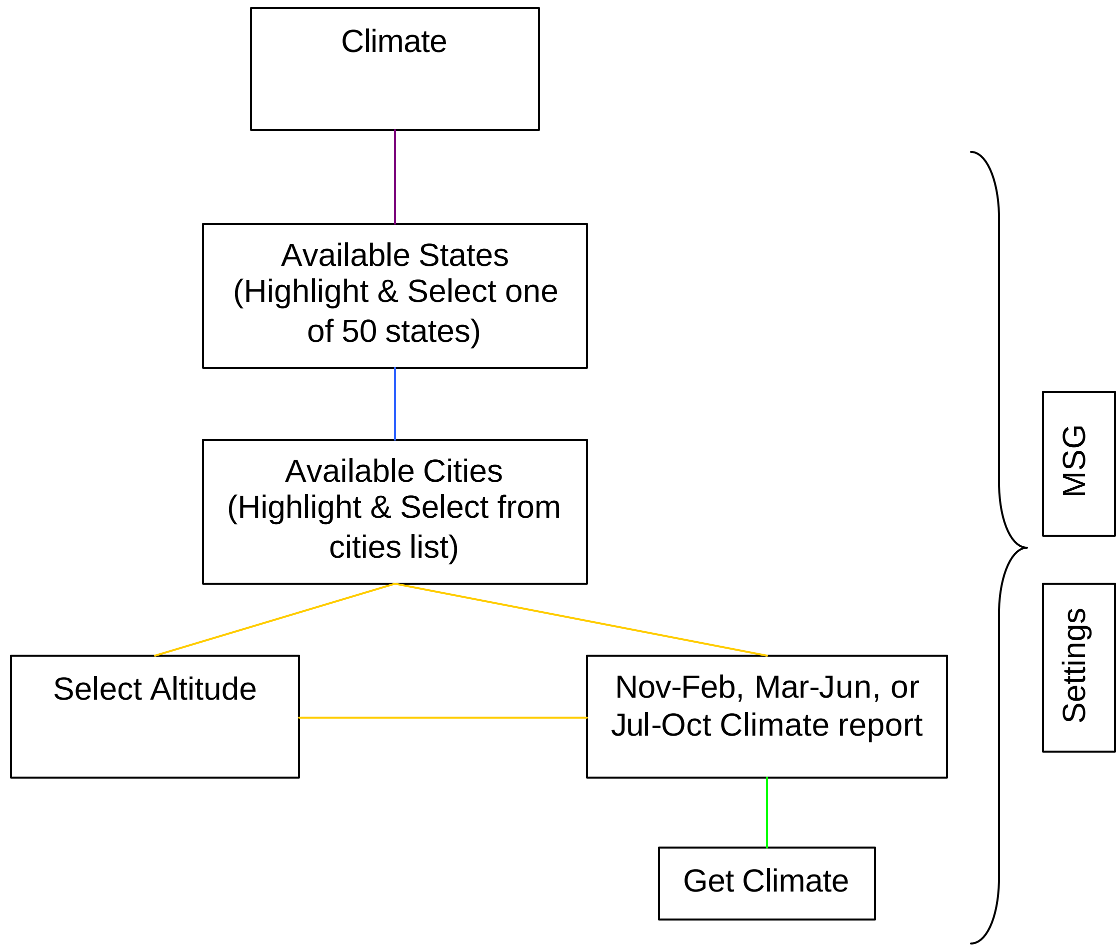


Figure E. Message Center Screen Functions

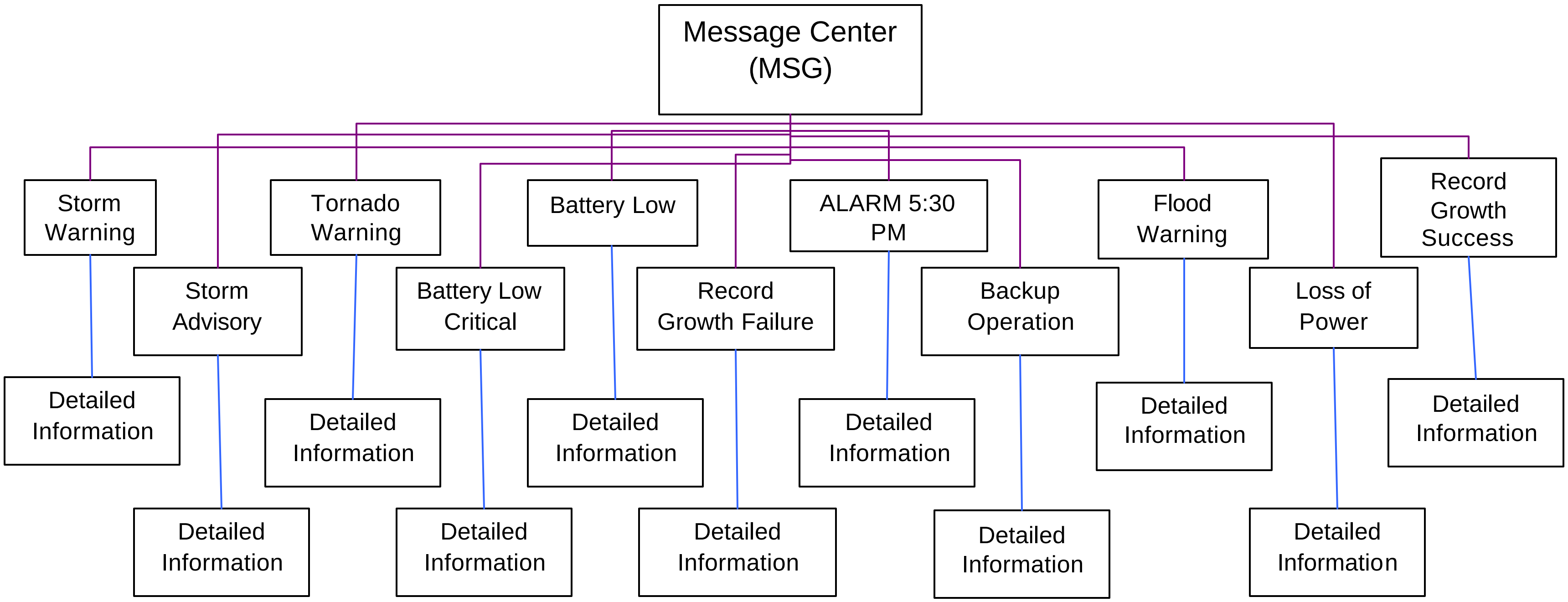


Figure F. Settings Screen Functions

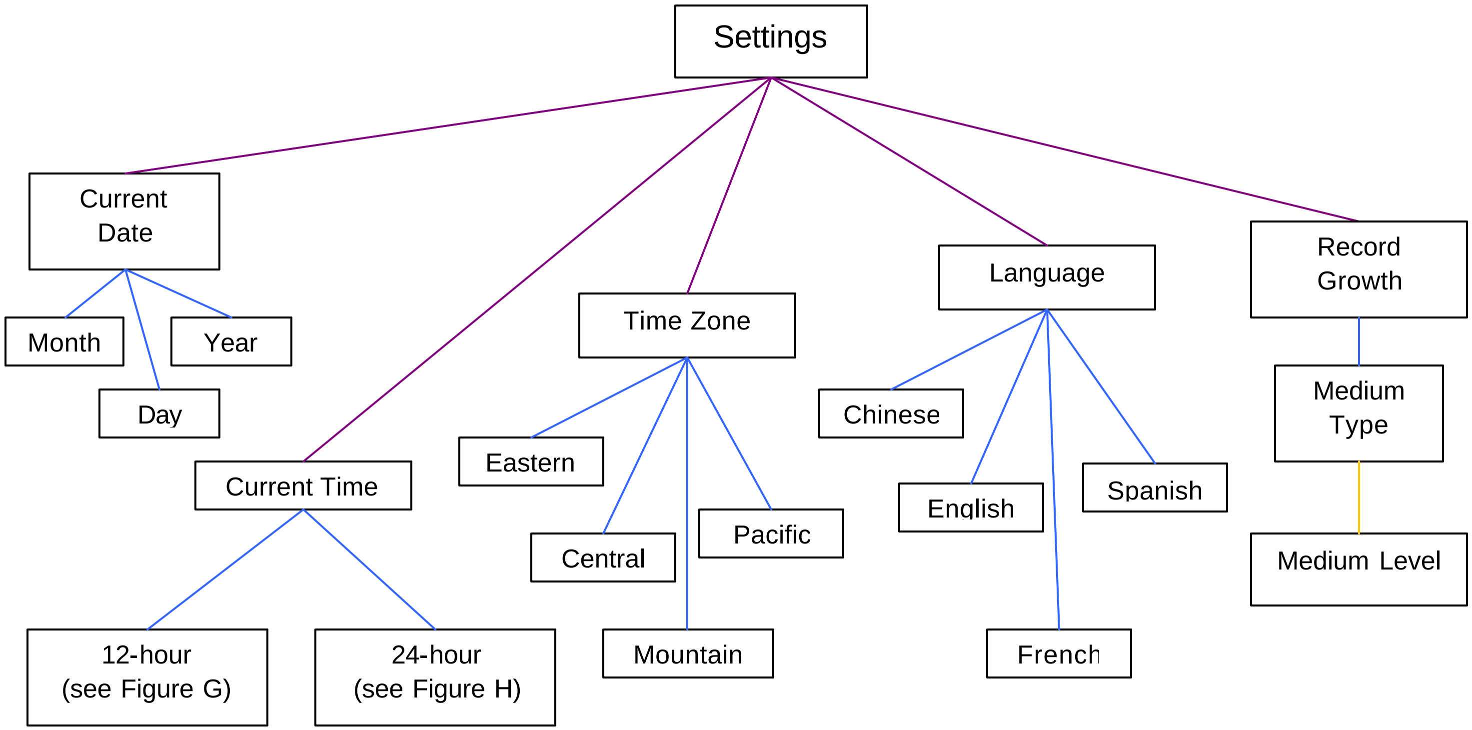


Figure G. 12-hour Settings Screen Functions

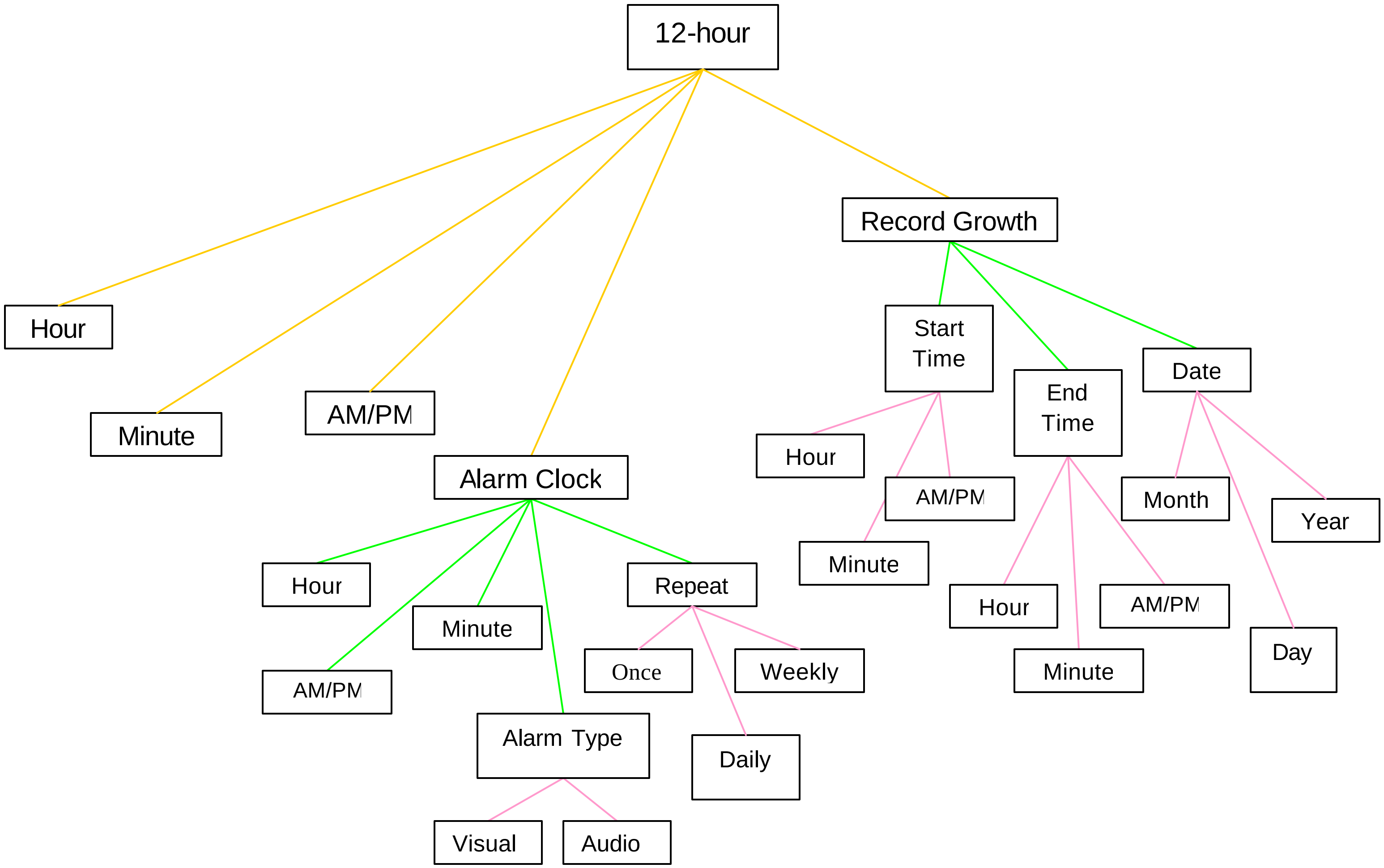


Figure H. 24-hour Settings Screen Functions

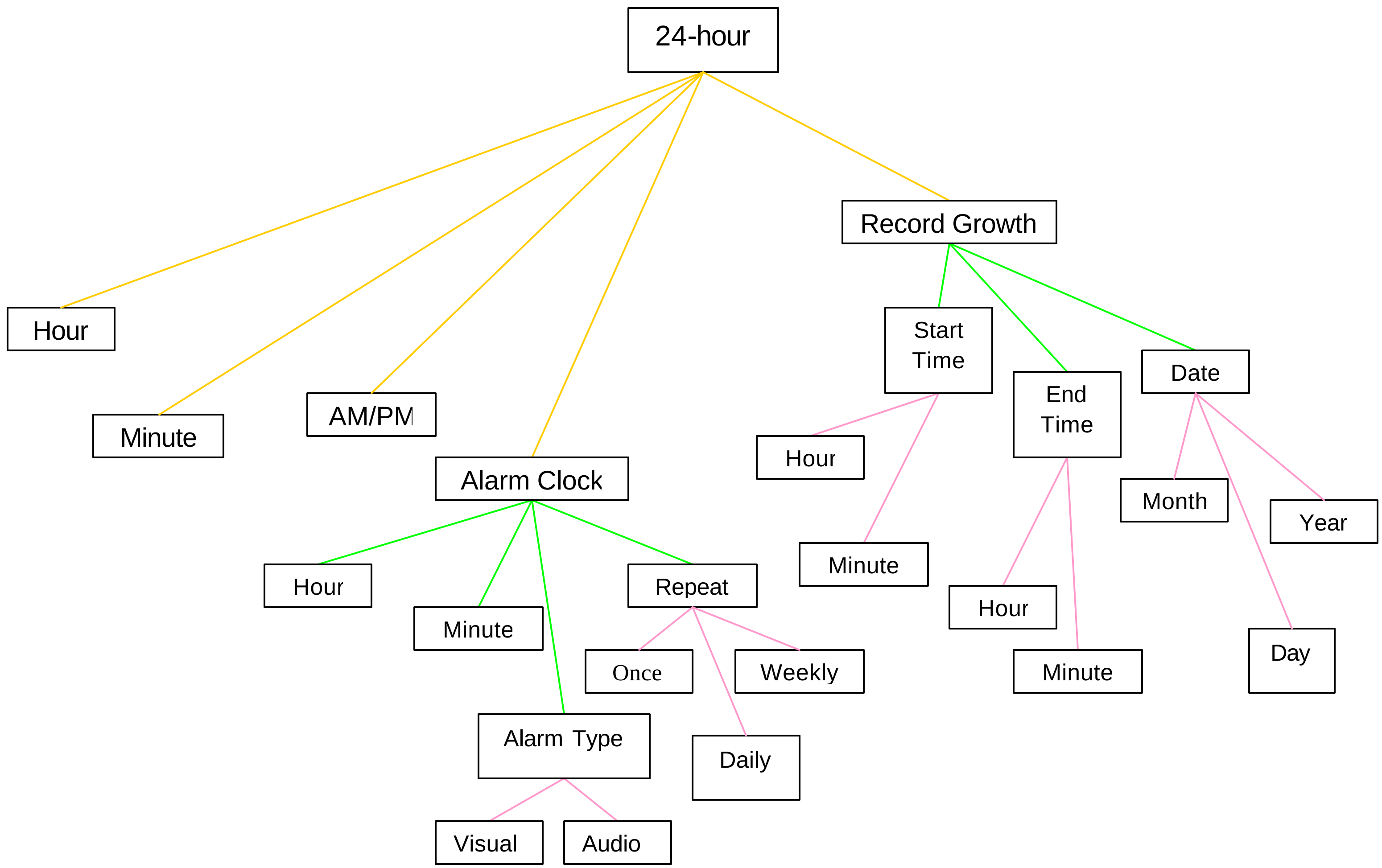
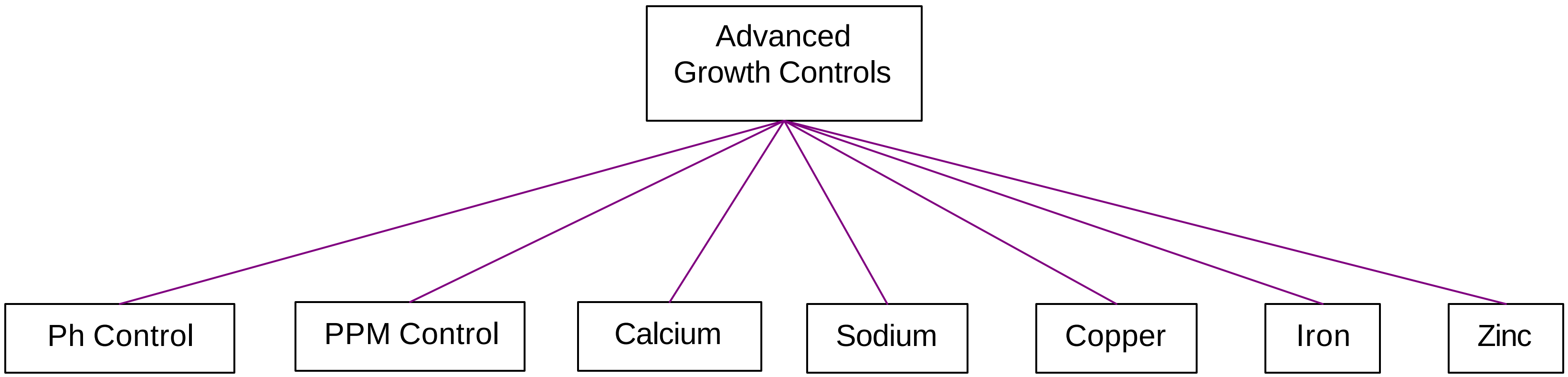


Figure I. Advance Growth Control Screen Functions



APPENDIX D

EXPERIMENTAL PROTOCOL AND SCRIPT

Day 1

When the participant arrives:

1. If necessary: Go meet them in the lobby about 20 min before they plan to be here (since they are always early). Give them a parking pass for their car and either go put it on there yourself or let them go do it.
2. Gather them together and lead them into the testing room.
3. Go over the consent forms:

   "This is the consent form. It has a brief description of the study. Today, you will do several ability tests followed by a mouse training session. In the next session you will complete training on a new system on a computer, followed by several tasks to measure what you have learned. Please read the consent form carefully and ask me any questions you may have. Once you are sure you understand what you have to do for this study, and all your questions have been answered please sign both consent forms here <point to sign line> **at the bottom and date both here** <point to date line>**."**

4. Give one copy of the consent form to the participant:

   "This is your copy of the consent form. It is identical to the one I will keep. Please refer to it later if you experience any problems or have any questions when you are home."

5. Collect the signed consent form from each participant.

6. **"At this time please turn off cell phones and similar devices."**

During Data Collection:

1. CREATE individual testing:

    Follow instructions necessary for individual testing

2. 10-minute break:

    "You can now take a 10-minute break, while I set up the next tasks."

    During break set up mouse training:

    Double-click – mousetrain icon on desktop

    Enter participant 3-digit number (1st number on folder) in Sub Num box > click OK

3. Mouse training:

    "Now you will begin mouse and control training, which is designed to familiarize you to using the mouse and operating the controls that are used in the system you will be trained on in the next session. You are to read the task presented in the middle of the screen and use the control available to complete that task. Work at your own pace as accurately as possible. Let's do a task and you can ask me any questions that you may have. <have the participant perform the task> **Each task has a different control that operates in a different way. Complete the following tasks and continue until a score appears on the screen. Let me know when the score appears. I will be available throughout the training session if you have any questions. Do you**

understand the task? **<**answer questions**>** **You can now continue."**

<Write start time on mouse training section of the participant sheet>

4. Schedule Day 2

<Write end time and %correct on mouse training section of the participant sheet> **"This completes mouse training and our session for today. However, remember this is a multiple day study and we need to schedule a time for you to return within the next 7 days for the final session of this study."** **<**Schedule Day 2 **>**

Day 2

When the participant arrives:

1. If necessary: Go meet them in the lobby about 20 min before they plan to be here (since they are always early). Give them a parking pass for their car and either go put it on there yourself or let them go do it.
2. Gather them together and lead them into the testing room.
3. Go over the consent form again:

   "This is the consent form you signed several days ago. It has a brief description of the study. Today, you will do a refresher mouse training session, then you will complete training on a new system on a computer, followed by several tasks to measure what you have learned. Please read the consent form carefully and ask me any questions you may have."
4. Collect the signed consent form from participant.
5. **"At this time please turn off cell phones and similar devices."**
6. Set up mouse training:

Double-click – refreshmt icon on the desktop

Enter participant 3-digit number (1st number on folder) in Sub Num box > click OK

7. **Refresher Mouse Training:**

"During the previous session you completed mouse and control training. The following tasks are the same as those from the previous session; however this mouse training is much shorter. You are to read the task presented in the middle of the screen and use the control available to complete that task. Complete the following tasks and continue until a score appears on the screen. Work at your own pace and be as accurate as possible. Let me know when the score appears. I will be available throughout the training session if you have any questions. Do you understand the task? <answer questions**> You can now begin."** <Write start time on the refresher mouse training section of the participant sheet>

******As participant continues through the tasks a number will appear after every task, this is a counter to let you know where the participant is, but is not the number correct. Participant should not need a break during training. If he/she does DO NOT exit the program, let it run during the next task and when the participant returns, click 'Task Complete'. Make a note of this and write the number in the lower right down so that trial can be deleted from the data, do worry about the exact trial, it will be apparent when looking at the data.

6. <Write end time and %correct on the refresher mouse training section of the participant sheet> **"Now you have a 5-minute break. You can get up and**

stretch and get a drink of water out in the hall while I set up the next tasks" <Allow participants to get up and stretch and get water while you are setting up training tasks.>

8. During break set up HGC training program:

   Double-click –TrainHGC icon desktop

Training Phase:

1. Set up training:
   a. The presentation folder should display either action or concept training instructions. (NOTE: participant should receive the training condition that matches condition name on folder: action or concept)
   b. The laptop monitor should have the HGC program with demographics screen up. Filled out with the appropriate 3-digit participant number (1st number on folder), select the appropriate task order (2nd number on the folder tab), select the appropriate age group (older or younger), Device – Touchscreen, Vibration – OFF, Mouse Pointer – ON. Select OK.

2. Explain task:

   "The first task is to read the instructions on this piece of paper <point to paper**> and follow the instructions using the mouse to your right on the laptop monitor <**point to laptop monitor**>. The monitor is designed to simulate a hydroponic garden control. Hydroponic gardening is gardening without soil. These types of gardens use nutrient enriched water, which flows under the roots of the plants in reservoirs causing them to grow quicker and larger. During these tasks, some of these instructions may be difficult and**

some may be easy, but do your best to follow each one. Remember, each task has a goal <point to goal> **and the steps needed to accomplish this goal** <point to steps>**. I will flip the tasks when you complete each on"**

3. Practice tasks:

"Let's do practice task #1 together and ask any questions you may have. <walk through task 1> **The last thing you do is** <read last instruction> **which ends the task; the Stop Sign is located at the upper left corner of the screen** <point to the Stop Sign>**. Make sure you click the Stop Sign at the end of each task. (Answer questions and correct any mistakes). Now let's do practice task #2** <walk through and answer questions and correct any mistakes>**. Let's do practice task #3** <walk through and answer questions and correct any mistakes>**. Let's do practice task #4** <walk through and answer questions and correct any mistakes>**. Let's do practice task #5** <walk through and answer questions and correct any mistakes>. **Let's do practice task #6** <walk through and answer questions and correct any mistakes>**.**

**If the participant needs a break before the designated break, break between tasks and resume when the participant returns.

4. "Now you will complete the following tasks just as you completed the practice tasks". "You can now begin task #1, continue through the tasks at your own pace as accurately as you can. We want you to learn to do these tasks so please complete them accurately and at your own pace. (If testing 2 participants**: "Everyone is completing different tasks so some participants may be finished before others".) "Any more questions before we begin?"**

"OK, you can now begin task #1." <Write Part I start time on the action/concept training section of the participant sheet and circle the appropriate training>

5. When the break appears (after 17 trials):

   <Write Part I end time on the action/concept training section of the participant sheet> **"You can now take a short 5 minute break, the restrooms are located out the door and follow the hall to the left; water fountains are located near the restrooms."**

6. After break:

   "Now please continue the tasks by clicking your mouse on the screen" <Write Part II start time on the action/concept training section of the participant sheet>

7. When task is complete:

   <Write Part II end time on the action/concept training section of the participant sheet> **"Now that you have completed training you will take a 10 minute break while I set up the next task".**

8. Select "Q" on the keyboard to end the program

Assessment Phase:

<u>System performance (Task 1) -</u>

1. Set up Task 1:

   a. Double-click – Task1HGC icon on desktop

      The laptop monitor should have the HGC program (it will look the same as the training task) with demographics filled out with the appropriate 3-digit participant number (1st number on folder), select the appropriate task order (3rd number on the folder tab), select the appropriate age group (older or younger), Device – Touchscreen, Vibration – OFF, Mouse Pointer – ON. Select OK until the participant is at the computer station, ready to begin.

b. In the presentation notebook use Task 1-counterbalance number; the counterbalance number is the 3rd number on the folder tab. (ex: Task 1-2 = Task 1, counterbalance 2)

2. **"This task is similar to the tasks you completed earlier; however notice that you are given the goal of the task, but not the steps to complete the task. You are to complete the following tasks by performing the steps necessary to accomplish the given goal** <point to goal>**. Some of these tasks may be difficult and some may be easy, but try your best to complete each one. Please work at your own pace as accurately as possible. Remember,** <click Start Task> **read the goal then click the stop sign** <click Stop Sign>**. Are there any questions before you begin?"** <Write Part I start time on the Task 1 section of the participant sheet>

3. When the break appears (after 17 trials):

   <Write Part I end time on the Task 1 section of the participant sheet> **"You can now take a short 5 minute break, the restrooms are located out the door and follow the hall to the right; water fountains are located near the restrooms and to the left of the door."**

4. After break:

   <Write Part II start time on the Task 1 section of the participant sheet> **"Now please continue the tasks by clicking your mouse one the screen"**

5. When task is complete:

   <Write Part II end time in the Task 1 section of the participant sheet> **"Now that you have completed this task you will take a 5 minute break while I set up the next task."**

6. Select "Q" on the keyboard to end the program

<u>System sub-goal task (Task 2)–</u>

1. Set up Task 2:

   a. Double-click – Task2 icon on desktop

      The laptop monitor should have the HGC program (Task2.exe) with demographics filled out with the appropriate 3-digit participant number (1^{st} number on folder), select the appropriate task order (4^{th} number on the folder tab), select the appropriate age group (older or younger), Device – Touchscreen, Vibration – OFF, Mouse Pointer – ON. Select OK

   b. In presentation notebook use Task 2-counterbalance number; the counterbalance number is the 4^{th} number on the folder tab.

      (ex: Task 2-2 = Task 2, counterbalance 2)

2. **"You will now perform two tasks. Read through the entire task first, and then perform the steps needed to accomplish this task."** <click Start Task> **"After completing the entire task, click the stop sign"** <click Stop sign> **"For each task you should work at your own pace and as accurately as possible.**

Here is the first task." <Write Goal 1 start time on the Task 2 section of the participant sheet>

3. When first task is complete: <Write Goal 1 end time on the Task 2 section of the participant sheet and flip to 2^{nd} task> **"Here is the 2^{nd} task"** <Write Goal 2 start time on the Task 2 section of the participant sheet>

4. When task is complete: <Write Goal 2 end time on the Task 2 section of the participant sheet>

   "Please move to the table. There are 2 pencil-paper tasks to complete".

5. Select "Q" on the keyboard to end the program

Troubleshooting task (Task 3)–

1. Take the task labeled Task 3 out of folder, give participant pencil
2. **"The following items are scenarios of individuals who are having trouble using a Hydroponic Garden Control, the system you were just using. Read each of the scenarios then decide if the solution provided is the correct solution to solve the problem. The last sentence <**point to the last sentence of #1**> is the solution provided for the above problem <**point to the above problem**>. Circle A for True, if you think the solution provided is correct and B for False, if you think the solution provided is wrong. Some of the questions may be difficult or confusing, but please if you are unsure of the answer choose your best guess. Please work at your own pace and be as accurate as possible, you may begin."** <Write start time on the Task 3 section of the participant sheet>

3. When task is complete:

<Write end time on the Task 3 section of the participant sheet>

"Please take a short 5 minute break, while I set up the final set of tasks"

<u>Surface Feature task –</u>

Surface Feature without words:

1. Take the task labeled Task 4 out of folder, give participant pencil

2. "**For each highlighted location <**point to the blanks**>, write the label based on what you remember from the computer system you've been using. This task may be difficult but try your best to complete each screen to your best ability. Once you complete a screen fill-in page please move onto the next page. You cannot return to a page once you have passed it. Work at your own pace as accurately as possible. If you cannot remember a label you can skip it, however once you pass a page you can't return to it. Any questions? You may now begin**" <Write start time for each screen on the Task 4 section of the participant sheet, don't stop the participant between screens just pay attention> (If participant tries to return to the previous page tell him/her that it is not allowed)

3. <Write end time for Task 4>

Surface Feature with words:

1. Take the task labeled Task 5 out of folder, give participant pencil

2. **"This task is similar to the task you just completed, but as you can see you are provided a word list of labels. For each highlighted location <**point to the blanks**>, write the label based on what you remember from the computer**

system using the list below. There are an equal number of labels in the list to blanks on the screen. This task may be difficult, but try your best to complete each screen to your best ability. Once you complete a page please move onto the next page, however, you cannot return to a page once you have passed it. Work at your own pace as accurately as possible. If you cannot remember a label you can skip it, however once you pass a page you can't return to it. Any questions? You may now begin" <Write start time for each screen on the Task 5 section of the participant sheet, don't stop the participant between screens just pay attention> (If participant tries to return to the previous page tell him/her that it is not allowed)

3. <Write end time for Task 5>

End of study

1. Exit interview:
    a. Part I: Structured interview
        i. Get structured interview out of participant folder
        ii. Follow script on interview sheet
    b. Part II: Questionnaire
        i. Get questionnaire out of participant folder
        ii. Turn to Part II exit interview and read aloud the introduction and then give him/her the questionnaire
2. Hand out debriefing and go over it:

   "The study you just did is designed to help us figure out what type of training helps develop and understanding of a system structure. There are two

different types of training involved in this study. One type focuses on completing specific step-by-step instructions and the other focuses on completing generalized steps. As you probably noticed, some of the tasks were more difficult than others. Hopefully, we can see by how long it takes everyone to complete the tasks and how many they got correct which training method helps develop a better system understanding. Do you have any questions about the study?"

3. Compensation:
    a. Fill out checks and have participant sign sheet (no SSN needed) and offer Lab pen and newsletter to participants
    b. Assign participants credits in Experimetrix later
4. Thank participant and (if necessary) walk him/her out to the lobby.

APPENDIX E

EXAMPLE EXIT INTERVIEW

The following questions are for you to tell me your opinion, feelings, or problems you had throughout this study. Read and answer each question, feel free to make comments in the spaces below each question.

Note: Superscripts indicate coding scheme and were not visible on the exit interview presented to participants during the study.

1. How confident would you be in using this system tomorrow? Circle one:

   Not at all confident[1] Somewhat confident[2] Confident[3] Very confident[4]

2. Rate how you thought the training helped you in learning the system. Circle one:

   Poor[1] Fair[2] Good[3] Excellent[4]

3. Did you like the training?

   - ☐ Yes[1]
   - ☐ No[0]

4. Do you think training was adequate for learning the system?

   - ☐ Yes[1]
   - ☐ No[0]

5. What would you change in the training?

6. Have you ever had any experience using any type of hydroponic gardening system?

   - ☐ Yes[1]
   - ☐ No[0]

7. If you selected yes, Do you consider yourself (check all that apply):

   - ☐ A current user (you own one now)
   - ☐ A previous user (you owned one a while ago)
   - ☐ Very familiar with this type of device
   - ☐ Somewhat familiar with this type of device

8. You may use the space below to write any comments about this study:

Exit Interview Results

The following results are from the questionnaire which focused on obtaining personal performance evaluations, improvement suggestions, and previous experience with similar systems. Younger participants reported that they would be confident or very confident (M = 3.469, SD = .621) when asked about their ability to use the hydroponic garden control tomorrow, where as older adults who reported that they would be not at all confident or somewhat confident (M = 2.39, SD = .715). Participants in the action training condition (M = 2.80, SD = .873) and concept training condition (M = 3.06, SD = .840) reported their confidence levels between somewhat confident and confident on their ability to use the hydroponic garden control tomorrow. Participants reported that the training was good in helping them learn the system (M = 3.175, SD = .610) and that the training was adequate for learning the system, (M = .889, SD = .317). Overall, participants reported favorably when asked if they liked the training they received (M = .889, SD = .317).

APPENDIX F

Table 1. Tasks during Training and at Test

Tasks during Training			Tasks at Test			
Screen	Goal	# of Steps	Screen	Task Type	Goal (*mapping*)	# of Steps
Seeds	Plant Sage	7	Seeds	Trained	Plant Lilac	7
Seeds	Plant Lilac	7	Seeds	Trained	View Seed Info Periwinkle	7
Seeds	Plant Grape	7	Seeds	Trained	Adjust Amt to 5	4
Seeds	View Seed Info Spinach	7	Seeds	Untrained	Fertilize Strawberry (*plant*)	7
Seeds	View Seed Info Norway Spruce	7	Seeds	Untrained	Uproot Oregano (*plant*)	7
Seeds	View Seed Info Periwinkle	7	Seeds	Untrained	Plant Row 2 Tarragon (*1 step > plant*)	8
Seeds	Adjust Amt to 9	4	Medium	Trained	Adjust Gel to 96	5
Seeds	Adjust Amt to 5	4	Medium	Trained	Adjust Lqd to 600	5
Seeds	Adjust Amt to 15	4	Medium	Trained	Adjust Amt to 2	4
Medium	Adjust Gel to 100	5	Medium	Untrained	Adjust Lqd to Preset 1 (*1 step < adjust lqd*)	4
Medium	Adjust Gel to 96	5	Medium	Untrained	Adjust Gel to Preset 4 (*1 step < adjust gel*)	4
Medium	Adjust Gel to 90	5	Medium	Untrained	Store Gel 105 to Preset 3 (*1 step > adjust gel*)	6
Medium	Adjust Lqd to 1010	5	Climate	Trained	Nov-Feb Toledo, OR	6
Medium	Adjust Lqd to 1250	5	Climate	Trained	Alt Clearfield, UT to 1500	5
Medium	Adjust Lqd 600	5	Climate	Trained	Nov-Feb & Alt Sacramento, CA to 500	7
Medium	Adjust Amt to 8	4	Climate	Untrained	Mar-June Birmingham, AL (*Nov-Feb*)	6
Medium	Adjust Amt to 2	4	Climate	Untrained	July-Oct & Alt San Antonio, TX to 7000 (*Nov-Feb & Alt*)	7
Medium	Adjust Amt to 10	4	Climate	Untrained	Alt Durham, NC to 6000 (*Alt*)	5
Climate	Nov-Feb Southport, NC	6	ADV	Trained	(from Medium) Ph Control to -13	5
Climate	Nov-Feb Toledo, OR	6	ADV	Trained	(from Seeds) Zinc to 7	5
Climate	Nov-Feb Moose Pass, AK	6	ADV	Untrained	(from Seeds) PPM to -5	5
Climate	Alt Aspen, CO to 6700	5	ADV	Untrained	(from Medium) Sodium to 1	5
Climate	Alt New Orleans, LA to 0	5	MSG	Trained	(from Seeds) Flood Warning	5
Climate	Alt Clearfield, UT to 1500	5	MSG	Trained	(from Medium) Storm Warning	5
Climate	Nov-Feb & Alt Boston, MA to 800	7	MSG	Trained	(from Climate) Fertilizing Failure	5
Climate	Nov-Feb & Alt Sacramento, CA to 500	7	MSG	Untrained	(from Medium) Tornado Warning	5
Climate	Nov-Feb Beaver, OK to 3800	7	MSG	Untrained	(from Seeds) Planting Reminder	5

Tasks during Training			Tasks at Test			
Screen	Goal	# of Step	Screen	Task Type	Goal (*mapping*)	# of Step
ADV	(from Medium) Ph Control to -13	5	MSG	Untrained	(from Climate) Fertilizer Success	5
ADV	(from Seeds) Zinc to 7	5	Settings	Trained	(from Medium) Current Time 11:15am	8
MSG	(from Seeds) Flood Warning	5	Settings	Trained	(from Seeds) Time Zone Pacific	5
MSG	(from Medium) Storm Warning	5	Settings	Trained	(from Climate) Daily Audio Alert 10am	10
MSG	(from Climate) Fertilizing Failure	5	Settings	Untrained	(from Medium) Current Date 2-28-03	7
Settings	(from Seeds) Time Zone Pacific	5	Settings	Untrained	(from Seeds) Language Spanish	5
Settings	(from Medium) Current Time 11:15am	8	Settings	Untrained	(from Climate) Record Growth Gel 99 on 2-1-03,	9
Settings	(from Climate) Daily Audio Alert 10am	10				

APPENDIX G

Table 1. Task Presentation Order and Number of Steps during Training

Training Task Presentation Order 1			Training Task Presentation Order 2		
Screen	Goal	# of Steps	Screen	Goal	# of Steps
Medium	Adjust Amt to 8	4	Seeds	Plant Sage	7
Seeds	View Seed Info Spinach	7	Climate	Nov-Feb & Alt Boston, MA to 800	7
Climate	Nov-Feb & Alt Boston, MA to 800	7	Settings	(from Seeds) Time Zone Pacific	5
Medium	Adjust Lqd to 1250	5	ADV	(from Medium) Ph Control to -13	5
Climate	Alt Aspen, CO to 6700	5	Climate	Nov-Feb Toledo, OR	6
Seeds	Adjust Amt to 15	4	Seeds	Plant Lilac	7
Medium	Adjust Gel to 90	5	Medium	Adjust Lqd to 1250	5
Climate	Nov-Feb Toledo, OR	6	Seeds	View Seed Info Spinach	7
MSG	(from Seeds) Flood Warning	5	Climate	Alt New Orleans, LA to 0	5
Medium	Adjust Amt to 10	4	Seeds	Adjust Amt to 9	4
Climate	Nov-Feb Southport, NC	6	Medium	Adjust Gel to 100	5
Seeds	View Seed Info Periwinkle	7	Seeds	Plant Grape	7
MSG	(from Medium) Storm Warning	5	Climate	Alt Clearfield, UT to 1500	5
Seeds	Plant Sage	7	Medium	Adjust Gel to 90	5
Medium	Adjust Gel to 96	5	Climate	Nov-Feb & Alt Beaver, OK to 3800	7
Settings	(from Seeds) Time Zone Pacific	5	Seeds	Adjust Amt to 15	4
Climate	Nov-Feb & Alt Sacramento, CA to 500	7	Climate	Nov-Feb Southport, NC	6
ADV	(from Seeds) Zinc to 7	5	Medium	Adjust Gel to 96	5
Seeds	Adjust Amt to 5	4	Settings	(from Climate) Daily Audio Alert 10am	10
Climate	Nov-Feb & Alt Beaver, OK to 3800	7	Seeds	View Seed Info Periwinkle	7
Seeds	Plant Grape	7	Medium	Adjust Amt to 2	4

Training Task Presentation Order 1			Training Task Presentation Order 2		
Screen	Goal	# of Steps	Screen	Goal	# of Steps
Medium	Adjust Amt to 2	4	MSG	(from Seeds) Flood Warning	5
Settings	(from Medium) Current Time 11:15am	8	ADV	(from Seeds) Zinc to 7	5
Climate	Alt Clearfield, UT to 1500	5	Medium	Adjust Amt to 8	4
Seeds	Plant Lilac	7	Climate	Alt Aspen, CO to 6700	5
Medium	Adjust Lqd 600	5	Medium	Adjust Lqd 600	5
Seeds	Adjust Amt to 9	4	Seeds	Adjust Amt to 5	4
Medium	Adjust Lqd to 1010	5	Climate	Nov-Feb & Alt Sacramento, CA to 500	7
Climate	Nov-Feb Moose Pass, AK	6	Medium	Adjust Lqd to 1010	5
MSG	(from Climate) Fertilizing Failure	5	MSG	(from Climate) Fertilizing Failure	5
Medium	Adjust Gel to 100	5	Settings	(from Medium) Current Time 11:15am	8
Settings	(from Climate) Daily Audio Alert 10am	10	Climate	Nov-Feb Moose Pass, AK	6
ADV	(from Medium) Ph Control to -13	5	Medium	Adjust Amt to 10	4
Seeds	View Seed Info Norway Spruce	7	MSG	(from Medium) Storm Warning	5
Climate	Alt New Orleans, LA to 0	5	Seeds	View Seed Info Norway Spruce	7

APPENDIX H

Table 1. Participant Counterbalances

Subject Number	Training Type	Training CB	System Performance CB	Subgoals CB
(0/1)01	Action	1	1	1
(0/1)02	Action	1	1	1
(0/1)03	Action	1	1	2
(0/1)04	Action	1	1	2
(0/1)05	Action	1	2	1
(0/1)06	Action	1	2	1
(0/1)07	Action	1	2	2
(0/1)08	Action	1	2	2
(0/1)09	Action	2	1	1
(0/1)10	Action	2	1	1
(0/1)11	Action	2	1	2
(0/1)12	Action	2	1	2
(0/1)13	Action	2	2	1
(0/1)14	Action	2	2	1
(0/1)15	Action	2	2	2
(0/1)16	Action	2	2	2
(0/1)17	Concept	1	1	1
(0/1)18	Concept	1	1	1
(0/1)19	Concept	1	1	2
(0/1)20	Concept	1	1	2
(0/1)21	Concept	1	2	1
(0/1)22	Concept	1	2	1
(0/1)23	Concept	1	2	2
(0/1)24	Concept	1	2	2
(0/1)25	Concept	2	1	1
(0/1)26	Concept	2	1	1
(0/1)27	Concept	2	1	2
(0/1)28	Concept	2	1	2
(0/1)29	Concept	2	2	1
(0/1)30	Concept	2	2	1
(0/1)31	Concept	2	2	2
(0/1)32	Concept	2	2	2

Note: (0/1): 0 = younger adults, 1 = older adults

APPENDIX I

Table 1. Structure of Troubleshooting Task

Troubleshooting task	Answer	Screen	Task Type
Kevin wanted to increase Copper nutrient level to +10 but the current time options appeared. The current time options appeared because he selected Settings instead of the ADV.	TRUE	ADV	Trained
Elaine wanted to adjust the PPM Control to 8, so she clicked 'Settings', but was unable to accomplish her goal. Elaine could not adjust the PPM Control because she clicked 'Settings' instead of 'MSG'.	FALSE	ADV	Untrained
Ralph wanted to set the system to the climate of Madison, Wisconsin so he selected the correct state and city but the 'Set Climate' button was still "grayed out". He could not select the 'Set Climate' button because the appropriate Altitude was not selected.	FALSE	Climate	Trained
Andrew is planting some trees native to Aspen area of Colorado, so he wants to adjust the altitude to mimic that of the area. After selecting Colorado, Andrew tries to adjust the altitude but the altitude control is "grayed out". The control is "grayed out" because he did not select the appropriate city.	TRUE	Climate	Untrained
Henry wanted to select Gel Medium level 101 but the medium selector controls were not visible. The controls were hidden because Henry did not select a Medium type.	TRUE	Medium	Trained
Patrick wants to set the growing medium to Gel Medium Preset 1, but the Preset 4 button was inaccessible for Patrick to use. He cannot use Gel Medium Preset 1 because he did not select the medium level first.	FALSE	Medium	Untrained
Xavier knows he had a "Fertilizing Failure" on 8-2-2001 but he cannot find the detailed information in the Settings screen. To view more information on the recording he needs to select the corresponding date in the Current Date section of the Settings screen.	FALSE	MSG	Trained
Lara tried to view information on a tornado warning that occurred on 8-4-2001, but she keeps getting information on a fertilizing success, which occurred on 6-24-2001. Lara is getting the wrong information because she did not select the correct date in the Settings screen.	FALSE	MSG	Untrained
Tommy wants to plant Sunflower seeds. He first attempted to select the flower seed category but it was unavailable. Tommy could not select the seed category because he did not select the correct growing medium.	FALSE	Seed	Trained
Adam is trying to plant a SEED but he keeps getting the message "NO Poisonous plants available!" Adam is having a problem planting a SEED because he selected the Poisonous Type instead of the Non-poison Type.	TRUE	Seed	Untrained
Janice wanted to set the alarm type to a daily audio alert, but the 'Alarm 5:30pm' message appeared instead. She could not set the visual alarm type because she was in the message history screen instead of the ADV screen.	FALSE	Settings	Trained
In the Record Growth section the start time is "grayed out" and Zachary cannot record the growth of all his plants using Liquid Medium at level 800. He cannot adjust the start time because he neglected to select the appropriate clock setting of 12-hour or 24-hour.	TRUE	Settings	Untrained

APPENDIX J

TROUBLESHOOTING TASK

The following items are scenarios of individuals who are having trouble using a Hydroponic Garden Control. Hydroponic gardening is gardening without soil. These types of gardens use nutrient enriched water, which flows under the roots of the plants in reservoirs causing them to grow quicker and larger.

Read each of the scenarios then decide if the solution provided is either True or False. **Circle A for True and B for False.** Some of the questions may be difficult or confusing, but please if you are unsure of the answer choose your best guess.

1. Henry wanted to select Gel Medium level 101 but the medium selector controls were not visible. The controls were hidden because Henry did not select a Medium type.

   a. True
   b. False

2. Tommy wants to plant Sunflower seeds. He first attempted to select the flower seed category but it was unavailable. Tommy could not select the seed category because he did not select the correct growing medium.

   a. True
   b. False

3. In the Record Growth section the start time is "grayed out" and Zachary cannot record the growth of all his plants using Liquid Medium at level 800. He cannot adjust the start time because he neglected to select the appropriate clock setting of 12-hour or 24-hour.

   a. True
   b. False

4. Janice wanted to set the alarm type to a daily audio alert, but the 'Alarm 5:30pm' message appeared instead. She could not set the visual alarm type because she was in the message history screen instead of the ADV screen.

   a. True
   b. False

5. Ralph wanted to set the system to the climate of Madison, Wisconsin so he selected the correct state and city but the ‘Set Climate’ button was still “grayed out”. He could not select the ‘Set Climate’ button because the appropriate Altitude was not selected.

   a. True
   b. False

6. Patrick wants to set the growing medium to Gel Medium Preset 1, but the Preset 1 button was inaccessible for Patrick to use. He cannot use Gel Medium Preset 1 because he did not select the medium level first.

   a. True
   b. False

7. Elaine wanted to adjust the PPM Control to 8, so she clicked ‘Settings’, but was unable to accomplish her goal. Elaine could not adjust the PPM Control because she clicked ‘Settings’ instead of ‘MSG’.

   a. True
   b. False

8. Kevin wanted to increase Copper nutrient level to +10 but the current time options appeared. The current time options appeared because he selected Settings instead of the ADV.

   a. True
   b. False

9. Andrew is planting some trees native to Aspen area of Colorado, so he wants to adjust the altitude to mimic that of the area. After selecting Colorado, Andrew tries to adjust the altitude but the altitude control is “grayed out”. The control is “grayed out” because he did not select the appropriate city.

   a. True
   b. False

10. Lara tried to view information on a tornado warning that occurred on 8-4-2001, but she keeps getting information on a fertilizing success, which occurred on 6-24-2001. Lara is getting the wrong information because she did not select the correct date in the Settings screen.

   a. True
   b. False

11. Adam is trying to plant a SEED but he keeps getting the message "NO Poisonous plants available!" Adam is having a problem planting a SEED because he selected the Poisonous Type instead of the Non-poisonous Type.

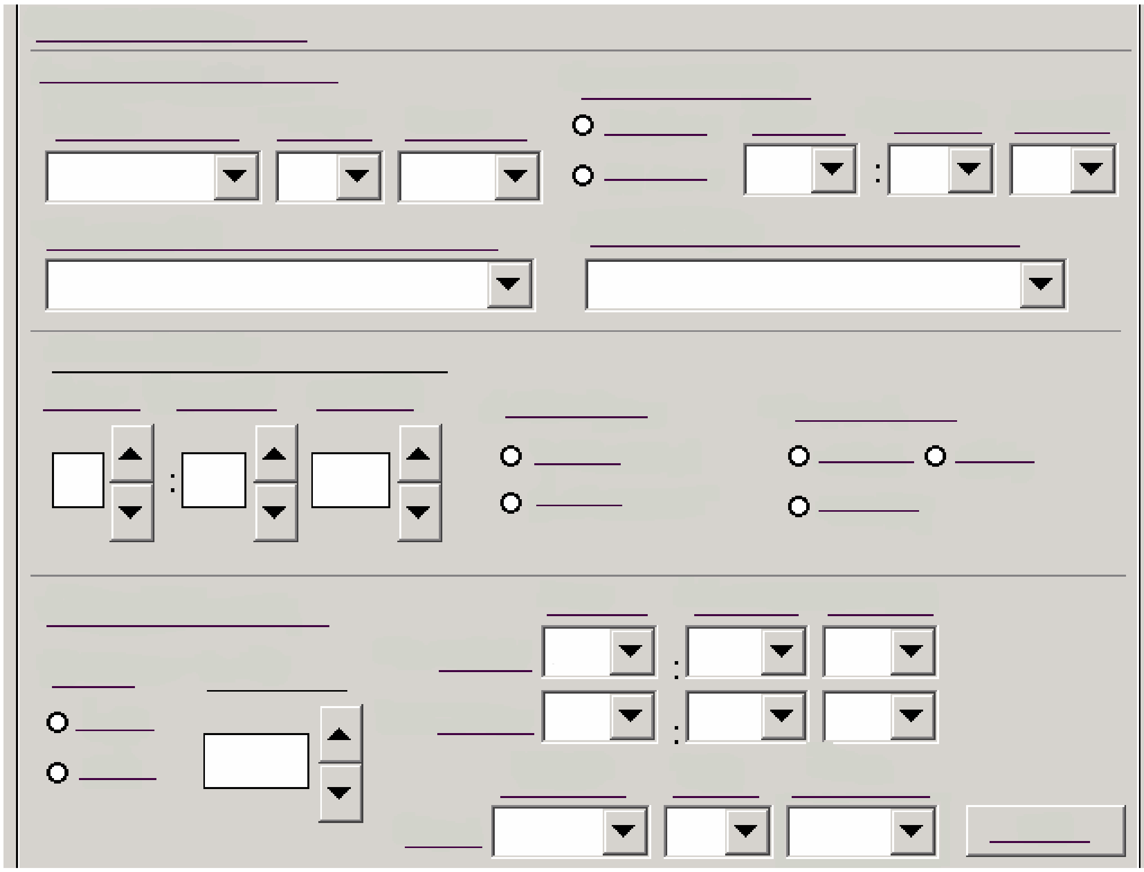
    a. True
    b. False

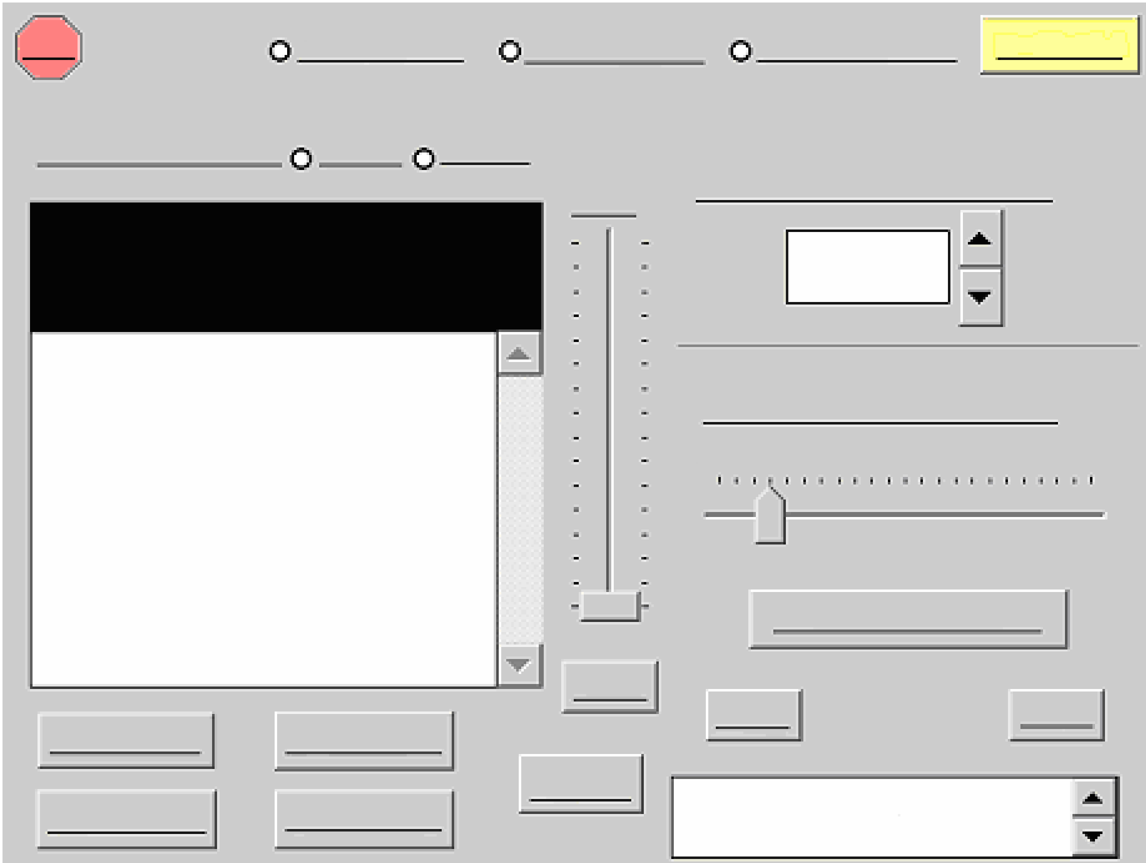
12. Xavier knows he had a "Fertilizing Failure" on 8-2-2001 but he cannot find the detailed information in the Settings screen. To view more information on the recording he needs to select the corresponding date in the Current Date section of the Settings screen.

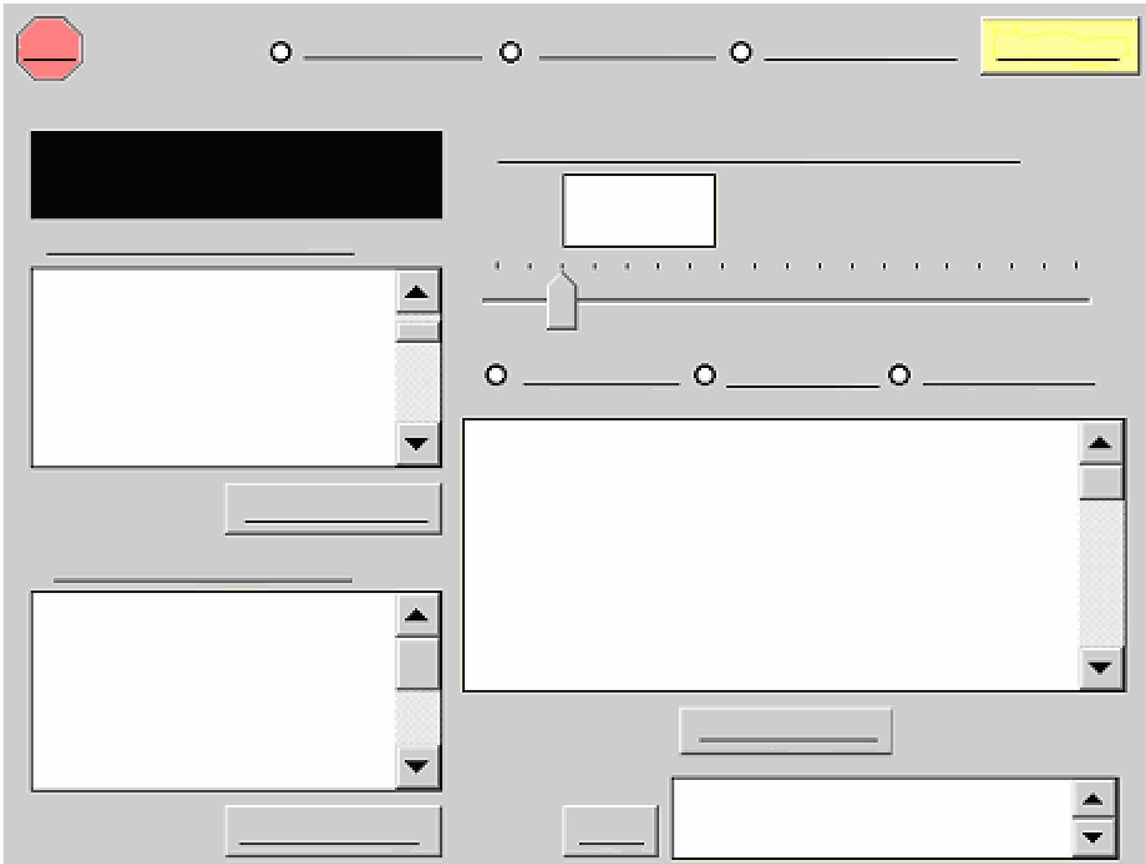
    a. True
    b. False

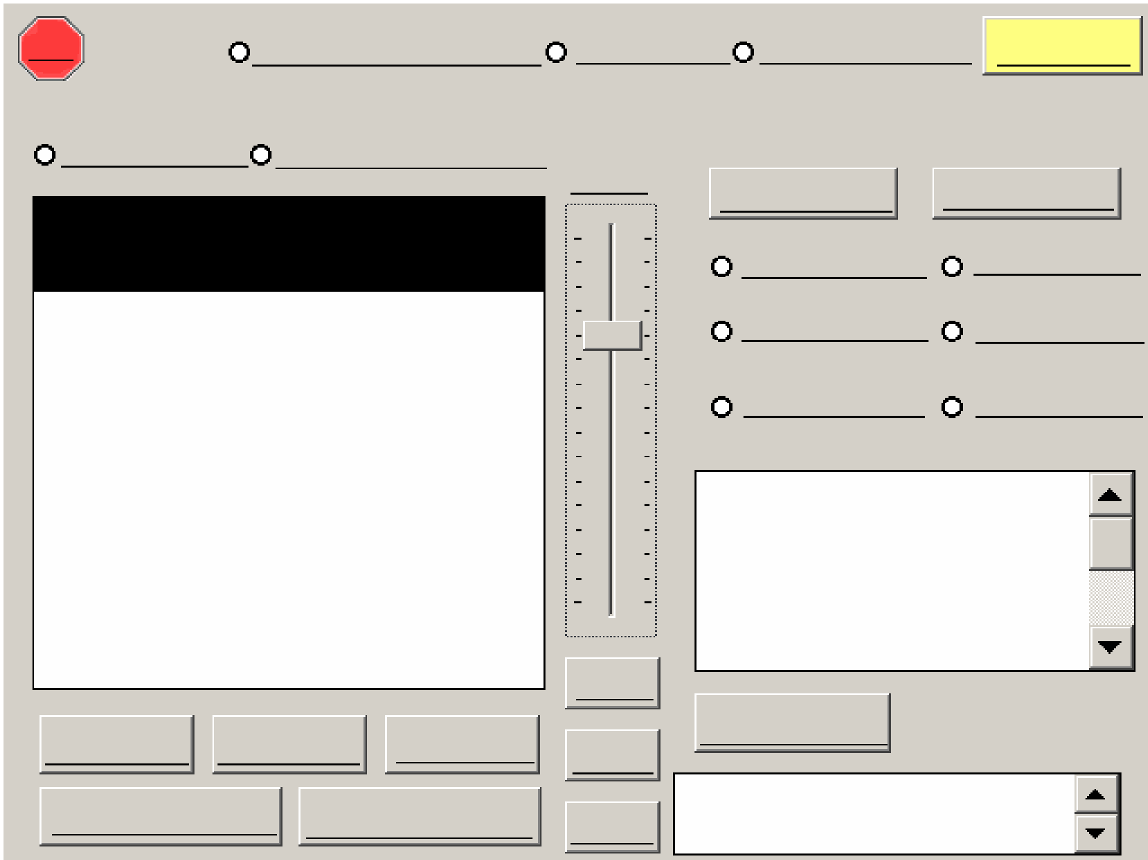
APPENDIX K

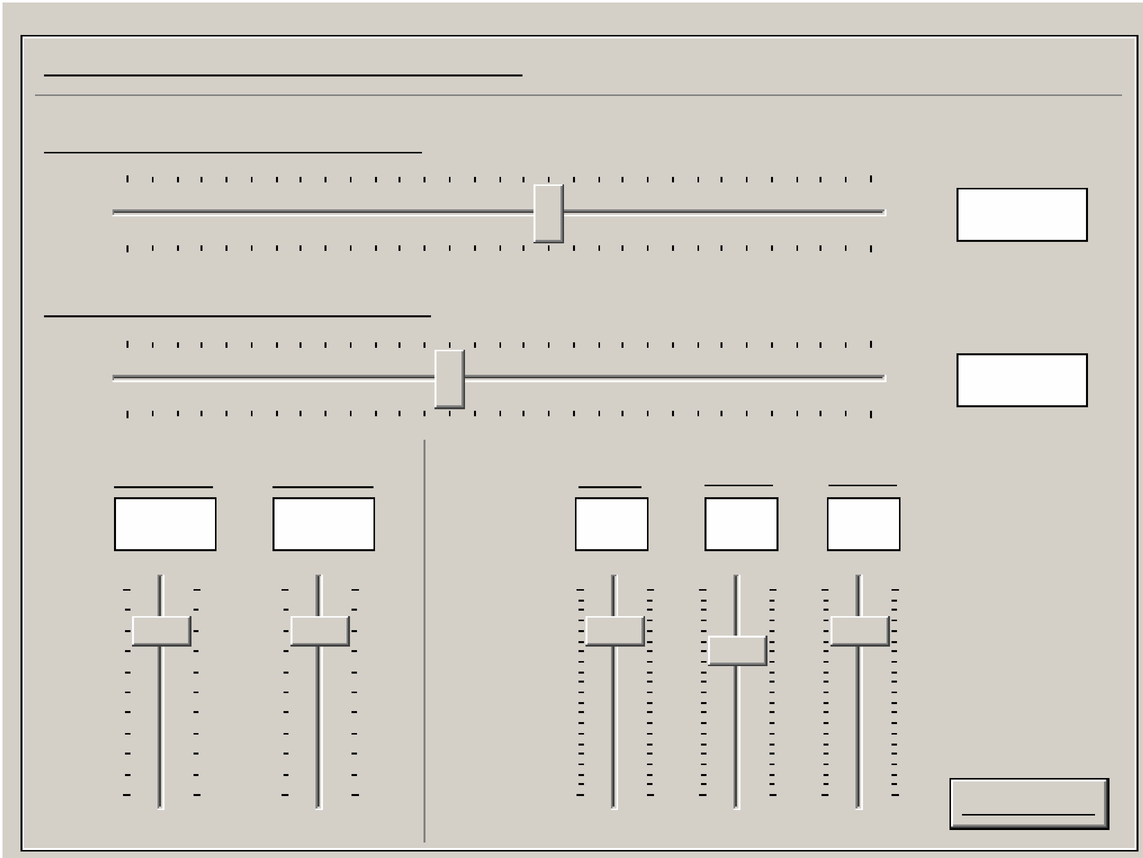
SYSTEM LAYOUT TASK WITHOUT WORD LIST

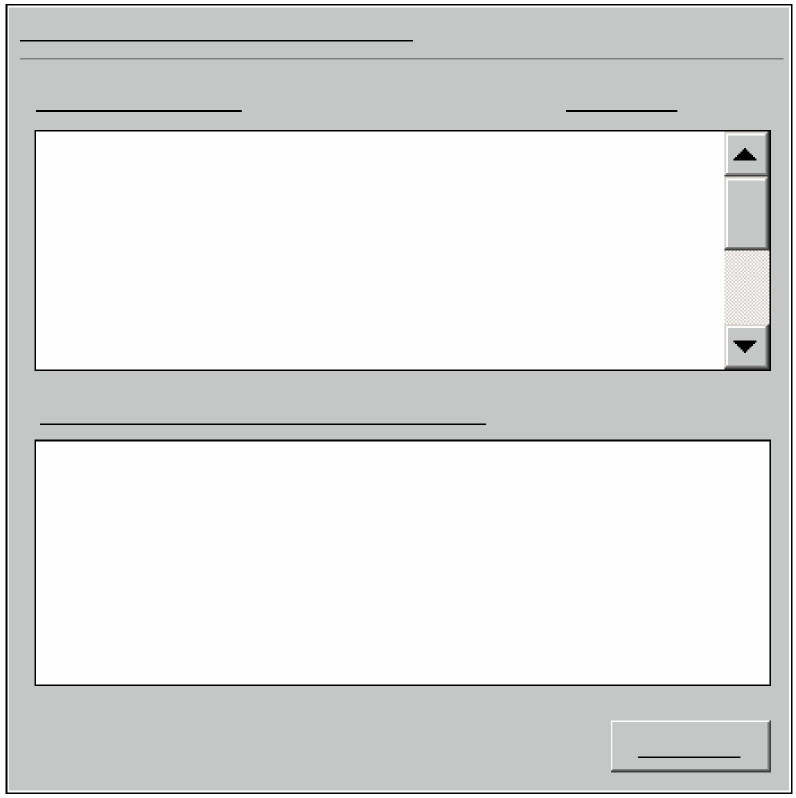






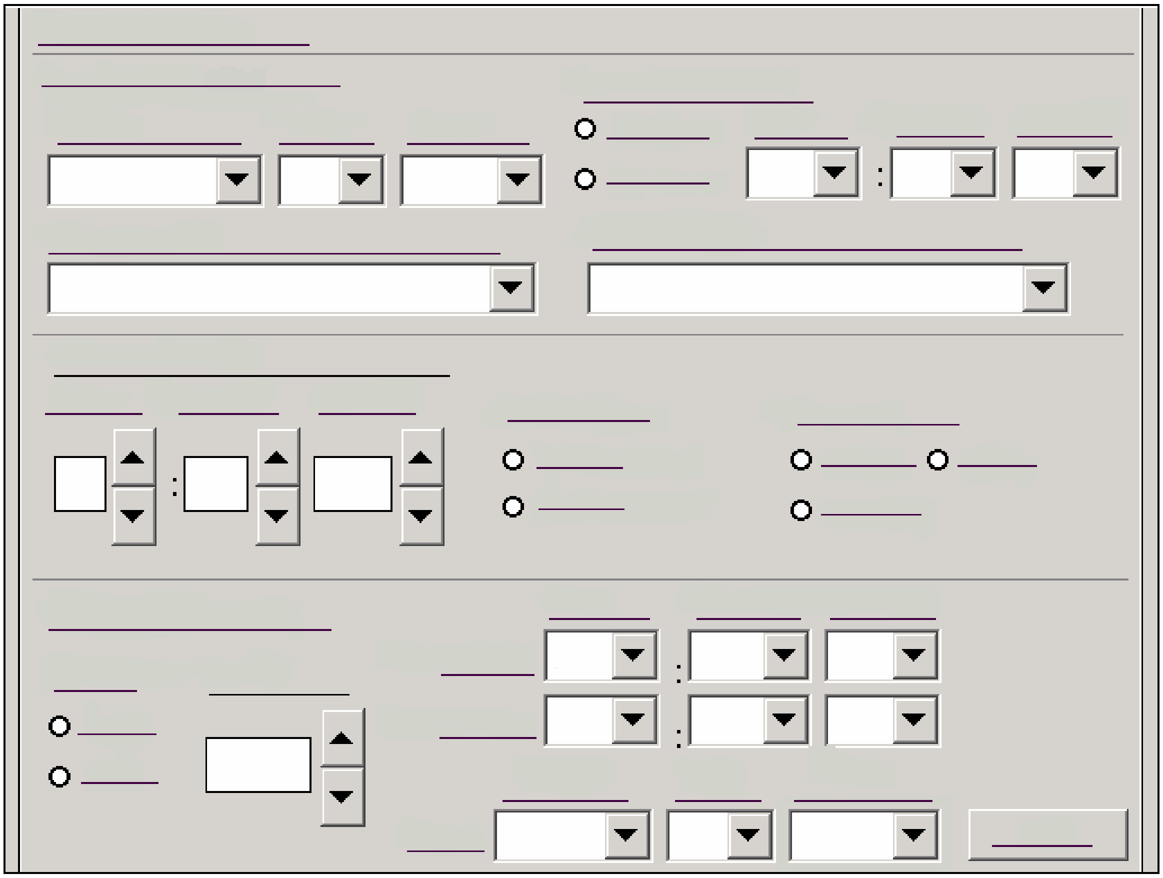






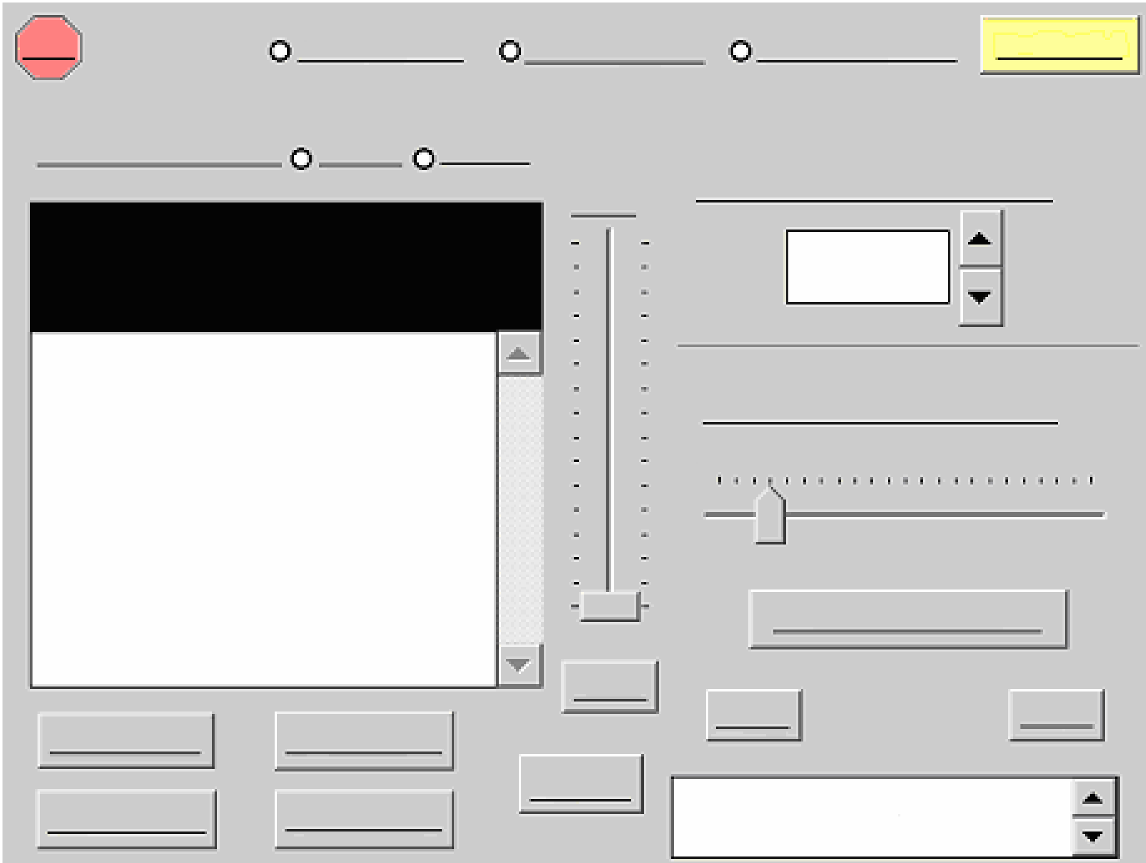
APPENDIX L

SYSTEM LAYOUT TASK WITH WORD LIST



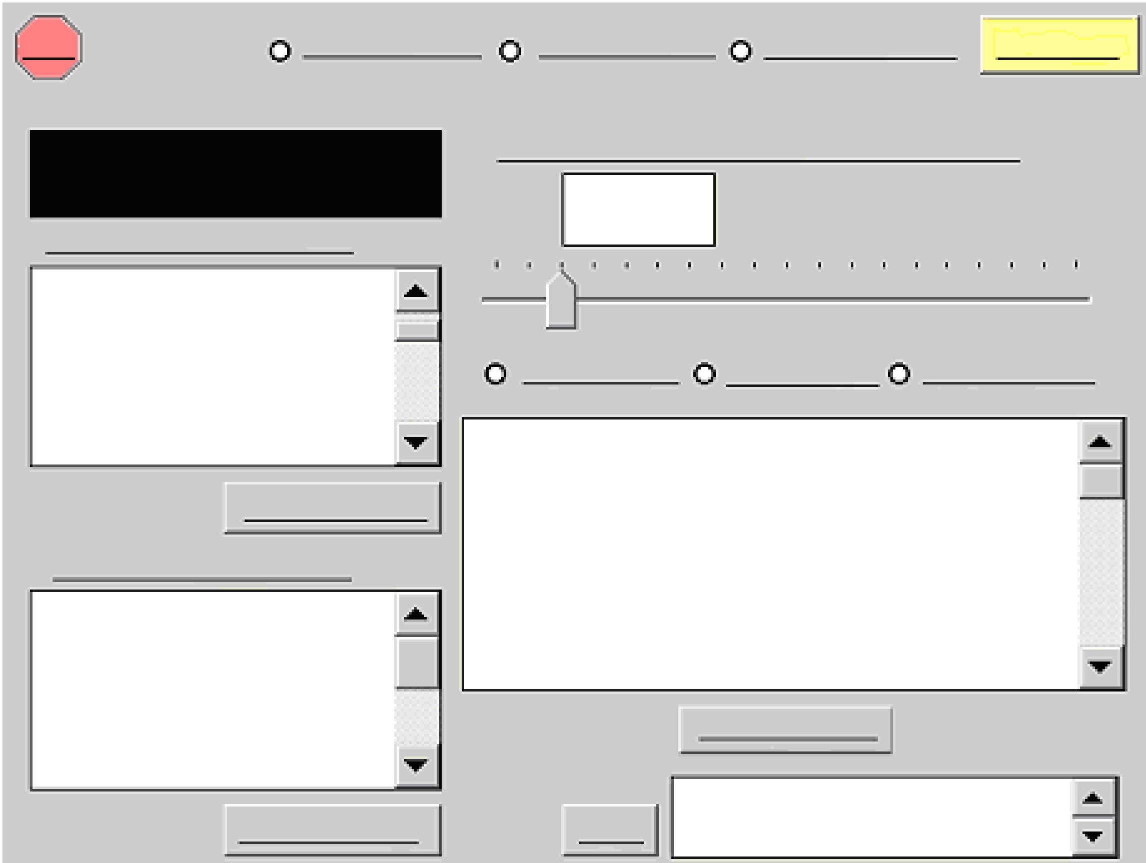
Word list

12-hour	Day	Month
24-hour	End time	Month
Alarm Clock	Gel	OK
Alarm type	Hour	Once
AM/PM	Hour	Record Growth
AM/PM	Hour	Repeat
AM/PM	Language	Start time
Audio alert	Level	Time zone
Current date	Lqd	User Settings
Current time	Medium	Visual alert
Daily	Minutes	Weekly
Date	Minutes	Year
Day	Minutes	Year



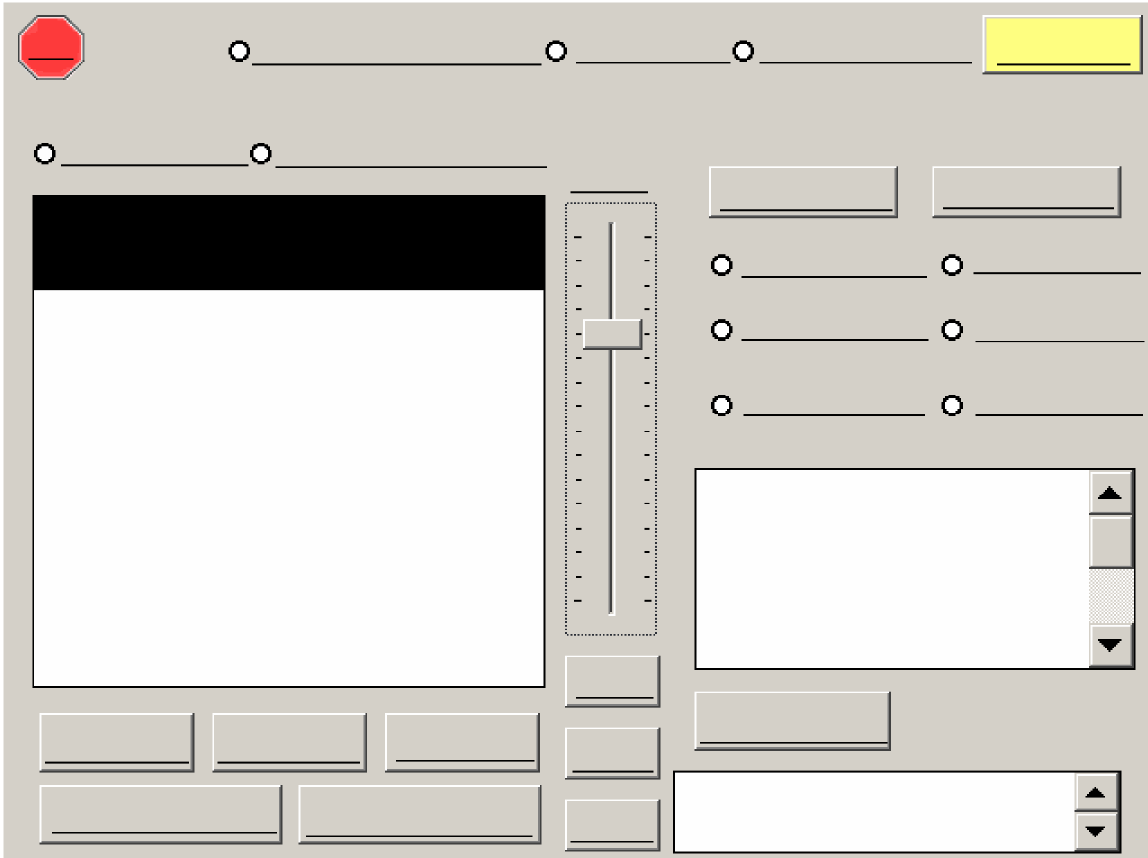
Word List

Adv	Preset 3
Gel	Preset 4
Seeds	Medium
Lqd	Select a medium
Medium Selector 1	Select level
Medium Selector 2	Settings
MSG	Stop
OK	Store
Preset 1	Amt
Preset 2	Climate



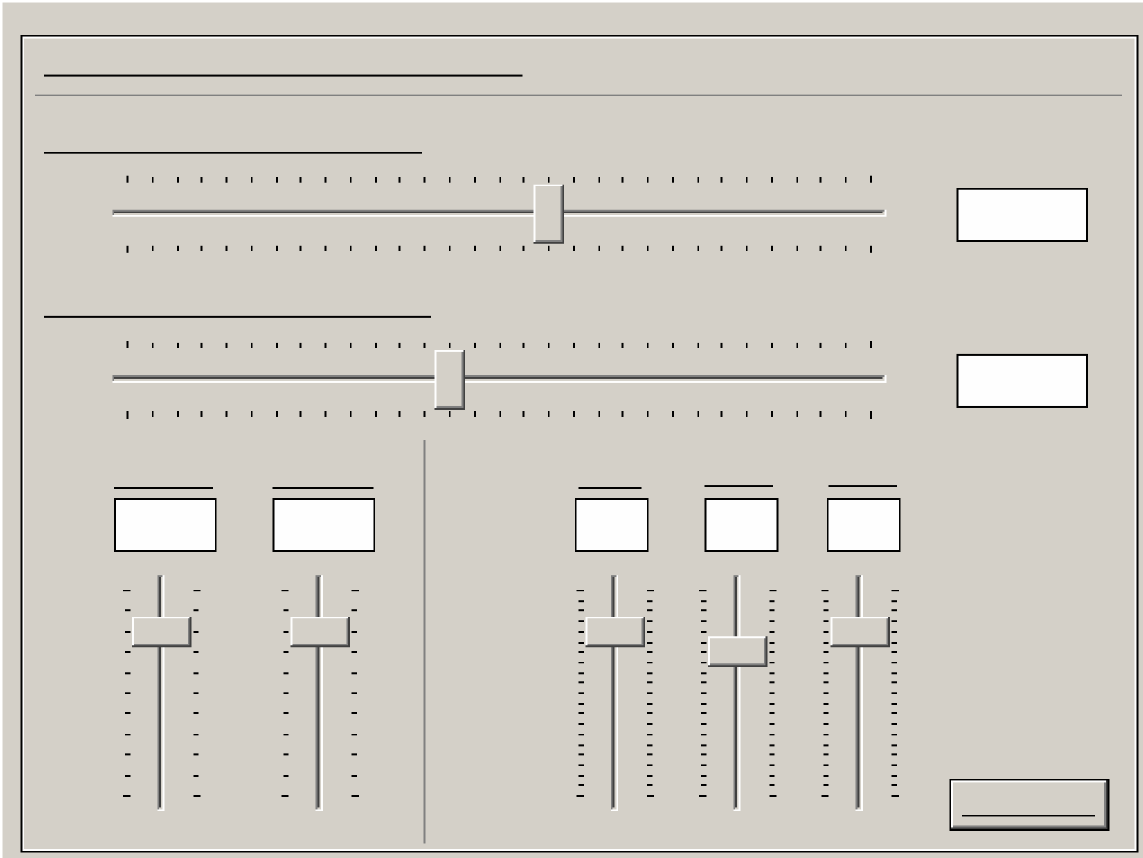
Word List

Available Cities	Seeds
Available States	Select City
Climate	Select State
Jul-Oct	Select Your Altitude
Mar-Jun	Set Climate
Medium	Settings
MSG	Stop
Nov-Feb	



Word list

ADV
Amt
Climate
Fertilize
Flower
Fruit
Herb
Medium
MSG
Next Row
Non-poison
OK
Plant
Poisonous
Previous Row
Row List
Seeds
Seed Information
Select Seed
Settings
Shrub
Stop
Up-root
Vegetable
Tree



Word List

Advance Growth Controls

Calcium

Copper

Iron

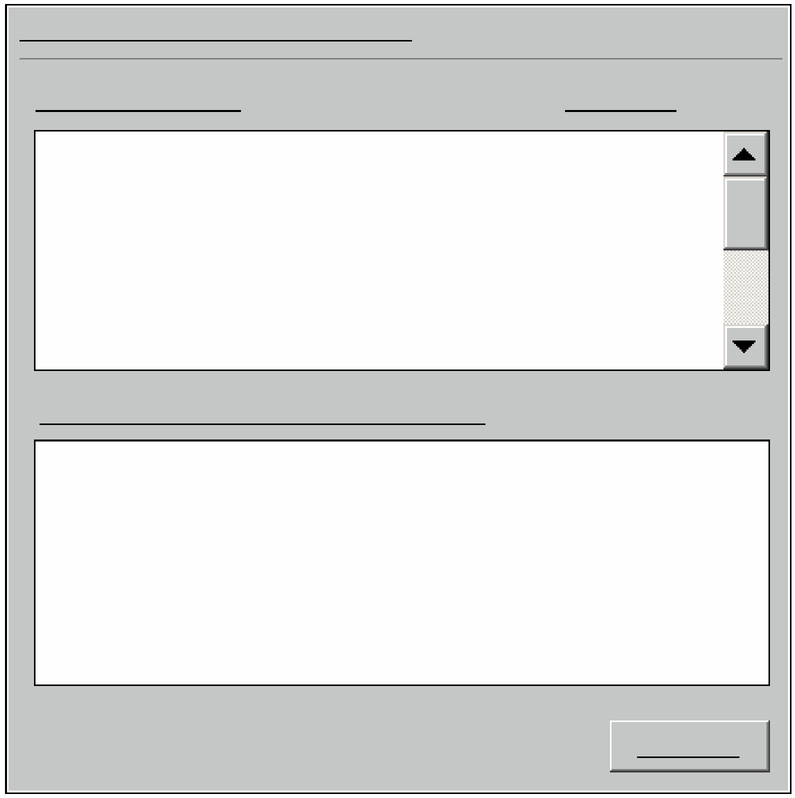
OK

Ph Control

PPM

Sodium

Zinc



Word List

Date

Detailed Information

Message

Message History

OK

REFERENCES

Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review*, 89, 369-406.

Anderson, J. R. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.

Anderson, J. R. (1989). Practice, working memory and the ACT-super(*) theory of skill acquisition: A comment on Carlson, Sullivan, and Schneider. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 527-530.

Bruce, P. R., & Herman, J. F. (1986). Adult age differences in spatial memory: effects of distinctiveness and repeated experience. *Journal of Gerontology, 41*, 744-777.

Brown, J. L., Fischo, V. V., & Hanna, G. (1993). *The Nelson-Denney Reading Test*. Chicago: Riverside Publishing Co.

Carlson, R. A., Sullivan, M. A., & Schneider, W. (1989). Practice and working memory effects in building procedural skill. *Journal of Experimental Psychology: Learning Memory, and Cognition, 15*, 517-526.

Carlson, R. A. & Schneider, W. (1989). Practice effects and composition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 531-533.

Catrambone, R. (1995). Aiding subgoal learning: Effects on transfer. *Journal of Educational Psychology, 87*, 5-17.

Catrambone, R. (1998). The subgoal learning model: Creating better examples so that students can solve novel problems. *Journal of Experimental Psychology: General, 127*, 355-376.

Cerella, J. (1985). Information processing rates in the elderly. *Psychological Bulletin, 98*, 67-83.

Charness, N., Kelley, C. L., Bosman, E. A., & Mottram, M. (1996). Cognitive theory and word processing training: When prediction fails. In W. A. Rogers, A. D. Fisk, & N. Walker (Eds.), *Aging and skilled performance: Advances in theory and applications* (pp. 241-265). Mahwah, NJ: Erlbaum.

Charness, N., Kelley, C. L., Bosman, E. A., & Mottram, M. (2001). Word-processing training and retraining: Effects of adult age, experience, and interface. *Psychology and Aging, 16*(1), 110-127.

Charness, N., Schuman, C. E., & Boritz, G. A. (1992). Training older adults in words processing: Effects of age, training technique and computer anxiety. *International Journal of Aging and Technology, 5*, 79-106.

Campbell, D.T. & Stanley, J.C. (1963). *Experimental and quasi-experimental designs for research*. Boston: Houghton Mifflin Company.

Craik, F. I. M. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.), *Human memory and cognitive abilities* (pp. 409-422). Amsterdam: Elsevier.

Czaja, S. J., Hammond, K., Blascovich, J. J., & Swede, H. (1989). Age related differences in learning to use a text-editing system. *Behavior and Information Technology, 8*, 309-319.

Czaja, S. J., Sharit, J., Charness, N., Fisk, A. D., & Rogers, W. A. (2001). The Center for Research and Education on Aging and Technology Enhancement (CREATE): A program to enhance technology for older adults. *Gerontechnology, 1*, 50-59.

Day, E. A., Winfred, A. & Gettman, D. (2001). Knowledge structures and the acquisition of a complex skill. *Journal of Applied Psychology, 86*, 1022-1033.

Dix, A., Finlay, J., Abowd, G., & Beale, R. (1998). *Human-computer interaction* (2nd ed.). New York: Prentice Hall Europe.

Egan, D. E., & Gomez, L. M. (1985). Assaying, isolating, and accommodating individual differences in learning a complex skill. In R.F. Dillon (Vol. Ed.), *Individual differences in cognition: Vol. 2* (pp. 173-217). New York: Academic Press.

Ekstrom, R. B., French, J. W., Harman, H. H., & Dermen, D. (1976). *Manual for Kit of Factor Referenced Cognitive Test*. Princeton, NJ: Educational Testing Service.

Elias, P. K., Elias, M. F., Robbins, M. A. & Gage, P. (1987). Acquisition of word-processing skills by younger, middle-aged, and older adults. *Psychology and Aging, 2*, 340-348.

Federal Interagency Forum on Aging-Related Statistics. (2000). *Older Americans 2000: Key indicators of well-being*. Retrieved March 25, 2002, from http://www.agingstats.gov

Fisk, A. D., & Fisher D. L. (1994). Brinley plots and theories of aging: The explicit, muddled, and implicit debates. *Journal of Gerontology, 49*(2), P81-P89.

Fisk, A. D., Fisher, D. L. & Rogers, W. A. (1992). General slowing alone cannot explain age-related search effects: Reply to Cerella (1991). *Journal of Experimental Psychology: General, 121*(1), 73-78.

Fisk, A. D., McGee, N. D., & Giambra, L. M. (1988). The influence of age on consistent and varied semantic-category search performance. *Psychology and Aging, 3*, 323-333.

Fisk, A. D., Rogers, W. A., & Giambra, L. M. (1990). Consistent and varied memory/visual search: Is there an interaction between age and response-set effects? *Journals of Gerontology, 45*, 81-71

Folstein, M. F., Folstein, S. E,. & McHugh, P. R. (1975). 'Mini-mental State': A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189-198.

Freudenthal, D. (2001). Age differences in the performance of information retrieval tasks, *Behaviour & Information Technology, 20*(1), 9-22.

Gleitman, H., Fridlund, A. J., & Reisberg, D. (1999). *Psychology* (5th ed.). New York: W.W. Norton & Co.

Golden, C. J. (1978). *Stroop Color and Word Test. A manual for Clinical and Experimental Uses.* Wood Dale, IL: Steelting Company.

Hakstian, A. R., & Cattell, R. B. (1982). *Manual for the comprehensive ability battery (CAB).* Champaign, IL: Institute for Personality and Ability Testing.

Hartley, A. A., Hartley, J. T. & Johnson, S. A. (1984). The older adult as a computer user. In P. K. Robinson, J. Livingston, and J. E. Birren (Eds.), *Aging and technology advances* (pp. 347-348). New York: Plenum Press.

Jackson, D. N. (1998). *MAB-II.: Multidimensional Aptitude Battery*. Port Huron, MI: Sigma Assessment Systems, Inc.

Jamieson, B. A., & Rogers, W. A. (2000). Age-related effects of blocked and random practice schedules on learning a new technology. *Journal of Gerontology: Psychological Sciences, 55B*(6), 343-353.

Kraiger, K. Salas, E., & Cannon-Bowers, J. A. (1995). Measuring knowledge organization as a method for assessing learning during training. *Human Factors, 37*, 804-816.

Mead, S. E. & Fisk, A. D. (1998). Measuring skill acquisition and retention with an ATM simulator: The need for age specific training. *Human Factors, 40(3)*, 516-523.

Mead, S. E., Sit, R. A., Rogers, W. A., Jamieson, B. A, & Rousseau, G. K. (2000). Influences of general computer experience and age on library database search performance, *Behaviour & Information Technology, 19*(2), 107-123.

Moray, N. (1999). Mental models in theory and practice. In D. Gopher and A. Koriat (Eds.), *Attention and Performance XVII Cognitive regulation of performance: Interaction of theory and application* (pp. 223-258). Cambridge: The MIT Press.

Norman, D. A. (1983). Some observations on mental models. In D. Gentner and A. L. Stevens (Eds.), *Mental models* (pp. 7-14). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Park, D. C. (1992). Applied cognitive aging research. In F. I. M. Craik & T. A. Salthouse (Eds.), *Handbook of aging and cognition* (pp. 449-494). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Reitan, R. M. (1992). *Trail Making Test: Manual for administration and scoring*. Tucson, AZ: Reitan Neuropsychology Laboratory.

Rogers, W. A., Fisk, A. D., Mead, S. E., Walker, N., & Caberea, E. F. (1996). Training older adults to use automatic teller machines. *Human Factors, 38*, 425-433.

Salthouse, T. A. (1993). Speed mediation of adult age differences in cognition. *Developmental Psychology, 29*, 722-738.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*, 403-428.

Sanderson, P. M. (1990). Knowledge acquisition and fault diagnosis: Experiments with PLAULT. *IEEE Transactions on Systems, Man, and Cybernetics, 20,* 225-242.

Shiffrin, R. M. & Schneider, W. (1997). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84*, 127-190.

Shipley, W. C. (1986). *Shipley Institute of Living Scale*. Los Angeles: Western Psychological Services.

Tulving, E. (1985). How many memory systems are there? *American Psychologist, 40*, 385-398.

U.S. Department of Commerce (Economics and Statistics Administration & National Telecommunications and Information Administration). (2002). *A nation online: How Americans are expanding their use of the Internet*. Retrieved March 25, 2002, from http://www.ntia.doc.gov/ntiahome/dn/

Wechsler, D. (1997) *Wechsler Adult Intelligence Scale III. (3rd Ed.).* San Antonio, TX: The Psychological Corporation.

Wyman, B. G., Randel, J. M. (1998). The relation of knowledge organization to performance of a complex cognitive task. *Applied Cognitive Psychology, 12,* 251-264.

Zacks, R. T., Hasher, L., & Li, K. Z. H. (2000). Human memory. In F. I. M. Craik and T. A. Salthouse (Eds.), *The handbook of aging and cognition* (2nd edition, pp. 293-357). Mahwah, NJ: Erlbaum.

Zandri, E., & Charness, N. (1989). Training older and younger adults to use software. *Educational Gerontology, 15*, 615-631.

Zeitz, C. M. & Spoehr, K. T. (1989). Knowledge organization and the acquisition of procedural expertise. *Applied Cognitive Psychology, 3*, 313-336.