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Cross-Modal Interface Design in Crisis Control Systems: The Role of Gender

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CROSS-MODAL INTERFACE DESIGN IN CRISIS CONTROL SYSTEMS: THE ROLE OF GENDER

by

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ABSTRACT

Leading human-computer interaction (HCI) researchers recognize a fundamental difference exists between men and women. Some HCI research has been done regarding gender differences in hand-eye coordination for interactions with computer touch display interfaces, navigation through virtual environments (VE) and language in computer-mediated communication. In these previous studies, gender differences were found in the use of words and language in computer-mediated communication and in navigation strategies for VE but no gender-related differences were found for the hand-eye coordination needed to effectively use a touch display.

The current study used a cross-modal (auditory-visual), dual-task, computer interface to examine gender differences in crisis control simulations. For the primary task of alarm monitoring, no gender differences were found for average or maximum response and completion times. Likewise, no gender differences were found in terms of error rates for the primary task or the number correct on the secondary task. However, in terms of minimum response and completion times for alarm monitoring, gender differences were found.

Chapter 1

INTRODUCTION

The study of human-computer interaction seeks to gain understanding of how computer interfaces, which facilitate the flow of information between the human and the computer, can be effectively designed [Shneiderman97]. This understanding comes from analyzing the tasks to be accomplished with the interface and from understanding how any information transmitted by the interface may be perceived and interpreted by the human using it. Because the tasks involved in this study require a division of the subject's attention, it is important to understand current theories of attention in terms of how cognitive resources are used. One cognitive resource involved in a divided attention task is memory. The following discussions of the structure of memory (especially episodic memory), attention and mental resource allocation provide theoretical background for the current hypothesis that gender differences will be found either in performance of the primary alarm monitoring task, performance of the secondary task or both.

1.1 Theories of Human Memory and Gender Differences

In their meta-analysis of previous studies reporting gender differences favoring women in episodic memory tasks, Herlitz et al. refer to 5 separate but interacting systems: procedural memory, perceptual representation memory, semantic memory, primary memory and episodic memory [Herlitz97]. This model of human memory was first proposed by

Schacter and Tulving in 1994 [Schacter94]. A summary of Schacter and Tulving's model is represented in table 1.

System	Other terms	Subsystems	Retrieval
Procedural	Nondeclarative	Motor skills Cognitive skills Simple conditioning	Implicit
Perceptual Representation (PRS)	Nondeclarative	Visual word form Auditory word form Structural description	Implicit
Semantic	Generic Factual Knowledge	Spatial Relational	Implicit
Primary	Working	Visual Auditory	Explicit
Episodic	Personal Autobiographical Event memory		Explicit

Table 1: Major Systems of Human Learning and Memory

Procedural memory is distinguished as the memory system concerned with learning and memory functions not supported by the other four major systems [Schacter94, page 27]. Procedural memory is characterized by gradual, incremental learning and seems well-suited for picking up invariances in the environment over time [Schacter94, page 26]. It is important to note that procedural memory deals with behavioral skills, such as those related to successful computer use, while the other four memory systems deal with cognition, an important component of problem solving.

One of the cognitive-memory systems, working (or primary) memory, deals with the temporary holding and processing of information [Schacter94, page 27]. Because of the temporary nature of the information processed by this memory system it is sometimes referred to as short-term memory. The other three systems deal with long term memory. Since people use both short-term and long-term memory for information processing and problem solving and since there are limitations to how much information can be stored and retrieved from either type of memory, HCI research seeks to understand how a computer interface can be designed to accomplish a specified task (solve a problem) without overloading the memory of the person using the interface [Schneiderman97]. For the current study, the allocation and use of semantic memory for spatial processing and episodic memory for personal or event memory is explored by using either a mental rotation (spatial) task or a fact recall (event) task as the secondary task in the computerized, dual-task paradigm.

Since Tulving and Schacter first proposed their theory of how human memory is organized, neurobiological research using non-invasive techniques like functional magnetic resonance imaging (fMRI) have been used to study brain activation during cognitive tasks similar to the tasks in this study [Schlaepfer95, Cohen96, Gur99, Kraut02, Menon02, Greicius03]. This research provides direct physical evidence to support the theory of multiple memory systems working together to accomplish a task. Additionally, these studies have begun to correlate the neural structures of the brain with the cognitive functions (like encoding and retrieval from semantic or episodic memory) they support. In terms of the tasks in the current study, fMRI research has shown several possible neural mechanisms for mental rotation and fact recall.

For example, Cohen et al. suggest "…the neural structures most involved in mental rotation…are the frontal eye fields…, the extrastriate visual regions of the superior parietal lobule and…[the cortical area]…V5…" [Cohen96, page 99]. Further evidence of the role of the parietal lobes in spatial tasks is provided by Trojano, et al. [Trojano00]. In this study, "…subjects are asked to imagine pairs of times that are presented acoustically and to judge at which of the two times the clock hands form the greater angle" [Trojano00, page 473]. By comparing their results to previous studies, Trojano and his colleagues concluded that the cognitive function of analyzing visual space either through perception, such as a computer interface, or imagination has a common neural basis in the parietal lobes [Trojano00].

For episodic memory tasks like word or fact recall, "…studies have shown that the medial temporal lobe (MTL), particularly the hippocampus, are involved in episodic memory…" [Menon02, page 261]. As researchers have investigated the hippocampus' role in episodic memory, two models have emerged. "One model, outlined by Moser and Moser … has proposed that episodic memory is subserved by the posterior two-thirds of the hippocampus alone. A second model, derived by Lepage, et al…has suggested that…the anterior hippocampus is activated by memory encoding while the posterior hippocampus is activated by memory retrieval" [Greicius03, page 164]. In contrast, work by Greicius and his colleagues found that during episodic memory tasks (encoding and retrieval) the hippocampus acts as a rather homogeneous unit [Greicius03, page 173]. Additionally, their study "…did not rule out the possibility that encoding and retrieval of visuospatial material preferentially activate the posterior hippocampus. This possibility is consistent with the Moser and Moser model" [Greicius03, page 173].

Another study, conducted by Menon, et al., found evidence showing a functional relationship between episodic and semantic memory. Specifically, they found the left lateral temporal lobe region of semantic memory is involved in accurate retrieval from episodic memory [Menon02]. So even though different neural structures are involved in the two types of memory, they are interdependent rather than independent systems. Other studies designed to examine working memory have shown that "…storage of verbal material in working memory is typically associated with activations at anterior brain regions in the frontal lobe and at a more posterior region in the parietal lobe" [Shaywitz99, page 1197].

With regards to gender, neuroscience has shown that there are anatomical differences between male and female brains. Ruben Gur and his colleagues have shown that male brains have higher volumes of white matter [Gur99]. Since white matter is composed of long axons that reach from one region of the brain to the other, this brain tissue is directly involved in an individual's sense of spatial orientation and is likely responsible for the consistent advantage of males on tests of spatial skills [Gur99]. Female brains are denser in gray matter, consisting of neuronal cell tissue and dendrites, which enable women to make quick computations [Gur99]. In 1995, Schlaepfer and his colleagues examined the structural differences of the cerebral cortex between men and women using magnetic resonance imaging (MRI). They theorized that the consistent dimorphic findings of male advantage on spatial problems and female advantage for verbal abilities "…should also be reflected in functional and/or structural brain differences between the sexes" [Schlaepfer95, page 130]. Their findings included a significantly smaller brain volume for females and higher gray matter percentage for women than men in the dorsolateral prefrontal cortex and superior temporal gyrus, both regions of the brain closely linked to high order verbal function [Schlaepfer95]. This finding "...of increased gray matter in women in higher-order cortical centers concerned with verbal function..." [Schlaepfer95, page 134] supports the generally found result of female advantage for verbal cognitive tasks.

Gur and his associates found gender differences when comparing brain region activation and lateralization for a verbal and a spatial task [Gur00]. For the verbal task, they observed left-lateralized changes in the "inferior parietal and planum temporal regions in both men and women, but only men showed right-lateralized increase for the spatial task in these regions" [Gur00, page 157]. Further analysis revealed these cortical regions activated by both tasks: the lateral frontal, medial frontal, mid-temporal, occipitoparietal and occipital. For the verbal task, the activation of these regions was more left-lateralized for both men and women. For the spatial task, activation was more right-lateralized but men also showed some left activation [Gur00]. Gur et al. suggest that "...failure to activate the appropriate hemisphere in regions directly involved in task performance may explain certain sex differences in performance" [Gur00, page 157].

1.2 Theories of Attention

Attention research focuses on the selective processing of incoming sensory information [Driver01]. It is important to remember that our perception of the world is influenced by what we choose to pay attention to, not just the sensory input we receive [Driver01]. The design of the current study calls for subjects to use a computer interface which will present information regarding two different tasks. The subjects will be required to divide their attention between the primary task of alarm monitoring and one of two secondary tasks.

Wickens describes the concept of divided attention for a concurrent, dual-task scenario as "...an inferred construct used to describe the cost in performance of the tasks associated with their concurrence" [Wickens80, page 239]. To elaborate on this definition, Wickens [Wickens80] also identifies structural and capacity theories for trends related to divided attention for dual tasks. Structural theories describe performance of a dual task in terms of competition for information-processing structures. By comparison, capacity theories contend attention is a resource to be allocated between each task. For the current study, the design of the dual-task computer interface assumes attention is a competition for information-processing resources. Inclusion of the auditory (alarm sounds) and visual (indicator stops moving and changes color) clues allow the subject to pay attention to the secondary task until an alarm condition occurs. Once the alarm clues are received and processed, a conscious and deliberate decision is made by the subject to switch their attention to the primary task.

Similarly, research has shown short-term memory is a resource shared among tasks. The capacity of short-term memory is generally accepted as seven plus or minus 2 chunks and this memory decays in approximately 200 milliseconds unless refreshed [Sutcliffe89]. Because of this limitation, computer interface designs should generally not require a computer user to remember more than seven or so steps for entering data into or obtaining information from an interface. In the current study, subjects were required to complete four (4) steps for the primary task plus either two (2) steps for the mental-rotation secondary task or four (4) steps for the fact-recall secondary task.

When discussing the relationship between attention and long-term memory, it is interesting to note several studies have offered evidence that attention is involved in recall [Rumelhart72, Martin70, Johnston70]. One theory proposed by Rumelhart et al. is that retrieval from long-term memory involves holding a retrieval plan in working memory [Baddeley84]. Studies by Martin and by Trumbo and their associates have offered further evidence of the heavy attentional or working memory demands of retrieval [Baddeley84]. In their own work, Baddeley and his associates concluded that "...a demanding concurrent task does not substantially reduce the probability of retrieving and item from either episodic or semantic memory" [Baddeley84, page 518]. They also found that a task that interferes or distracts attention during learning reduces the amount learned. Because of the contrasting conclusions reached by Baddeley and his colleagues, they caution against any one measure being the source of conclusions about attentional demand [Baddeley84, page 539].

1.3 Human-computer Interaction Research and Gender

As stated above, some HCI research has been done to identify gender differences for different types of computerized tasks. Currently, the research topics receiving attention are computer-based communication [Herring94], controlling touch-screen computer displays [Johnson95] and navigation of virtual environments [Cutmore00]. Herring found different communication styles for men and women who participate in computer-mediated discussion lists. Her research has refuted the idea that computer-mediated communication is more gender-neutral and therefore more democratic than other forms of communication. Cutmore and his colleagues have found gender differences in navigating virtual environments. Specifically, "…males acquire route knowledge from landmarks faster than females" [Cutmore00]. Furthermore, Cutmore offers suggestions for adjusting VE interfaces for accommodating these observed differences. In contrast, Johnson did not find any gender differences in studying panning of touch-controlled interfaces. The lack of effect for gender included both performance measures (i.e. accuracy) and preference measures for the interface. The current study seeks to add to the body of HCI research in terms of potential gender differences in learning and using computer-based crisis-control interfaces.

Chapter 2

METHOD DESCRIPTION

The objective of this study is to extend work done by Michelle Dawn Sculley, a former UNF College of Computer Science and Engineering graduate student [Sculley91]. Sculley's research tested the user's performance on two separate tasks. The primary task was monitoring alarm conditions and the secondary task was completing a spreadsheet. In Sculley's work, two display types, graphical and textual, were used. In analyzing her results, Sculley found subjects performed better on graphical displays than on textual ones for crisis control simulations. Therefore, this study uses only a graphical display and does not seek to examine the textual vs. graphical question again.

In the current work, the primary task remains alarm monitoring. During testing, subjects were required to monitor three separate tanks, each tank having three status indicators. These indicators displayed information to the subjects regarding the volume, temperature and pressure of each tank. The display included numerical ranges for each indicator that was displayed to the left of a vertical bar. The vertical bar included a sliding button that moved randomly between the numerical indicators. The safety range for the temperature indicators was defined as a low of 32 and a high of 35. On the display, the numbers ranged from 31 to 36. Subjects were instructed that if the sliding button reached either the 31 or 36, the indicator was out of range. In addition to the button reaching either limit, the bar color changed to red when there was an alarm. A similar design was used for volume and pressure, however, each had its own unique range of indicator values. Figure 1 shows the indicators in the normal (non-alarm) state with Tank 1 displaying a temperature reading of 34, a volume reading of 75 and a pressure reading of 104. The Tank 2 and Tank 3 readings are also within the safety range for each indicator.

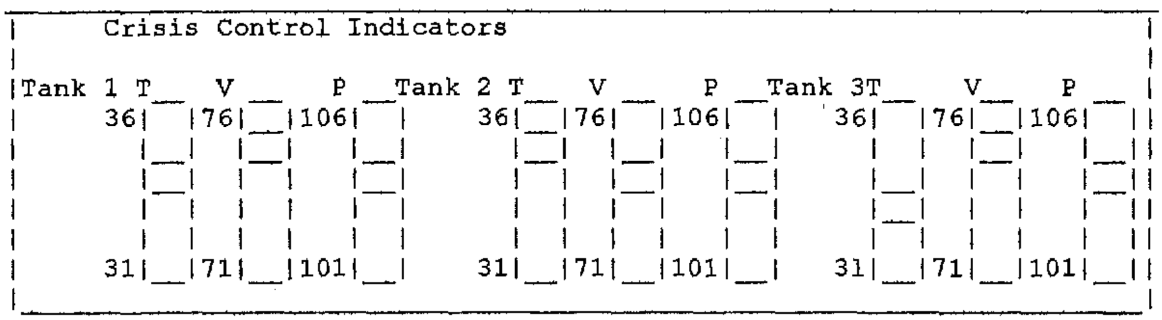


Figure 1: Tank Indicators

With the total number of indicators being nine, the subjects were within the short-term memory capabilities (seven plus or minus 2) reported by Miller [Miller56] and others.

Subjects were instructed to observe the indicators to determine if an alarm condition occurred. If an alarm was observed, the subjects were instructed to reset the alarm by following a series of steps to enter information in the system interface. These steps included entering which tank had the alarm condition, which indicator (attribute) was out of safety range and which direction the indicator should move to reset the alarm. Figure 2 shows the buttons in the interface used by the subject to control (reset) the alarm.

```
 ___________________________________________________________________________
|                                                                           |
|                              Controls                                      |
|                                ___ ___ ___                 ___ ___     _______ |
|Tank |* 1|* 2|* 3| Attribute |* T|* V|* P| Change |* U|* D|  |Submit||
|     |___|___|___|           |___|___|___|        |___|___|  |_______||
|___________________________________________________________________________|
```

Figure 2: Control Buttons

Although the primary task remains the same, the spreadsheet task from Sculley's original project has been replaced with two different tasks: mental rotation of a standardized picture or recall of newly acquired facts. Research has consistently shown significant differences between male and female subject performance on mental rotation tasks, with males generally outperforming females [Ginn99, Kass98, Masters98]. Recent work by Herlitz et al. shows significant gender differences in fact recall tasks where females outperform males [Herlitz97]. By replacing the spreadsheet task with either the mental rotation task or the fact recall task, the current study seeks to find support for the possibility of gender difference in how subjects will perceive and perform the sub-tasks as well as if the sub-tasks will interfere with the primary task. Therefore, sub-task type and gender become two of the independent variables to be investigated.

Another independent variable being investigated is type of auditory alarm used to present the auditory warning signal to the subject. The interface employs either an auditory icon (earcon), a ding, or no sound. The ding and auditory icons are distinguished from each other by the meanings represented by each sound type. While both sound types are capable of indicating an alarm has occurred (and thus initiating a switch between primary and secondary tasks), the auditory icon also conveys which attribute (pressure, temperature or volume) is involved in the alarm. In the current interface under investigation, a "popping" sound is used to indicate an alarm for one of the pressure attributes, a "sliding whistle" indicates an alarm for one of the temperature attributes and a "tone changing in pitch" indicates an alarm for one of the volume attributes. While some researchers further distinguish earcons and auditory icons [Skantze03], the two terms are used interchangeably in this paper to indicate a sound which has been metaphorically mapped to a specific meaning and attempts to take advantage of a subject's experience with real-world or naturally occurring sounds (such as popping being related to pressure). This approach is the same as Sculley's work where subjects receiving a sound signal performed better that those not receiving a sound.

Two of the dependent variables being analyzed are response time (average, minimum, maximum) and completion time (average, minimum, maximum). Response time is defined as the total elapsed time in seconds from when the alarm is displayed to when the subject presses the 'Submit' button in the control section of the interface regardless of the accuracy of the response. Completion time (which is a subset of response time) is defined as the total elapsed time in seconds from when the alarm is displayed to when the subject presses the 'Submit' button in the control section of the interface and completes the task by resetting the alarm. Resetting the alarm requires the subject to correctly enter tank, attribute and change direction in the control portion of the interface. For response error rate the original three dependent variables from Sculley's work (tank errors, attribute errors and change errors) are used and a fourth rate, extra button push error, is introduced. A tank error is defined as a subject's response where the alarm was set for a particular tank but the subject entered a different tank in his or her response. For example, if tank 2 had an alarm condition for its volume indicator and the subject entered tank 1 or tank 3 in their response, this was captured as a tank error. Similarly, if the alarm condition was for the volume indicator and the subject entered either pressure or temperature in their response, this was captured as an attribute error. The same error capture method was used for change direction. It was possible for the subject to enter more than one value incorrectly on a single response. In this case, the program captured each error as a separate occurrence of the error type. The fourth error measure, the extra button push error, is included because the current interface introduces a "point-and-click" button for resetting the alarm which can be pushed even when there is not an alarm to reset. If, during a trial, a subject accidentally pushes the reset button, the computer program records the button push but does not change the display of information on the screen. Error rates for each dependent variable are calculated as the total number of errors (by type) divided by the total number of responses.

Another dependent variable under investigation is the number of correct responses on either the mental rotation task or the fact recall task. Quantitatively, the average number of correct responses for the mental rotation task is expected to be higher than the average number of correct responses for the fact recall task. This is due to the structure of the mental rotation task as compared to the structure of the fact recall task. In other words, because the subject only has to make a simple decision about whether two images are the same in the mental rotation task subjects should be able to pace themselves more quickly on the mental rotation task. For fact recall, the subject has to read, learn and remember a set of five facts then read, comprehend and answer five questions. In this case, a subject's pace will naturally be slower. The slower pace of the fact recall task means there is less opportunity to answer questions and therefore, quantitatively, the total number of responses for the two tasks will be very different.

A summary of the experimental design is provided in Table 2. From this table, we see the intended subject distribution between test scenarios. For the trials, subjects were randomly assigned to each test condition to achieve a balanced distribution of male and female subjects per group.

	No Sound Mental Rotation Task	Ding Mental Rotation Task	Earcon Mental Rotation Task	No Sound Fact Recall Task	Ding Fact Recall Task	Earcon Fact Recall Task
Female	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on MRT	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on MRT	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on MRT	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on FRT	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on FRT	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on FRT
Male	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on MRT	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on MRT	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on MRT	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on FRT	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on FRT	10 Subjects • Resp. Time • Comp. Time • Error Rate • Number Corr. on FRT

Table 2: Summary of Experimental Design

One final method difference between this study and Sculley's work is the integration of the interfaces for the primary and secondary task into a single computer display. In Sculley's work, the secondary task was displayed on a separate computer from the primary task. Subjects were required to physically turn their heads and eyes from one display to the other. In the current work, the secondary task is displayed in the middle of the same screen as the primary task. The display for the primary task is accomplished in two parts with the upper display having all nine indicators and the lower display having the buttons and radio buttons used by the subject to reset alarms. Diagrams showing the integration of the interface are available in the appendices.

Chapter 3

DATA COLLECTION

3.1 Subjects

One hundred and fifteen subjects from a mid-size university in the southeastern United States participated in the study. Of these, sixty-three were female and fifty-two were male. Subjects were students from introductory computer courses offered by the Computer and Information Sciences Department to non-Computer Science majors. Participation was voluntary and each subject received extra credit at the discretion of his or her instructor.

3.2 Apparatus

The practices and trials were run on one of 10 Dell PC's running Red Hat Linux (release 7.2) in the Computer and Information Sciences Department's graduate laboratory. Each PC had a color monitor of diagonal measure 17 inches (16 inches viewable) and could be physically adjusted by subject. Subjects entered all responses through a point and click device (Microsoft Intellimouse 1.1A PS/2 compatible).

All computer programs were written in TCL/TK version 8.3. The 48 image pairs used for the mental rotation task were part of the standard set of 260 images purchased from Life Science Associates [Snodgrass80] with a grant from the Bette Soldwedel Foundation. Subjects testing the interfaces with sound used a single ear piece inserted into the ear.

An internal clock was used to record response and completion times. Each trial ran for a total of twenty minutes.

3.3 Procedure

Four computer programs were created to run the trials. One program ran the combined crisis control and mental rotation task interface for the subjects to practice. Another program ran the combined crisis control and fact recall interface for the subjects to practice. The other two programs ran the different interfaces, but used the actual test line drawings or facts. These programs were also responsible for collecting demographic data from each subject.

Each program accepted a parameter indicating if sounds were to be played when an alarm was displayed. These parameters were "ding" if a single ding was played, "earcon" if a realistic tone was played and "none" if no sound was played. The programs controlled the update of the indicators through random routines which simulated random samples from the tanks. The programs also controlled the display of either the line drawing pair for the mental rotation task or the sets of facts and questions for the fact recall task.

The line drawings used for the mental rotation task were based on the standardized set of 260 pictures published in 1980 by Snodgrass and Vanderwart [Snodgrass80]. These standardized pictures have been used in several mental rotation tasks including work published by Murray [Murray99]. In Murray's work, the pictures are presented in pairs with the first image presented with a rotation angle of 60 degrees. After 500 milliseconds, the second image in the pair was presented at either a 60, 120 or 240 degree of rotation and the subject was asked to determine if the second image was the same as the first. The next pair was not presented until the subject entered a response of either 'same' or 'different'. A similar procedure was used in the current study. For example, one of the image pairs in the current study was ant-beetle with an expected subject response of 'different'. Figure 3 shows how the first image (the ant) was presented to the subject.

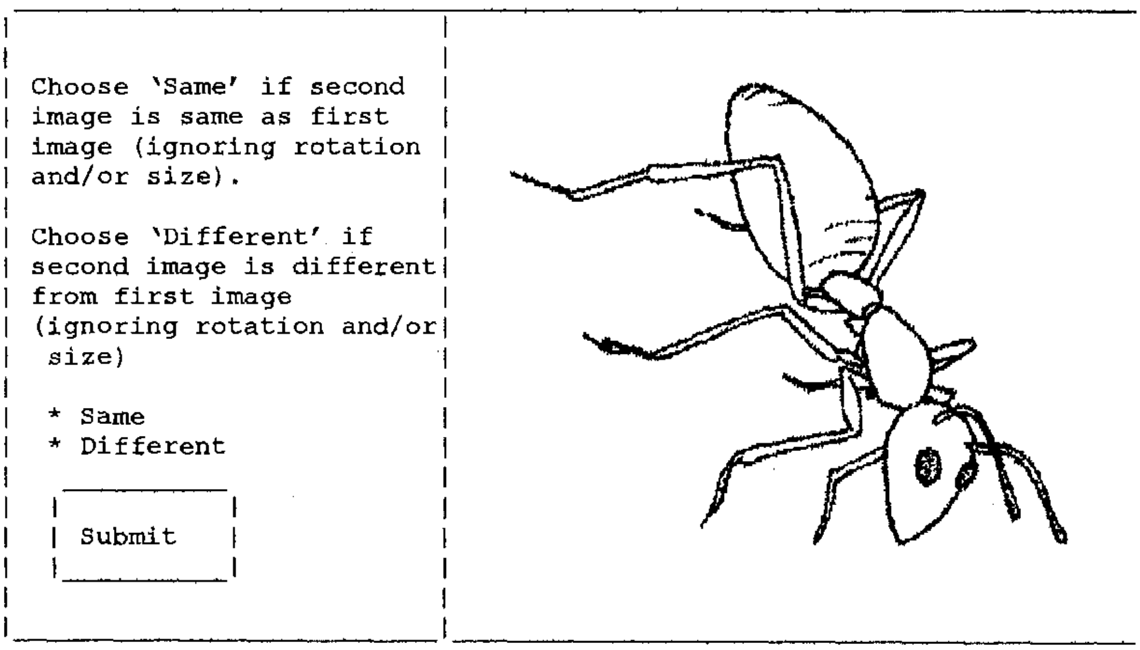


Figure 3: Mental Rotation Task - First Image Display

The second image in the pair (the beetle) was presented with a rotation angle of 240 degrees. Figure 4 shows how the beetle drawing was displayed by the interface.

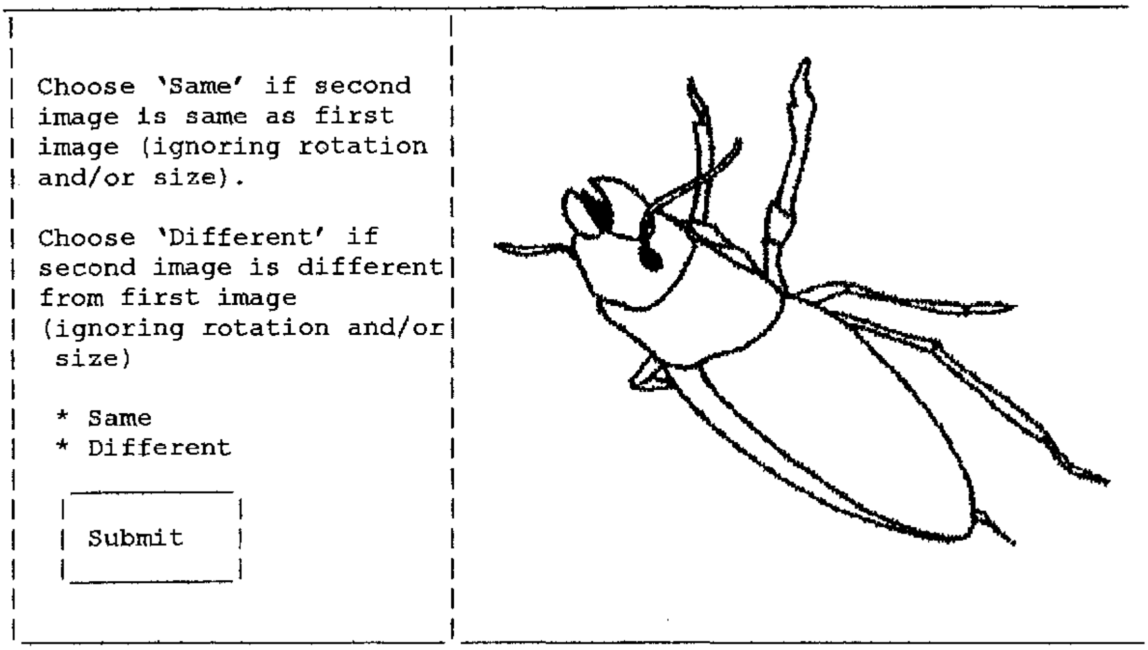


Figure 4: Mental Rotation Task - Second Image Display

The beetle image was displayed until the subject selected either 'Same' or 'Different' and pressed the submit button. Once submit was pressed, the subject's answer was recorded and the next image pair was displayed.

For the fact recall tasks, a series of one hundred fact statements were presented in groups of five at a time. The subjects were asked to study and memorize the facts and then press a button on the interface labeled 'View Questions' to be presented with a set of five questions based on the facts. Figure 5 shows how the interface displayed facts to the subject.

```
 ________________________________________________________________________
|                          |                                             |
|                          | In his spare time, Bob Hope likes to        |
|                          | bake pies.                                  |
|                          |                                             |
|                          | Jill Eikenberry's favorite color is         |
|                          | blue.                                       |
|                          |                                             |
|                          | Astrid Lungren collects baseball cards.     |
| Study facts displayed    |                                             |
|  to the right. Press     | Tom Hanks was born in July.                 |
|  button when ready to    |                                             |
|  view questions.         | Susan Surandon plays left guard on her      |
|                          |   local basketball team.                    |
|   ___________________    |                                             |
|  |                   |   |                                             |
|  | View Questions    |   |                                             |
|  |___________________|   |                                             |
|__________________________|_____________________________________________|
```

Figure 5: Fact Recall Task - Facts Display

Once the subject pressed the 'View Questions' button, the interface changed to display the questions and answers. Figure 6 shows how the questions and answers appeared to the subject.

```
 ________________________________________________________________________
|                          |                                             |
|                          |What is Jill Eikenberry's favorite color?    |
|                          |o red   o green   o blue   o yellow          |
|                          |                                             |
|                          |What position does Susan Surandon play?      |
|                          |o left guard o forward o tackle o striker    |
|                          |                                             |
|                          |What does Astrid Lungren collect?            |
|                          |o baseball cards o stamps o coins o shells   |
| Select appropriate       |                                             |
| answer for each question.|What month was Tom Hanks born?               |
| Press button when ready  |o January  o August  o June  o July          |
| to submit answers.       |                                             |
|                          |Bob Hope likes to bake what item?            |
|                          |o cakes  o pies  o cookies  o bread          |
|   ___________________    |                                             |
|  |                   |   |                                             |
|  | Submit Answers    |   |                                             |
|  |___________________|   |                                             |
|__________________________|_____________________________________________|
```

Figure 6: Fact Recall Task - Questions Display

Subjects indicated their choice by highlighting a radio button positioned to the left of the answer. Once the selection of answers was complete, the subject pressed a button labeled 'Submit Answers'. The program recorded the answers and then displayed the next group of facts. The design of the fact recall task for the current study was based on a similar task used by Herlitz et al. [Herlitz97].

During the trials, subjects were first asked to read through hardcopy instructions. These instructions included information about the alarm monitoring task as well as the appropriate sub-task. Once subjects had read the instructions, each subject was allowed three (3) minutes to practice. During the practice, subjects were able to reset several alarms as well as practice either identifying images for the mental rotation task or memorizing facts for the fact recall task. During practice, the programs displayed images or facts that were not used during the actual trial. Therefore, the subjects were able to learn how to use the various components of the interface (radio buttons, push buttons, etc.) but they did not have an opportunity to memorize any of the images or facts.

Chapter 4

RESULTS

A total of one-hundred fifteen subjects participated in the study. During data analysis, two subjects were identified as outliers having average response times greater than three standard deviations from the mean for the subject pool. These outliers were eliminated and the final subject pool included one-hundred thirteen subjects, sixty-two females and fifty-one males. The final subject distribution is summarized in Table 3:

	Totals	No Sound Mental Rotation Task	Ding Mental Rotation Task	Earcon Mental Rotation Task	No Sound Fact Recall Task	Ding Fact Recall Task	Earcon Fact Recall Task
Female	62	11	11	11	11	8	10
Male	51	8	8	9	8	9	9
	113	19	19	20	19	17	19

Table 3: Final Subject Distribution

From demographic information collected during each trial, seventy-five percent of the subjects indicated they had no experience with crisis control systems. Those indicating intermediate or novice level experience were fourteen and eight percent respectively. This is a good indication that the majority of the subject pool needed to learn how to effectively use a crisis control interface.

Ninety-eight percent of the subjects indicated either normal or corrected vision and all subjects identified three different colored boxes (red, yellow and blue) correctly. This is a good indication that the subjects were capable of seeing the visual stimuli of the interface clearly and there were no problems with distinguishing the red color of the alarm indicator. Additionally, ninety-six percent of the subjects indicated no problems with hearing.

Regarding handedness, eighty-eight percent of the subjects indicated they were right handed, six percent indicated they were ambidextrous and five percent indicated they were left handed. The fact that more subjects identified themselves as ambidextrous rather than left handed is interesting. This reporting of handedness may be due to the self-evaluation nature of the demographic survey. It may also be because the category of ambidextrous was offered and subjects who would normally have identified themselves as left handed chose ambidextrous. Considering the computers used at trial were all configured for right handed people (with the pointing device on the right of the keyboard and the left mouse button configured as the primary "clicking" button), even subjects who identified themselves as left handed may have actually performed in an ambidextrous manner since no subject requested to have the pointing device repositioned on the left of the keyboard. Since left-handed and ambidextrous subjects were distributed across all groups, no further analysis of this variable was done.

Statistical tests were performed on the remaining subject data, with emphasis given to these dependent variables: response time, completion time (including response time), tank error rate, attribute error rate, direction error rate, extra button push error rate and total correct on the secondary task. The extra button push error rate is an additional measure not included in Sculley's original work. It was added for this project because the integration of the primary and secondary tasks into a single interface introduces additional complexity in the interface design. The interface has two submit buttons, one for the primary task and one for the secondary task. Care was taken to clearly label the buttons but it was hypothesized that subjects might still confuse the two submit buttons and therefore press either button at unintended or unexpected times. Since the interface was programmed to continue the tasks (both primary and secondary) regardless of the extra button push, subjects were not aware of this measure as an error.

The primary statistical test used to analyze the data in the current study was the analysis of variance procedure (ANOVA). Each ANOVA generated several statistical values about variable interaction which is captured in the tables below. The 'Source' column in the ANOVA table indicates which main effect or variable interaction is being used to partition or categorize the data. The 'DF' column indicates degrees of freedom or the number of categories for the main effect minus one. For example, in the ANOVA tables below 'Interface' is listed under source. This category represents either the interface with the mental rotation sub-task or the interface with the fact-recall sub-task. The degree of freedom for this measure is one because there are two total categories the dependent variables can be grouped in. Also listed in the ANOVA table is the 'SS' (Sum of Squares) and 'MS' (Mean Square) columns. The Sum of Squares describes the variance of the data in terms of deviations from the mean and is computed by the ANOVA procedure. The Mean Square is the Sum of Squares value divided by the degree of freedom. This value is also computed by the ANOVA. Finally, the ANOVA tables list 'F' and 'p' values. The 'F' value or F ratio describes whether the sample means are within sampling variability of each other. The 'p' value represents the probability the observed statistical difference between means occurred by chance. For this paper, any main effect or interaction with a 'p' value less than or equal to .05 was considered significant and included in the discussion. Also included in the result was the 'p' value for each ANOVA model. Again the 'p' value represents the probability the observed statistical difference between means occurred by chance but in this context it describes the variability of the dependent variable before any interaction with any independent variables are considered.

4.1 Response Time

The key independent variables investigated were interface group (either Crisis Control with a mental rotation task (CC-MRT) or Crisis Control with a fact recall task(CC-FRT)), auditory group (no sound, ding or earcon) and gender (F or M). Table 4 shows the average response time, average minimum response time and average maximum response time broken down by these variables.

Interface, Gender, Auditory group	Average (sec)	Average Minimum (sec)	Average Maximum (sec)
CC-MRT, F, No sound	12.096	6.455	26.818
CC-MRT, F, Ding	12.112	6.636	37.273
CC-MRT, F, Earcon	10.474	5.818	25.091
CC-MRT, M, No sound	10.307	6.000	22.125
CC-MRT, M, Ding	10.650	5.625	21.375
CC-MRT, M, Earcon	11.551	6.222	25.556
CC-FRT, F, No sound	11.305	5.000	26.727
CC-FRT, F, Ding	9.461	5.125	22.750
CC-FRT, F, Earcon	33.521	6.500	79.100
CC-FRT, M, No sound	16.068	5.500	42.125
CC-FRT, M, Ding	16.637	5.556	56.778
CC-FRT, M, Earcon	16.091	5.111	69.222

Table 4: Response Times by Interface, Gender, Auditory Group

4.1.1 Average Response Time

In order to understand potential interaction of interface, gender and auditory group with respect to average response time, an analysis of variance (ANOVA) was performed. Table 5 gives the results of the ANOVA.

Source	DF	SS	MS	F	p
Interface	1	1072.45	1072.45	2.12	0.1482
Gender	1	56.83	56.83	0.11	0.7380
Auditory Group	2	805.06	402.53	0.80	0.4536
Interface*Gender	1	15.46	15.46	0.03	0.8615
Interface*Auditory Group	2	983.10	491.55	0.97	0.3815
Gender*Auditory Group	2	641.78	320.89	0.64	0.5320
Interface*Gender*Auditory Group	2	1077.59	538.80	1.07	0.3481
Error	101	51028.05	505.23		

Table 5: Analysis of Variance: Average Response Time

The probability of the whole model was 0.6036 and from the details of the ANOVA, we determine there are no significant differences between subjects for average response time. This holds true for each of the main effects as well as the variable interactions computed by the ANOVA.

4.1.2 Average Minimum Response Time

In order to understand potential interaction of interface, gender and auditory group with respect to average minimum response time, an analysis of variance (ANOVA) was performed. Table 6 gives the results of the ANOVA.

Source	DF	SS	MS	F	p
Interface	1	13.15	13.15	9.04	0.0033
Gender	1	1.84	1.84	1.27	0.2632
Auditory Group	2	0.71	0.35	0.24	0.7851
Interface*Gender	1	0.22	0.22	0.15	0.7007
Interface*Auditory Group	2	4.19	2.10	1.44	0.2412
Gender*Auditory Group	2	1.20	0.60	0.41	0.6624
Interface*Gender*Auditory Group	2	14.33	7.16	4.93	0.0091
Error	101	146.83	1.45		

Table 6: Analysis of Variance: Average Minimum Response Time

The probability of the whole model was 0.0183 and from the details of the ANOVA, we determine there are significant differences between subjects for average minimum response time. The Student-Newman-Keuls post hoc test for interface and average minimum response time shows the subjects using the mental rotation task interface had significantly higher minimum response times. Specifically, the mean for subjects with the MRT interface was 6.1552 while the mean for the subjects with the FRT interface was 5.4727.

When gender and auditory group are factored in with interface type, the results are also significant, showing a p value of 0.0091. To further analyze this result, multiple contrast post hoc tests were run based on the interaction groups in Table 7:

Interface, Gender, Auditory Group	Interaction Group
CC0-MRT, M, None	Group 1
CC0-MRT, M, Ding	Group 2
CC0-MRT, M, Earcon	Group 3
CC0-MRT, F, None	Group 4
CC0-MRT, F, Ding	Group 5
CC0-MRT, F, Earcon	Group 6
CC1-FRT, M, None	Group 7
CC1-FRT, M, Ding	Group 8
CC1-FRT, M, Earcon	Group 9
CC1-FRT, F, None	Group 10
CC1-FRT, F, Ding	Group 11
CC1-FRT, F, Earcon	Group 12

Table 7: Post Hoc Test Interaction Groups

Twelve of the post hoc comparisons revealed significant differences. A summary of the comparisons with significant differences is listed in Table 8:

Source (contrast A and B)	DF	SS	MS	F	p	Means of A	Means of B
Group 3 and Group 10	1	7.394	7.394	5.09	0.0263	6.22	5.00
Group 4 and Group 9	1	8.934	8.934	6.15	0.0148	6.45	5.11
Group 4 and Group 10	1	11.636	11.636	8.00	0.0056	6.45	5.00
Group 4 and Group 11	1	8.187	8.187	5.63	0.0195	6.45	5.13
Group 5 and Group 7	1	5.981	5.981	4.11	0.0452	6.64	5.50
Group 5 and Group 8	1	5.782	5.782	3.98	0.0488	6.64	5.56
Group 5 and Group 9	1	11.516	11.516	7.92	0.0059	6.64	5.11
Group 5 and Group 10	1	14.727	14.727	10.13	0.0019	6.64	5.00
Group 5 and Group 11	1	10.580	10.580	7.28	0.0082	6.64	5.13
Group 9 and Group 12	1	9.137	9.137	6.29	0.0138	5.11	6.50
Group 10 and Group 12	1	11.790	11.790	8.11	0.0053	5.00	6.50
Group 11 and Group 12	1	8.403	8.403	5.78	0.0180	5.13	6.50

Table 8: Post Hoc Test Results for Average Minimum Response Times

In the table above the column labeled "Means of A" documents the results for the means procedure for the first group listed under "Source". Likewise, the column "Means of B" is the same result for the second group listed under "Source".

4.1.3 Average Maximum Response Time

Subject performance was also measured in terms of longest (maximum) response times. The results of the ANOVA are displayed in Table 9.

Source	DF	SS	MS	F	p
Interface	1	14807.38	14807.38	3.84	0.0528
Gender	1	244.78	244.78	0.06	0.8016
Auditory Group	2	8284.58	4142.29	1.07	0.3456
Interface*Gender	1	2653.01	2653.01	0.69	0.4089
Interface*Auditory Group	2	10041.04	5020.52	1.30	0.2767
Gender*Auditory Group	2	835.27	417.63	0.11	0.8975
Interface*Gender*Auditory Group	2	4202.59	2101.30	0.54	0.5817
Error	101	389632.27	3857.75		

Table 9: Analysis of Variance: Average Maximum Response Time

The probability of the whole model was 0.4805. The only interaction of interest is for interface group which has a p value of 0.0528. Depending on rounding, this result could be considered significant. Since many researchers use even more stringent criteria for defining a significant p value (i.e. <= .03) we chose not to round this value down to meet our .05 criteria.

4.2 Completion Time

Completion time for the trials was defined as the time necessary to correct an alarm. Table 10 shows the average completion time, average minimum completion time and average maximum completion time broken down by the primary independent variables being investigated.

Interface, Gender, Auditory group	Average (sec)	Average Minimum (sec)	Average Maximum (sec)
CC-MRT, F, No sound	11.65	6.455	26.182
CC-MRT, F, Ding	11.88	6.636	37.000
CC-MRT, F, Earcon	10.405	5.818	25.091
CC-MRT, M, No sound	10.293	6.000	22.125
CC-MRT, M, Ding	10.496	5.625	21.125
CC-MRT, M, Earcon	11.302	6.222	25.556
CC-FRT, F, No sound	11.348	5.000	26.545
CC-FRT, F, Ding	9.305	5.125	22.750
CC-FRT, F, Earcon	30.362	6.500	75.900
CC-FRT, M, No sound	15.672	5.500	40.625
CC-FRT, M, Ding	14.635	5.556	56.778
CC-FRT, M, Earcon	14.950	5.333	61.667

Table 10: Completion Times by Interface, Gender, Auditory Group

4.2.1 Average Completion Time

In order to understand potential interaction of interface, gender and auditory group with respect to average completion time, an analysis of variance (ANOVA) was performed. Table 11 gives the results of the ANOVA.

Source	DF	SS	MS	F	p
Interface	1	765.36	765.36	1.91	0.1700
Gender	1	56.21	56.21	0.14	0.7088
Auditory Group	2	607.15	303.57	0.76	0.4715
Interface*Gender	1	19.87	19.87	0.05	0.8243
Interface*Auditory Group	2	742.86	371.43	0.93	0.3991
Gender*Auditory Group	2	481.29	240.64	0.60	0.5505
Interface*Gender*Auditory Group	2	799.31	399.66	1.00	0.3725
Error	101	40474.97	400.74		

Table 11: Analysis of Variance: Average Completion Time

The probability of the whole model was 0.6517 and from the details of the ANOVA, we determine there are no significant differences between subjects for average completion time. This holds true for each of the main effects and variable interactions computed by the ANOVA.

4.2.2 Average Minimum Completion Time

In order to understand potential interaction of interface, gender and auditory group with respect to average minimum completion time, an analysis of variance (ANOVA) was performed. Table 12 gives the results of the ANOVA.

Source	DF	SS	MS	F	p
Interface	1	11.78	11.78	8.63	0.0041
Gender	1	1.34	1.34	0.98	0.3245
Auditory Group	2	1.18	0.59	0.43	0.6503
Interface*Gender	1	0.45	0.45	0.33	0.5688
Interface*Auditory Group	2	5.31	2.65	1.94	0.1485
Gender*Auditory Group	2	0.82	0.41	0.30	0.7403
Interface*Gender*Auditory Group	2	12.31	6.16	4.51	0.0133
Error	101	137.94	1.37		

Table 12: Analysis of Variance: Average Minimum Completion Time

The probability of the whole model was 0.0193 and from the details of the ANOVA, we determine there are significant differences between subjects for average minimum completion time. The Student-Newman-Keuls post hoc test for interface and average minimum completion time shows the subjects using the mental rotation task interface had significantly higher minimum completion times. Specifically, the mean for subjects with the MRT interface was 6.1552 while the mean for the subjects with the FRT interface was 5.5091.

When gender and auditory group are factored in with interface type, the results are also significant showing a p value of 0.0133. To further analyze this result, multiple contrast post hoc tests were run based on the interaction groups in Table 13:

Interface, Gender, Auditory Group	Interaction Group
CC0-MRT, M, None	Group 1
CC0-MRT, M, Ding	Group 2
CC0-MRT, M, Earcon	Group 3
CC0-MRT, F, None	Group 4
CC0-MRT, F, Ding	Group 5
CC0-MRT, F, Earcon	Group 6
CC1-FRT, M, None	Group 7
CC1-FRT, M, Ding	Group 8
CC1-FRT, M, Earcon	Group 9
CC1-FRT, F, None	Group 10
CC1-FRT, F, Ding	Group 11
CC1-FRT, F, Earcon	Group 12

Table 13: Post Hoc Test Interaction Groups

Twelve of the post hoc comparisons revealed significant differences. A summary of the comparisons with differences is listed in Table 14.

Source (contrast A and B)	DF	SS	MS	F	p	Means of A	Means of B
Group 3 and Group 10	1	7.394	7.394	5.41	0.0220	6.22	5.00
Group 4 and Group 9	1	6.223	6.223	4.56	0.0352	6.45	5.33
Group 4 and Group 10	1	11.636	11.636	8.52	0.0043	6.45	5.00
Group 4 and Group 11	1	8.187	8.187	5.99	0.0161	6.45	5.13
Group 5 and Group 7	1	5.981	5.981	4.38	0.0389	6.64	5.50
Group 5 and Group 8	1	5.782	5.782	4.23	0.0422	6.64	5.56
Group 5 and Group 9	1	8.405	8.405	6.15	0.0148	6.64	5.33
Group 5 and Group 10	1	14.727	14.727	10.78	0.0014	6.64	5.00
Group 5 and Group 11	1	10.580	10.580	7.75	0.0064	6.64	5.13
Group 9 and Group 12	1	6.447	6.447	4.72	0.0321	5.33	6.50
Group 10 and Group 12	1	11.790	11.790	8.63	0.0041	5.00	6.50
Group 11 and Group 12	1	8.403	8.403	6.15	0.0148	5.13	6.50

Table 14: Post Hoc Test Results for Average Minimum Completion Times

In the table above the column labeled "Means of A" documents the results for the means procedure for the first group listed under

"Source". Likewise, the column "Means of B" is the same result for the second group listed under "Source".

4.2.3 Average Maximum Completion Time

Subject performance was also measured in terms of longest (maximum) completion times. The results of the ANOVA are displayed in Table 15.

Source	DF	SS	MS	F	p
Interface	1	12492.99	12492.99	3.17	0.0781
Gender	1	127.82	127.82	0.03	0.8575
Auditory Group	2	6578.74	3289.37	0.83	0.4372
Interface*Gender	1	2105.54	2105.54	0.53	0.4666
Interface*Auditory Group	2	7591.06	3795.53	0.96	0.3854
Gender*Auditory Group	2	1146.07	573.04	0.15	0.8649
Interface*Gender*Auditory Group	2	4829.82	2414.91	0.61	0.5441
Error	101	398285.08	3943.42		

Table 15: Analysis of Variance: Average Maximum Completion Times

The probability of the whole model was 0.6359. From the details of the ANOVA, we determine there are no significant differences with regards to maximum completion times.

4.3 Accuracy of Responses

During the trials, data was collected on four types of errors related to resetting the alarms: errors in identifying a tank, errors in identifying an attribute of the tank, errors in identifying the necessary direction change and extra button pushes. As described above, the extra button push error was the result of a subject pressing the 'Submit' button when an alarm was not present.

For the secondary tasks, data was collected about how many image pairs were correctly identified in the mental rotation task or how many facts were correctly recalled in the fact recall task. Care was taken to note the structural differences of the two secondary tasks when analyzing the data. Quantitatively, the number correct on the mental rotation task should be much higher than the number correct on the fact recall regardless of how well the subjects perform. This is because subjects are able to pace themselves much quicker through the 48 pairs of images of the mental rotation task than through the 100 facts and questions used in the fact recall task.

4.3.1 Tank Errors

In order to understand potential interaction of interface, gender and auditory group with respect to number of tank errors, an analysis of variance (ANOVA) was performed. The results of the ANOVA are displayed in table 16.

Source	DF	SS	MS	F	P
Interface	1	0.00900	0.00900	5.70	0.0188
Gender	1	0.00002	0.00002	0.01	0.9138
Auditory Group	2	0.00042	0.00021	0.13	0.8766
Interface*Gender	1	0.00264	0.00264	1.67	0.1989
Interface*Auditory Group	2	0.00127	0.00063	0.40	0.6700
Gender*Auditory Group	2	0.00259	0.00129	0.82	0.4435
Interface*Gender*Auditory Group	2	0.00308	0.00154	0.97	0.3808
Error	101	0.15948	0.00158		

Table 16: Analysis of Variance: Tank Errors

The probability of the entire model is not significant ($p = 0.3735$). However, one of the categories, interface, reveals a significant difference for tank errors between the two different interface types.

The Student-Newman-Keuls test shows the subjects using the fact-recall (FRT) interface committed more errors identifying the correct tank than subjects using the mental rotation task (MRT) interface. Specifically, the FRT subjects had a mean tank error rate of 0.0361 while the MRT subjects had a tank error rate of 0.0182. The tank error rate for subjects performing the fact recall task is nearly double the tank error rate for subjects performing the mental rotation task.

4.3.2 Attribute Errors

In order to understand potential interaction of interface, gender and auditory group with respect to number of attribute errors, an analysis of variance (ANOVA) was performed. The results of the ANOVA are displayed in table 17.

Source	DF	SS	MS	F	P
Interface	1	0.00003038	0.00003038	0.04	0.8326
Gender	1	0.00000003	0.00000003	0.00	0.9947
Auditory Group	2	0.00088993	0.00044496	0.66	0.5203
Interface*Gender	1	0.00023929	0.00023929	0.35	0.5534
Interface*Auditory Group	2	0.00082293	0.00041146	0.61	0.5464
Gender*Auditory Group	2	0.00025269	0.00012635	0.19	0.8300
Interface*Gender*Auditory Group	2	0.00035944	0.00017972	0.27	0.7673
Error	101	0.06834	0.00068		

Table 17: Analysis of Variance: Attribute Errors

The probability of the entire model is not significant (p = 0.9719). A review the details of the ANOVA reveals no significant differences for any of the computations.

4.3.3 Change Errors

In order to understand potential interaction of interface, gender and auditory group with respect to number of change errors, an analysis of variance (ANOVA) was performed. The results of the ANOVA are displayed in table 18.

Source	DF	SS	MS	F	P
Interface	1	0.00576	0.00576	1.44	0.2337
Gender	1	0.00252	0.00252	0.63	0.4300
Auditory Group	2	0.00579	0.00289	0.72	0.4890
Interface*Gender	1	0.00362	0.00362	0.90	0.3449
Interface*Auditory Group	2	0.00044	0.00022	0.05	0.9468
Gender*Auditory Group	2	0.01577	0.00788	1.96	0.1457
Interface*Gender*Auditory Group	2	0.01511	0.00756	1.88	0.1576
Error	101	0.40554	0.00402		

Table 18: Analysis of Variance: Change Errors

The probability of the entire model is not significant ($p = 0.3618$). A review the ANOVA reveals no significant differences for any of the computations with regard to change errors.

4.3.4 Extra Button Push Errors

In order to understand potential interaction of interface, gender and auditory group with respect to number of extra button push errors, an analysis of variance (ANOVA) was performed. The results of the ANOVA are displayed in table 19.

Source	DF	SS	MS	F	P
Interface	1	0.00694	0.00694	0.63	0.4276
Gender	1	0.00019	0.00019	0.02	0.8958
Auditory Group	2	0.01950	0.00973	0.89	0.4141
Interface*Gender	1	0.00047	0.00047	0.04	0.8370
Interface*Auditory Group	2	0.00212	0.00106	0.10	0.9077
Gender*Auditory Group	2	0.01028	0.00514	0.47	0.6264
Interface*Gender*Auditory Group	2	0.08115	0.04058	3.71	0.0279
Error	101	1.10496	0.01094		

Table 19: Analysis of Variance: Extra Button Push Errors

The probability of the entire model is not significant (p = 0.4499). A review the ANOVA reveals a significant difference for extra button push errors when interface, gender and auditory group are factored together.

To further analyze the significant 3-way interactions from the ANOVA, interaction groups were defined and multiple contrast post hoc tests were run. Table 20 lists the interaction groups:

Interface, Gender, Auditory Group	Interaction Group
CC0-MRT, M, None	Group 1
CC0-MRT, M, Ding	Group 2
CC0-MRT, M, Earcon	Group 3
CC0-MRT, F, None	Group 4
CC0-MRT, F, Ding	Group 5
CC0-MRT, F, Earcon	Group 6
CC1-FRT, M, None	Group 7
CC1-FRT, M, Ding	Group 8
CC1-FRT, M, Earcon	Group 9
CC1-FRT, F, None	Group 10
CC1-FRT, F, Ding	Group 11
CC1-FRT, F, Earcon	Group 12

Table 20: Interaction Groups for Extra Button Push Errors

Three of the comparisons showed significant differences and are summarized in Table 21.

Source (contrast A and B)	DF	SS	MS	F	p	Means of A	Means of B
Group 5 and Group 11	1	0.0440	0.0440	4.02	0.0475	0.012	0.109
Group 8 and Group 11	1	0.0469	0.0469	4.29	0.0410	0.004	0.109
Group 10 and Group 11	1	0.0472	0.0472	4.32	0.0402	0.008	0.109

Table 21: Post Hoc Results for Extra Button Push Error

The comparison between group 5 and 11 shows a significant difference between females using the MRT interface with a ding sound (group 5) and females using the FRT interface with a ding sound (group 11). This indicates that females in group 11 performing the fact recall sub-task made significantly more "extra button push" errors than the females in group 5, who were performing the mental rotation task.

Additionally, the post hoc test showed significant difference between group 8 and group 11. In group 8, males using the FRT interface with a ding sound committed less "extra button push" errors than females using the FRT interface with a ding sound.

The final test for the "extra button push" error data compared group 10 and group 11. This significant result indicates that females using the FRT interface with no sound committed fewer errors than females using the FRT interface with the ding sound.

4.3.5 Total Number Correct on Secondary Task

In order to understand potential interaction of interface, gender and auditory group with respect to number correct on either the mental rotation task or fact recall task, an analysis of variance (ANOVA) was performed. The results of the ANOVA are displayed in table 22.

Source	DF	SS	MS	F	P.
Interface	1	2824813.74	2824813.74	697.21	<.0001
Gender	1	8986.30	8986.30	2.22	0.1395
Auditory Group	2	6726.08	3363.04	0.83	0.4390
Interface*Gender	1	786.01	786.01	0.19	0.6605
Interface*Auditory Group	2	7175.20	3587.60	0.89	0.4157
Gender*Auditory Group	2	8280.94	4140.47	1.02	0.3636
Interface*Gender*Auditory Group	2	14178.79	7089.39	1.75	0.1790
Error	101	409211.83	4051.60		

Table 22: Analysis of Variance: Total Number Correct on Sub-task

The probability of the entire model is significant (p < .0001). A review of the ANOVA shows a significant difference for the total number correct by interface type. This is expected because the mental rotation task is faster paced than the fact recall task. Therefore, in the twenty minutes allotted for the trial, subjects were able to complete more mental rotation answers than fact recall answers. Quantitatively, subjects using the MRT interface had a mean of 425.64 total correct while the subjects using the FRT interface had a mean of 109.31 total correct. The MRT subjects cycled through the 48 image pairs approximately 8.9 times in the twenty minutes while the FRT subjects were only able to go through the 100 facts and questions once.

For this project, the important statistic for total correct is the computations done for gender. From the ANOVA results above, we see there are no significant differences for total correct on the secondary task that can be attributed to gender.

Chapter 5

DISCUSSION

Computer interfaces should be designed based on an understanding of the task(s) to be accomplished and the nature of the person(s) who will use the interface [Scheiderman97]. In this project, the tasks were divided into the primary task of monitoring an alarm system and one of two secondary tasks, either mental rotation of a simple line drawing or recall of a series of facts. Previous research on crisis control interfaces indicated an improvement of subject performance on crisis monitoring in a divided attention scenario when sound was included in the interface [Sculley91]. This project sought to explore subject performance on crisis control monitoring in a divided attention scenario in terms of possible gender differences.

5.1 Significance of Data Analysis

The primary question being examined in this project was whether or not significant differences would be found for subjects of different genders. The design of the interfaces used in the project incorporated secondary tasks where previous research has supported significant differences based on gender [Herlitz97, Murray99]. Data was collected on eleven dependent measures and analyzed in terms of interface, gender and auditory group using ANOVAs. There were no significant 2-way interactions for interface and gender, interface and auditory group or auditory group and gender. When the results of the ANOVA revealed a significant 3-way interaction for interface, gender and auditory group, subsequent multiple post hoc tests were run and the results analyzed.

Analysis of the ANOVAs indicates female and male subjects performed equally well on the primary alarm monitoring task (in terms of average response time, maximum response time, average completion time and maximum completion time). A significant performance difference (in terms of minimum response time and minimum completion time) was found between the interface displaying the mental rotation task and the interface displaying the fact recall task. Subjects, male and female, using the interface for both alarm monitoring and mental rotation had significantly slower minimum response times and minimum completion times than subjects performing the alarm monitoring and fact recall tasks. Minimum response time and minimum completion time measure a subject's performance in terms of how fast or proficient the subject becomes at completing the primary task of resetting an alarm condition. Baddeley and his colleagues have theorized that a task that distracts attention during learning reduces the amount learned [Baddeley84]. They also concluded "... a concurrent task during retrieval does have a clear effect on latency. It is suggested that this reflects response competition at output" [Baddeley84, page 518]. This leads us to two possible explanations for the performance difference observed in this study. Perhaps the performance difference between subjects using the fact recall interface and the mental rotation interface indicates learning the mental rotation task interferes more with learning the alarm monitoring task than learning the fact recall task. It is also possible the cognitive resources used for the mental rotation task compete more with the cognitive resources used for the alarm reset task than do the cognitive resources involved in fact recall.

A significant 3-way interaction for interface, gender and auditory group was found for both minimum response time and minimum completion time. To analyze the interaction, sixty-six between group post hoc comparisons were run. Of these sixty-six, twelve comparisons had significantly different results. The same twelve comparisons were significant for both minimum response time and minimum completion time. Since completion time is a sub-set of response time, the following discussion applies to both dependent measures.

In four of the twelve comparisons with significant results, it was not possible to determine a single factor responsible for the difference because the groups varied by interface, gender and auditory group. For example, the comparison between group 3 (CC0-MRT, M, Earcon) and group 10 (CC1-FRT, F, none) shows that group 3 had a significantly higher minimum response and completion times but it is not possible to single out gender, auditory group or interface as the cause of the difference. Perhaps all three factors acted together to cause the difference. Similar results were found for the comparison between group 4 (CC0-MRT, F, None) and group 9 (CC1-FRT, M, Earcon), group 5 (CC0-MRT, F, Ding) and group 7 (CC1-FRT, M, None) and group 5 and group 9. When taken as a whole, the results of these four multiple post hoc tests support the original finding of the ANOVA for minimum response time and minimum completion time. In these specific comparisons, subjects performing the mental rotation task (Group 3, 4 and 5) had significantly higher minimum response times than subjects performing the fact-recall task (Group 7, 9 and 10). The same main effect for interface was found in the original ANOVA results.

Three of the remaining post hoc results involve groups that vary by two of the three independent variables. In the comparison involving group 4 (CC0-MRT, F, None) and group 11 (CC1-FRT, F, Ding), females performing the MRT task and using no sound had significantly higher minimum response and completion times than females performing the FRT task and using the ding sound. This result seems to indicate females found the fact recall task interfered less with the alarm monitoring task than the mental rotation task. However, because the groups also varied by auditory group, a case could be made that inclusion of the ding sound resulted in faster minimum response and completions times for group 11 by calling the subjects attention to the alarm condition.

In the comparison between group 5 (CC0-MRT, F, Ding) and group 8 (CC1-FRT, M, Ding), females performing the mental rotation task and using the ding sound had higher minimum response and completion times than males performing the fact recall task and using the ding sound. Since both groups were using the ding sound, we can rule out auditory group as the source of the difference. This leaves the way females approach alarm monitoring while dealing with a mental rotation sub-task compared to how males approach alarm monitoring while dealing with a fact recall sub-task. In this particular case, it appears males were able to more quickly respond to alarms while distracted by the fact recall task than females were able to respond while distracted by the mental rotation task.

In the comparison between group 5 and group 10 (CC1-FRT, F, None), females performing the mental rotation task with a ding sound had significantly slower minimum response and completion times than females performing the fact recall task with no sound. This result seems to support the idea that inclusion of the auditory signal could not overcome the task-related interference of the mental rotation task in terms of making female performance on the mental rotation task equal to female performance on the fact recall task with no sound.

In the remaining five comparisons, the interaction groups only vary by one of the 3 main effects being compared. In two of these tests, females using the MRT interface had a higher minimum response time and completion time than females using the FRT interface. In one of the two cases (group 5 and 11), both groups used a ding sound while in the other case (group 4 and 10), no sound was included for either group. These results tend to support previous research that females perform better on verbal or linguistic tasks than they do on visual-spatial tasks. It is interesting to note that the same significant increase in minimum response time or completion time was not found for females using the MRT interface with earcon sound when compared to females using the FRT interface with earcon sound. Perhaps inclusion of the earcon sound in the MRT interface improved female subject performance (in terms of minimum response time and completion time) to the point where no significant difference between females using the MRT interface with earcon sound and females using the FRT interface with earcon sound was found.

The multiple contrast test results also show significant differences for auditory group for females within the fact-recall task interface type. Two of the comparisons (group 10 and 12 and group 11 and 12) show females using the FRT interface performed slower (in terms of minimum response time and minimum completion time) when the earcon sound was included. These results appear to indicate that the cognitive demands of processing a sound which includes meaning (earcon) interferes with female subject performance on the primary task of alarm monitoring when the subject also is completing a fact-recall secondary task. This same evidence of auditory interference was not found for females completing the mental-rotation secondary task. Likewise, within gender differences for auditory group for males was not found for either the fact recall interface type or the mental rotation interface type.

Finally, one of the post hoc tests shows a specific significant difference in terms of gender. In the test comparing group 9 (CC1-FRT, M, Earcon) and group 12 (CC1-FRT, F, Earcon), males using the FRT interface that includes the earcon sound performed better (in terms of minimum response and completion time) than females using the same interface. Since the original hypothesis was females would out perform males on the fact-recall task in all cases, this result tends to support the idea that subject performance can be influenced (in this case, positively) by the inclusion of sound in the crisis-control interface. It is interesting to note inclusion of the earcon sound in the mental rotation task did not reveal a similar significant improvement in terms of female performance when compared to males using the MRT interface that included the earcon sound.

So far the discussion has centered on subject performance in terms of minimum response time and minimum completion time for resetting the alarm (primary task). It is also important to evaluate an interface for the number of errors committed by the subject while performing a task with the interface. In the current work, a significant error result was found concerning tank errors. Subjects performing the fact recall task committed nearly twice the number of tank identification errors as subjects performing the mental rotation task. The fact recall subjects did not have similar difficulty regarding identification of the attribute or change needing attention for the alarm condition. One possible explanation for the significant error rate for tank identification could be that the same cognitive resources are involved in reading the facts being recalled and in reading the tank indicators. This explanation is supported by the structural theory of attention researched by Wickens and others [Wickens80]. It should be noted that no gender differences were found as far as a subject's ability to correctly identify the tank during the alarm reset task.

The extra button push error data analysis indicates that including the ding sound in the interface that combined alarm monitoring and fact recall tasks caused females to press the submit button associated with the alarm monitoring at unintended or unnecessary times. Since females using the FRT interface with the earcon sounds and females using the FRT interface without sound did not make a significant number of extra button push errors, it appears the confusion was the result of the ding sound itself. This same tendency did not appear for males using the FRT interface with the ding sound.

Overall, the data suggests inclusion of a secondary task into a crisis-control monitoring interface should follow certain guidelines. Specifically, the secondary task is more manageable and interferes less with the primary task if it is structured like the fact recall task (self-paced, reading facts, answering questions) as opposed to being structured like the mental rotation task. In terms of sound, no main effect was found for subject response time or completion time indicating the ding or earcon improved subject recognition of the alarm. However, in terms of interactions, this study suggests inclusion of the earcon sound is better than the ding sound because it does not seem to introduce confusion for female subjects.

5.2 Suggestions for Further Research

The purpose of this study was to analyze possible gender differences for subject performance on a crisis-control monitoring primary task when one of two secondary tasks was included. Results from this study provide preliminary indication that gender differences can be found for crisis control simulations in a dual-task, cross modal design. To further explore these results, it is suggested that different sub-tasks be used to increase the possible interference of the sub-task with the primary task. One possible change is to use the Shepard and Metzler chiral shapes [Shepard71] instead of the line drawing rotation used in the current study. It is expected all subjects would find the rotation of the chiral shapes more challenging than rotation of the simple line drawing in the current study. Perhaps more definitive gender differences could be recorded under such increased cognitive demand. Likewise, a more challenging verbal task might reveal greater differences between subjects.

Another possible extension of the current study would be to analyze the performance of subjects who received more than three minutes of practice. Saccuzzo and his colleagues found that practice was capable of eliminating some observed gender differences on a computerized spatial task [Saccuzzo96]. They also found the improvement in performance was durable. To extend the current study, subjects could be given more practice before each trial. Additionally, subjects could be re-tested at a later time to see if any performance improvement was durable.

Still another extension of the current study would be measuring if various configurations of the integrated interface affected performance. For example, how would placing the indicators and control buttons at the top of the interface with the secondary task at the bottom affect performance on either task? Similarly, would placing the interfaces for the two tasks side-by-side affect subject performance? These would be interesting questions to explore.

There also appears to be a trend in neuroscience to use functional magnetic resonance imaging (fMRI) to analyze brain activation during various cognitive tasks. It would be interesting to perform this same study to see if the differences identified for minimum response time, minimum completion time, tank errors and extra button push errors could be correlated to activation of different regions of the brain. Based on current fMRI research [Cohen96, Greicius03, Gur00, Schlaepfer95] it is predicted fMRI analysis of this study would reveal different brain regions involved in the mental rotation task, alarm monitoring task and fact recall task and provide direct, physical evidence to support the behavioral differences found.

APPENDIX A

Instruction Packet: Mental Rotation Task with No Sound

The following pages contain the instruction packet given to subjects using the crisis control system with the mental rotation sub-task and no auditory warning signal. The instructions include a description of the general steps of the experiment, instructions on how to complete the mental rotation task and a detailed description of the crisis control system.

GENERAL INSTRUCTIONS

PLEASE READ THESE INSTRUCTIONS COMPLETELY BEFORE YOU BEGIN.

Your objective is to complete the object identification task while monitoring the Crisis Control System. All information necessary to complete your task will be displayed on a single computer positioned directly in front of you.

STEP 1

Read the instructions for the Crisis Control System.

STEP 2

Complete the practice session on the Crisis Control System. The practice session will last approximately three minutes; several alarms will occur. Use this time to familiarize yourself with the screen, practice reacting to an alarm and identify object pairs.

The lab instructor will start the practice session. The lab instructor will indicate when it is time to end the practice session. At that time, you will be instructed to press the 'x' in the top right corner of the screen to close the practice screen.

STEP 3

When the practice session has ended, the lab instructor will start the actual Crisis Control System.

STEP 4

Answer the questions about your general experience. Use the mouse to select answers and press the 'Submit' button.

STEP 5

Begin the object identification task and start monitoring the Crisis Control indicators.

STEP 6

The lab instructor will indicate when it is time to end the monitoring session. At that time, press the 'x' in the top right corner of the screen to close the monitoring screen and stop the Crisis Control System.

PLEASE NOTE:

This study assumes that you have no outside assistance in completing your tasks. The instructions have been designed so that questions should not be necessary.

THE CRISIS CONTROL SYSTEM

This system is a simulation of an industrial power plant that houses three water tanks. In this simulation, it is extremely important that the temperature, volume and pressure of each tank stay within a safe range. It is your responsibility to see that corrective action is taken if any of these water tanks reaches an unsafe level.

The system monitor displays nine indicators that represent the attributes (temperature, volume and pressure) of the three water tanks. You will need to monitor the indicators to ensure all levels remain within the safety range. In the event of an alarm situation in which an indicator has fallen out of its safety range, you will be expected to correct the problem as quickly and accurately as possible.

In addition to tank information, the Crisis Control System also displays information about various objects. This information is presented in a series of image pairs. The first image presented identifies a familiar object such as an airplane. The second image in the pair either represents the same object or a completely different object. Your objective is to determine if the second image represents the same object or if it is a completely different object. Note that 'same' means the second image represents the same object. It does not mean that the image is exactly the same. For example, the second image may be presented in a different orientation or it may be larger or smaller than the first image while still depicting the same object. Differences in image presentation (orientation and/or size) should be ignored.

SCREEN LAYOUT

The computer screen has been divided into four (4) general areas. The top portion of the screen includes nine (9) indicators, three (3) for each of the three (3) water tanks. The indicators for Tank 1 are in the top left corner of the screen. The indicators for Tank 2 are in the top middle of the screen and the indicators for Tank 3 are in the top right corner. Each set of indicators is ordered as follows: temperature (labeled T), volume (labeled V) and pressure (labeled P). The bottom of the screen includes the buttons used to correct an alarm situation. The middle portion of the screen contains the area where the image pairs are displayed and includes the buttons used to indicate if the pairs are the 'same' or 'different'. The diagram below shows the layout of the screen.

Crisis Control Indicators

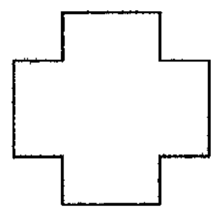
Tank 1 T___ V___ P___ Tank 2 T___ V___ P___ Tank 3 T___ V___ P___

Choose 'Same' if second image is same as first image (ignoring rotation and/or size).

Choose 'Different' if second image is different from first image (ignoring rotation and/or size)

* Same
* Different

Submit



Controls

Tank | * 1 | * 2 | * 3 | Attribute | * T | * V | * P | Change | * U | * D | Submit |

DESCRIPTION OF INDICATORS

Each attribute (temperature, volume and pressure) should always fall within its assigned safety range:

	Low	High
Temperature	32	35
Volume	72	75
Pressure	102	105

The safety ranges are marked on the right hand side of each indicator; you will, therefore, not need to memorize the values. An example of each type of indicator follows:

```
     ____            ____              ____
36  |____| T    76  |    | V    106   |    | P
35  |____|      75  |    |      105   |____|
34  |    |      74  |____|      104   |____|
33  |    |      73  |____|      103   |    |
32  |    |      72  |    |      102   |    |
31  |____|      71  |____|      101   |____|
```

The height of the solid bar or slider indicates the current value of the indicator. The above indicators are all within the safety range. It is acceptable for the bar to meet the safety marker; AN ALARM CONDITION OCCURS ONLY WHEN THE INDICATOR BAR GOES BEYOND THESE SAFETY MARKERS.

CORRECTING AN ALARM CONDITION

Four steps must be taken to correct an alarm condition in which an indicator has gone beyond its safety range. Any incorrect keys that are pressed will have no effect on the indicator's current value. As each of the following steps are correctly taken, the value of that step is displayed in the appropriate box at the bottom of the screen. Note, the phrase 'point and click' refers to using the mouse attached to the computer you are working on to direct the cursor to point at an area on the screen and then using the left mouse button to activate or select that area.

STEP 1. CHOOSE TANK.

```
TANK 1 ==> Point and click on '1' indicator
TANK 2 ==> Point and click on '2' indicator
TANK 3 ==> Point and click on '3' indicator
```

STEP 2. CHOOSE ATTRIBUTE.

```
TEMPERATURE ==> Point and click on 'T' indicator
VOLUME      ==> Point and click on 'V' indicator
PRESSURE    ==> Point and click on 'P' indicator
```

STEP 3. CHOOSE CHANGE.

```
INCREASE VALUE ==> Point and click on 'U' indicator
DECREASE VALUE ==> Point and click on 'D' indicator
```

STEP 4. SUBMIT ANSWER.

Point and click on 'SUBMIT' button in bottom part of the screen.

RECORDING OBJECT IDENTIFICATION ANSWERS

While you are monitoring the Crisis Control indicators, the system will present a series of object image pairs on the screen. The first image will be visible for a short time then the second image will appear. Your task is to determine if the second image represents the same object as the first image in the pair. For this task, it is important to remember that 'same' means the second image represents the same object as the first image in the pair. 'Same' does not necessarily mean the second image is exactly like the first image. Possible image differences for the same object pair include changes in size and/or orientation (rotation) of the image.

There are two steps to complete the object identification task:

STEP 1 ==> CHOOSE IMAGE TYPE.

SAME ==> Point and click at 'Same'
DIFFERENT ==> Point and click at 'Different'

STEP 2 ==> SUBMIT ANSWER.

'Point and click' on 'SUBMIT' button in the middle left part of the screen (directly under the Same/Different indicators).

Once the 'SUBMIT' button has been pressed, the next object pair will be presented.

APPENDIX B

Instruction Packet: Mental Rotation Task with Ding

The following pages contain the instruction packet given to subjects using the crisis control system with the mental rotation sub-task and a 'ding' auditory warning signal. The instructions include a description of the general steps of the experiment, instructions on how to complete the mental rotation task and a detailed description of the crisis control system.

GENERAL INSTRUCTIONS

PLEASE READ THESE INSTRUCTIONS COMPLETELY BEFORE YOU BEGIN.

Your objective is to complete the object identification task while monitoring the Crisis Control System. All information necessary to complete your task will be displayed on a single computer positioned directly in front of you.

STEP 1

Read the instructions for the Crisis Control System.

STEP 2

Complete the practice session on the Crisis Control System. The practice session will last approximately three minutes; several alarms will occur. Use this time to familiarize yourself with the screen, practice reacting to an alarm and identify object pairs.

The lab instructor will start the practice session. The lab instructor will indicate when it is time to end the practice session. At that time, you will be instructed to press the 'x' in the top right corner of the screen to close the practice screen.

STEP 3

When the practice session has ended, the lab instructor will start the actual Crisis Control System.

STEP 4

Answer the questions about your general experience. Use the mouse to select answers and press the 'Submit' button.

STEP 5

Begin the object identification task and start monitoring the Crisis Control indicators.

STEP 6

The lab instructor will indicate when it is time to end the monitoring session. At that time, press the 'x' in the top right corner of the screen to close the monitoring screen and stop the Crisis Control System.

PLEASE NOTE:

This study assumes that you have no outside assistance in completing your tasks. The instructions have been designed so that questions should not be necessary.

THE CRISIS CONTROL SYSTEM

This system is a simulation of an industrial power plant that houses three water tanks. In this simulation, it is extremely important that the temperature, volume and pressure of each tank stay within a safe range. It is your responsibility to see that corrective action is taken if any of these water tanks reaches an unsafe level.

The system monitor displays nine indicators that represent the attributes (temperature, volume and pressure) of the three water tanks. You will need to monitor the indicators to ensure all levels remain within the safety range. In the event of an alarm situation in which an indicator has fallen out of its safety range, you will be expected to correct the problem as quickly and accurately as possible.

In addition to tank information, the Crisis Control System also displays information about various objects. This information is presented in a series of image pairs. The first image presented identifies a familiar object such as an airplane. The second image in the pair either represents the same object or a completely different object. Your objective is to determine if the second image represents the same object or if it is a completely different object. Note that 'same' means the second image represents the same object. It does not mean that the image is exactly the same. For example, the second image may be presented in a different orientation or it may be larger or smaller than the first image while still depicting the same object. Differences in image presentation (orientation and/or size) should be ignored.

SCREEN LAYOUT

The computer screen has been divided into four (4) general areas. The top portion of the screen includes nine (9) indicators, three (3) for each of the three (3) water tanks. The indicators for Tank 1 are in the top left corner of the screen. The indicators for Tank 2 are in the top middle of the screen and the indicators for Tank 3 are in the top right corner. Each set of indicators is ordered as follows: temperature (labeled T), volume (labeled V) and pressure (labeled P). The bottom of the screen includes the buttons used to correct an alarm situation. The middle portion of the screen contains the area where the image pairs are displayed and includes the buttons used to indicate if the pairs are the 'same' or 'different'. The diagram below shows the layout of the screen.

Crisis Control Indicators

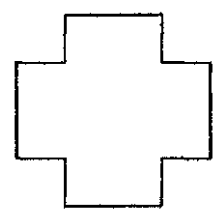
Tank 1 T ___ V ___ P ___ Tank 2 T ___ V ___ P ___ Tank 3 T ___ V ___ P ___

Choose 'Same' if second image is same as first image (ignoring rotation and/or size).

Choose 'Different' if second image is different from first image (ignoring rotation and/or size)

* Same
* Different

Submit



Controls

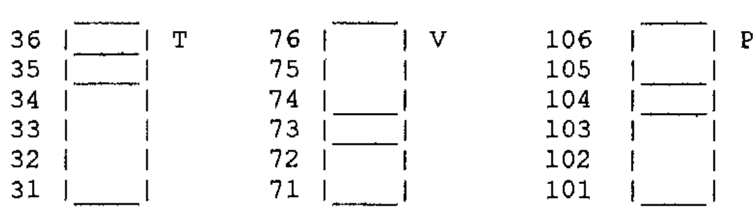
Tank | * 1 | * 2 | * 3 | Attribute | * T | * V | * P | Change | * U | * D | Submit |

DESCRIPTION OF INDICATORS

Each attribute (temperature, volume and pressure) should always fall within its assigned safety range:

	Low	High
Temperature	32	35
Volume	72	75
Pressure	102	105

The safety ranges are marked on the right hand side of each indicator; you will, therefore, not need to memorize the values. An example of each type of indicator follows:



The height of the solid bar or slider indicates the current value of the indicator. The above indicators are all within the safety range. It is acceptable for the bar to meet the safety marker; AN ALARM CONDITION OCCURS ONLY WHEN THE INDICATOR BAR GOES BEYOND THESE SAFETY MARKERS.

AUDITORY WARNING SIGNAL

An auditory DING is used to signal that a tank has reached an unsafe level. The ding is approximately one second in length. The warning signal will occur only once after each alarm. The sound of the ding should help you notice the alarm situation as quickly as possible.

CORRECTING AN ALARM CONDITION

Four steps must be taken to correct an alarm condition in which an indicator has gone beyond its safety range. Any incorrect keys that are pressed will have no effect on the indicator's current value. As each of the following steps are correctly taken, the value of that step is displayed in the appropriate box at the bottom of the screen. Note, the phrase 'point and click' refers to using the mouse attached to the computer you are working on to direct the cursor to point at an area on the screen and then using the left mouse button to activate or select that area.

STEP 1. CHOOSE TANK.

TANK 1 ==> Point and click on '1' indicator
TANK 2 ==> Point and click on '2' indicator
TANK 3 ==> Point and click on '3' indicator

STEP 2. CHOOSE ATTRIBUTE.

TEMPERATURE ==> Point and click on 'T' indicator
VOLUME ==> Point and click on 'V' indicator
PRESSURE ==> Point and click on 'P' indicator

STEP 3. CHOOSE CHANGE.

INCREASE VALUE ==> Point and click on 'U' indicator
DECREASE VALUE ==> Point and click on 'D' indicator

STEP 4. SUBMIT ANSWER.

Point and click on 'SUBMIT' button in bottom part of the screen.

RECORDING OBJECT IDENTIFICATION ANSWERS

While you are monitoring the Crisis Control indicators, the system will present a series of object image pairs on the screen. The first image will be visible for a short time then the second image will appear. Your task is to determine if the second image represents the same object as the first image in the pair. For this task, it is important to remember that 'same' means the second image represents the same object as the first image in the pair. 'Same' does not necessarily mean the second image is exactly like the first image. Possible image differences for the same object pair include changes in size and/or orientation (rotation) of the image.

There are two steps to complete the object identification task:

STEP 1 ==> CHOOSE IMAGE TYPE.

SAME ==> Point and click at 'Same'
DIFFERENT ==> Point and click at 'Different'

STEP 2 ==> SUBMIT ANSWER.

Point and click on 'SUBMIT' button in the middle left part of the screen (directly under the Same/Different indicators).

Once the 'SUBMIT' button has been pressed, the next object pair will be presented.

APPENDIX C

Instruction Packet: Mental Rotation Task with Earcon

The following pages contain the instruction packet given to subjects using the crisis control system with the mental rotation sub-task and an 'earcon' auditory warning signal. The instructions include a description of the general steps of the experiment, instructions on how to complete the mental rotation task and a detailed description of the crisis control system.

GENERAL INSTRUCTIONS

PLEASE READ THESE INSTRUCTIONS COMPLETELY BEFORE YOU BEGIN.

Your objective is to complete the object identification task while monitoring the Crisis Control System. All information necessary to complete your task will be displayed on a single computer positioned directly in front of you.

STEP 1

Read the instructions for the Crisis Control System.

STEP 2

Complete the practice session on the Crisis Control System. The practice session will last approximately three minutes; several alarms will occur. Use this time to familiarize yourself with the screen, practice reacting to an alarm and identify object pairs.

The lab instructor will start the practice session. The lab instructor will indicate when it is time to end the practice session. At that time, you will be instructed to press the 'x' in the top right corner of the screen to close the practice screen.

STEP 3

When the practice session has ended, the lab instructor will start the actual Crisis Control System.

STEP 4

Answer the questions about your general experience. Use the mouse to select answers and press the 'Submit' button.

STEP 5

Begin the object identification task and start monitoring the Crisis Control indicators.

STEP 6

The lab instructor will indicate when it is time to end the monitoring session. At that time, press the 'x' in the top right corner of the screen to close the monitoring screen and stop the Crisis Control System.

PLEASE NOTE:

This study assumes that you have no outside assistance in completing your tasks. The instructions have been designed so that questions should not be necessary.

THE CRISIS CONTROL SYSTEM

This system is a simulation of an industrial power plant that houses three water tanks. In this simulation, it is extremely important that the temperature, volume and pressure of each tank stay within a safe range. It is your responsibility to see that corrective action is taken if any of these water tanks reaches an unsafe level.

The system monitor displays nine indicators that represent the attributes (temperature, volume and pressure) of the three water tanks. You will need to monitor the indicators to ensure all levels remain within the safety range. In the event of an alarm situation in which an indicator has fallen out of its safety range, you will be expected to correct the problem as quickly and accurately as possible.

In addition to tank information, the Crisis Control System also displays information about various objects. This information is presented in a series of image pairs. The first image presented identifies a familiar object such as an airplane. The second image in the pair either represents the same object or a completely different object. Your objective is to determine if the second image represents the same object or if it is a completely different object. Note that 'same' means the second image represents the same object. It does not mean that the image is exactly the same. For example, the second image may be presented in a different orientation or it may be larger or smaller than the first image while still depicting the same object. Differences in image presentation (orientation and/or size) should be ignored.

SCREEN LAYOUT

The computer screen has been divided into four (4) general areas. The top portion of the screen includes nine (9) indicators, three (3) for each of the three (3) water tanks. The indicators for Tank 1 are in the top left corner of the screen. The indicators for Tank 2 are in the top middle of the screen and the indicators for Tank 3 are in the top right corner. Each set of indicators is ordered as follows: temperature (labeled T), volume (labeled V) and pressure (labeled P). The bottom of the screen includes the buttons used to correct an alarm situation. The middle portion of the screen contains the area where the image pairs are displayed and includes the buttons used to indicate if the pairs are the 'same' or 'different'. The diagram below shows the layout of the screen.

Crisis Control Indicators

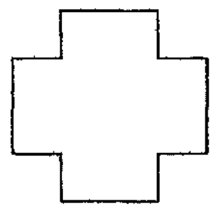
Tank 1 T___ V___ P___ Tank 2 T___ V___ P___ Tank 3 T___ V___ P___

Choose 'Same' if second image is same as first image (ignoring rotation and/or size).

Choose 'Different' if second image is different from first image (ignoring rotation and/or size)

* Same
* Different

Submit



Controls

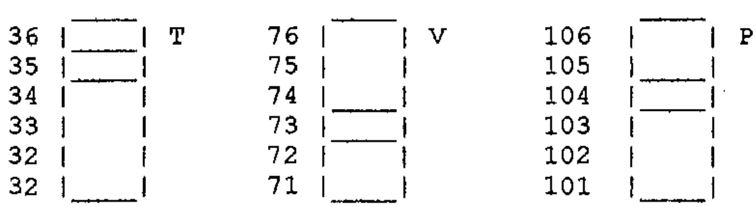
Tank |* 1|* 2|* 3| Attribute |* T|* V|* P| Change |* U|* D| |Submit|

DESCRIPTION OF INDICATORS

Each attribute (temperature, volume and pressure) should always fall within its assigned safety range:

	Low	High
Temperature	32	35
Volume	72	75
Pressure	102	105

The safety ranges are marked on the right hand side of each indicator; you will, therefore, not need to memorize the values. An example of each type of indicator follows:



The height of the solid bar or slider indicates the current value of the indicator. The above indicators are all within the safety range. It is acceptable for the bar to meet the safety marker; AN ALARM CONDITION OCCURS ONLY WHEN THE INDICATOR BAR GOES BEYOND THESE SAFETY MARKERS.

AUDITORY WARNING SIGNAL

Three (3) different types of auditory alarms are used to signal that a tank has reached an unsafe level. The sounds were chosen to signal the problem at hand - this should help you distinguish which indicator needs to be corrected.

ATTRIBUTE		AUDITORY SIGNAL
Temperature	==>	High pitched whistle
Volume	==>	Tone changing in pitch (siren)
Pressure	==>	Popping sound

Each warning signal lasts approximately one (1) second. The signal will occur only once for each alarm situation.

CORRECTING AN ALARM CONDITION

Four steps must be taken to correct an alarm condition in which an indicator has gone beyond its safety range. Any incorrect keys that are pressed will have no effect on the indicator's current value. As each of the following steps are correctly taken, the value of that step is displayed in the appropriate box at the bottom of the screen. Note, the phrase 'point and click' refers to using the mouse attached to the computer you are working on to direct the cursor to point at an area on the screen and then using the left mouse button to activate or select that area.

STEP 1. CHOOSE TANK.

TANK 1 ==> Point and click on '1' indicator
TANK 2 ==> Point and click on '2' indicator
TANK 3 ==> Point and click on '3' indicator

STEP 2. CHOOSE ATTRIBUTE.

TEMPERATURE ==> Point and click on 'T' indicator
VOLUME ==> Point and click on 'V' indicator
PRESSURE ==> Point and click on 'P' indicator

STEP 3. CHOOSE CHANGE.

INCREASE VALUE ==> Point and click on 'U' indicator
DECREASE VALUE ==> Point and click on 'D' indicator

STEP 4. SUBMIT ANSWER.

Point and click on 'SUBMIT' button in bottom part of the screen.

RECORDING OBJECT IDENTIFICATION ANSWERS

While you are monitoring the Crisis Control indicators, the system will present a series of object image pairs on the screen. The first image will be visible for a short time then the second image will appear. Your task is to determine if the second image represents the same object as the first image in the pair. For this task, it is important to remember that 'same' means the second image represents the same object as the first image in the pair. 'Same' does not necessarily mean the second image is exactly like the first image. Possible image differences for the same object pair include changes in size and/or orientation (rotation) of the image.

There are two steps to complete the object identification task:

STEP 1 ==> CHOOSE IMAGE TYPE.

SAME ==> Point and click at 'Same'
DIFFERENT ==> Point and click at 'Different'

STEP 2 ==> SUBMIT ANSWER.

Point and click on 'SUBMIT' button in the middle left part of the screen (directly under the Same/Different indicators).

Once the 'SUBMIT' button has been pressed, the next object pair will be presented.

APPENDIX D

Instruction Packet: Fact Recall Task with No Sound

The following pages contain the instruction packet given to subjects using the crisis control system with the fact recall sub-task and no auditory warning signal. The instructions include a description of the general steps of the experiment, instructions on how to complete the fact recall rotation task and a detailed description of the crisis control system.

GENERAL INSTRUCTIONS

PLEASE READ THESE INSTRUCTIONS COMPLETELY BEFORE YOU BEGIN.

Your objective is to complete a fact recall task while monitoring the Crisis Control System. All information necessary to complete your task will be displayed on a single computer positioned directly in front of you.

STEP 1

Read the instructions for the Crisis Control System.

STEP 2

Complete the practice session on the Crisis Control System. The practice session will last approximately three minutes; several alarms will occur. Use this time to familiarize yourself with the screen, practice reacting to an alarm and practice memorizing facts and answering questions.

The lab instructor will start the practice session. The lab instructor will indicate when it is time to end the practice session. At that time, you will be instructed to press the 'x' in the top right corner of the screen to close the practice screen.

STEP 3

When the practice session has ended, the lab instructor will start the actual Crisis Control System.

STEP 4

Answer the questions about your general experience. Use the mouse to select answers and press the 'Submit' button.

STEP 5

Begin the fact recall task and start monitoring the Crisis Control indicators.

STEP 6

The lab instructor will indicate when it is time to end the monitoring session. At that time, press the 'x' in the top right corner of the screen to close the monitoring screen and stop the Crisis Control System.

PLEASE NOTE:

This study assumes that you have no outside assistance in completing your tasks. The instructions have been designed so that questions should not be necessary.

THE CRISIS CONTROL SYSTEM

This system is a simulation of an industrial power plant that houses three water tanks. In this simulation, it is extremely important that the temperature, volume and pressure of each tank stay within a safe range. It is your responsibility to see that corrective action is taken if any of these water tanks reaches an unsafe level.

The system monitor displays nine indicators that represent the attributes (temperature, volume and pressure) of the three water tanks. You will need to monitor the indicators to ensure all levels remain within the safety range. In the event of an alarm situation in which an indicator has fallen out of its safety range, you will be expected to correct the problem as quickly and accurately as possible.

In addition to tank information, the Crisis Control System also displays facts and questions about well-known people. The facts are presented five (5) at a time. Your task is to memorize the five fact statements and then recall these facts by answering a set of five (5) questions based on these facts. Note that whether or not these fact statements are true is irrelevant to your task. You are simply to memorize the statements and then answer the questions as accurately and quickly as possible.

SCREEN LAYOUT

The computer screen has been divided into four (4) general areas. The top portion of the screen includes nine (9) indicators, three (3) for each of the three (3) water tanks. The indicators for Tank 1 are in the top left corner of the screen. The indicators for Tank 2 are in the top middle of the screen and the indicators for Tank 3 are in the top right corner. Each set of indicators is ordered as follows: temperature (labeled T), volume (labeled V) and pressure (labeled P). The bottom of the screen includes the buttons used to correct an alarm situation. The middle portion of the screen contains the area where the fact statements and questions are displayed. The diagram below shows the layout of the screen.

Crisis Control Indicators

Tank 1 T ___ V___ P___ Tank 2 T___ V___ P___ Tank 3 T___ V___ P___

Study facts displayed to the right. Press button when ready to view questions.

| View Questions |

Molly Smith's favorite color is green.

Pete Wilson is a good water skier.

Sammy Davidson likes Oreo cookies on his pizza.

Laura Walkman rides a bike to work.

Brittney Lopez likes to play Rummicube.

Controls

Tank |* 1|* 2|* 3| Attribute |* T|* V|* P| Change |* U|* D| |Submit|

DESCRIPTION OF INDICATORS

Each attribute (temperature, volume and pressure) should always fall within its assigned safety range:

	Low	High
Temperature	32	35
Volume	72	75
Pressure	102	105

The safety ranges are marked on the right hand side of each indicator; you will, therefore, not need to memorize the values. An example of each type of indicator follows:

```
    ____           ____              ____
36 |____| T    76 |    | V    106 |    | P
35 |____|      75 |    |      105 |____|
34 |    |      74 |____|      104 |____|
33 |    |      73 |____|      103 |    |
32 |    |      72 |    |      102 |    |
31 |____|      71 |____|      101 |____|
```

The height of the solid bar or slider indicates the current value of the indicator. The above indicators are all within the safety range. It is acceptable for the bar to meet the safety marker; AN ALARM CONDITION OCCURS ONLY WHEN THE INDICATOR BAR GOES BEYOND THESE SAFETY MARKERS.

CORRECTING AN ALARM CONDITION

Four steps must be taken to correct an alarm condition in which an indicator has gone beyond its safety range. Any incorrect keys that are pressed will have no effect on the indicator's current value. As each of the following steps are correctly taken, the value of that step is displayed in the appropriate box at the bottom of the screen. Note, the phrase 'point and click' refers to using the mouse attached to the computer you are working on to direct the cursor to point at an area on the screen and then using the left mouse button to activate or select that area.

STEP 1. CHOOSE TANK.

TANK 1 ==> Point and click on '1' indicator
TANK 2 ==> Point and click on '2' indicator
TANK 3 ==> Point and click on '3' indicator

STEP 2. CHOOSE ATTRIBUTE.

TEMPERATURE ==> Point and click on 'T' indicator
VOLUME ==> Point and click on 'V' indicator
PRESSURE ==> Point and click on 'P' indicator

STEP 3. CHOOSE CHANGE.

INCREASE VALUE ==> Point and click on 'U' indicator
DECREASE VALUE ==> Point and click on 'D' indicator

STEP 4. SUBMIT ANSWER.

Point and click on 'SUBMIT' button in bottom part of the screen.

MEMORIZING FACTS AND RECORDING ANSWERS TO QUESTIONS

While you are monitoring the Crisis Control indicators, the system will present a series of facts and questions. Your objective is to memorize the facts so you can answer the questions as quickly and accurately as possible. To memorize the facts and answer the questions follow these steps:

STEP 1 ==> MEMORIZE FACTS.

Read and study the five facts presented in the middle of the screen.

STEP 2 ==> VIEW QUESTIONS.

When you feel you have memorized the facts, point and click the 'VIEW QUESTIONS' button displayed in the middle left of the screen.

STEP 3 ==> ANSWER QUESTIONS.

Read each question. Choose the correct answer from the four (4) possible answers presented next to the question. To choose an answer, point and click at the appropriate indicator. Answer all five (5) questions.

STEP 4 ==> SUBMIT ANSWERS.

After choosing answers for all five (5) questions, point and click the 'SUBMIT ANSWERS' button displayed in the middle left of the screen.

Once the 'SUBMIT ANSWERS' button has been pressed, the next set of facts will be presented.

APPENDIX E

Instruction Packet: Fact Recall Task with Ding

The following pages contain the instruction packet given to subjects using the crisis control system with the fact recall sub-task and a 'ding' auditory warning signal. The instructions include a description of the general steps of the experiment, instructions on how to complete the fact recall task and a detailed description of the crisis control system.

GENERAL INSTRUCTIONS

PLEASE READ THESE INSTRUCTIONS COMPLETELY BEFORE YOU BEGIN.

Your objective is to complete a fact recall task while monitoring the Crisis Control System. All information necessary to complete your task will be displayed on a single computer positioned directly in front of you.

STEP 1

Read the instructions for the Crisis Control System.

STEP 2

Complete the practice session on the Crisis Control System. The practice session will last approximately three minutes; several alarms will occur. Use this time to familiarize yourself with the screen, practice reacting to an alarm and practice memorizing facts and answering questions.

The lab instructor will start the practice session. The lab instructor will indicate when it is time to end the practice session. At that time, you will be instructed to press the 'x' in the top right corner of the screen to close the practice screen.

STEP 3

When the practice session has ended, the lab instructor will start the actual Crisis Control System.

STEP 4

Answer the questions about your general experience. Use the mouse to select answers and press the 'Submit' button.

STEP 5

Begin the fact recall task and start monitoring the Crisis Control indicators.

STEP 6

The lab instructor will indicate when it is time to end the monitoring session. At that time, press the 'x' in the top right corner of the screen to close the monitoring screen and stop the Crisis Control System.

PLEASE NOTE:

This study assumes that you have no outside assistance in completing your tasks. The instructions have been designed so that questions should not be necessary.

THE CRISIS CONTROL SYSTEM

This system is a simulation of an industrial power plant that houses three water tanks. In this simulation, it is extremely important that the temperature, volume and pressure of each tank stay within a safe range. It is your responsibility to see that corrective action is taken if any of these water tanks reaches an unsafe level.

The system monitor displays nine indicators that represent the attributes (temperature, volume and pressure) of the three water tanks. You will need to monitor the indicators to ensure all levels remain within the safety range. In the event of an alarm situation in which an indicator has fallen out of its safety range, you will be expected to correct the problem as quickly and accurately as possible.

In addition to tank information, the Crisis Control System also displays facts and questions about well-known people. The facts are presented five (5) at a time. Your task is to memorize the five fact statements and then recall these facts by answering a set of five (5) questions based on these facts. Note that whether or not these fact statements are true is irrelevant to your task. You are simply to memorize the statements and then answer the questions as accurately and quickly as possible.

SCREEN LAYOUT

The computer screen has been divided into four (4) general areas. The top portion of the screen includes nine (9) indicators, three (3) for each of the three (3) water tanks. The indicators for Tank 1 are in the top left corner of the screen. The indicators for Tank 2 are in the top middle of the screen and the indicators for Tank 3 are in the top right corner. Each set of indicators is ordered as follows: temperature (labeled T), volume (labeled V) and pressure (labeled P). The bottom of the screen includes the buttons used to correct an alarm situation. The middle portion of the screen contains the area where the fact statements and questions are displayed. The diagram below shows the layout of the screen.

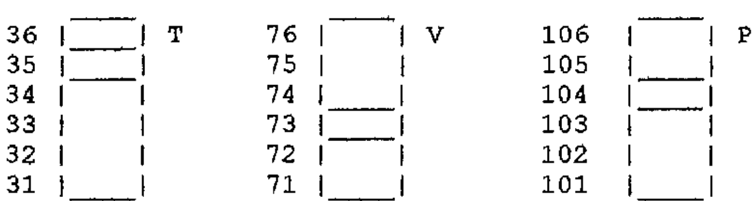
```
 ________________________________________________________________________
|      Crisis Control Indicators                                          |
|                                                                         |
| Tank 1 T ___ V___ P___  Tank 2  T___ V___ P___ Tank 3 T___ V___ P__    |
|          |  | |  | |  |          |  | |  | |  |        |  | |  | |  |   |
|          |  | |  | |  |          |  | |  | |  |        |  | |  | |  |   |
|          |  | |  | |  |          |  | |  | |  |        |  | |  | |  |   |
|          |__| |__| |__|          |__| |__| |__|        |__| |__| |__|   |
|_________________________________________________________________________|
|                          |                                              |
|                          |                                              |
|                          | Molly Smith's favorite color                 |
|                          |   is green.                                  |
|                          |                                              |
|                          | Pete Wilson is a good water                  |
|                          |   skier.                                     |
|                          |                                              |
|                          | Sammy Davidson likes Oreo                    |
|                          |   cookies on his pizza.                      |
| Study facts displayed    |                                              |
|  to the right. Press     | Laura Walkman rides a bike to                |
|  button when ready to    |   work.                                      |
|  view questions.         |                                              |
|                          | Brittney Lopez likes to play                 |
|    _________________     |   Rummicube.                                 |
|   |                 |    |                                              |
|   | View Questions  |    |                                              |
|   |_________________|    |                                              |
|                          |                                              |
|__________________________|______________________________________________|
|                                                                         |
|                               Controls                                  |
|       ___ ___ ___              ___ ___ ___          ___ ___     ______  |
|Tank  |* 1|* 2|* 3| Attribute |* T|* V|* P| Change |* U|* D|   |Submit| |
|      |___|___|___|            |___|___|___|        |___|___|   |______| |
|_________________________________________________________________________|
```

DESCRIPTION OF INDICATORS

Each attribute (temperature, volume and pressure) should always fall within its assigned safety range:

	Low	High
Temperature	32	35
Volume	72	75
Pressure	102	105

The safety ranges are marked on the right hand side of each indicator; you will, therefore, not need to memorize the values. An example of each type of indicator follows:



The height of the solid bar or slider indicates the current value of the indicator. The above indicators are all within the safety range. It is acceptable for the bar to meet the safety marker; AN ALARM CONDITION OCCURS ONLY WHEN THE INDICATOR BAR GOES BEYOND THESE SAFETY MARKERS.

AUDITORY WARNING SIGNAL

An auditory DING is used to signal that a tank has reached an unsafe level. The ding is approximately one second in length. The warning signal will occur only once after each alarm. The sound of the ding should help you notice the alarm situation as quickly as possible.

CORRECTING AN ALARM CONDITION

Four steps must be taken to correct an alarm condition in which an indicator has gone beyond its safety range. Any incorrect keys that are pressed will have no effect on the indicator's current value. As each of the following steps are correctly taken, the value of that step is displayed in the appropriate box at the bottom of the screen. Note, the phrase 'point and click' refers to using the mouse attached to the computer you are working on to direct the cursor to point at an area on the screen and then using the left mouse button to activate or select that area.

STEP 1. CHOOSE TANK.

TANK 1 ==> Point and click on '1' indicator
TANK 2 ==> Point and click on '2' indicator
TANK 3 ==> Point and click on '3' indicator

STEP 2. CHOOSE ATTRIBUTE.

TEMPERATURE ==> Point and click on 'T' indicator
VOLUME ==> Point and click on 'V' indicator
PRESSURE ==> Point and click on 'P' indicator

STEP 3. CHOOSE CHANGE.

INCREASE VALUE ==> Point and click on 'U' indicator
DECREASE VALUE ==> Point and click on 'D' indicator

STEP 4. SUBMIT ANSWER.

Point and click on 'SUBMIT' button in bottom part of the screen.

MEMORIZING FACTS AND RECORDING ANSWERS TO QUESTIONS

While you are monitoring the Crisis Control indicators, the system will present a series of facts and questions. Your objective is to memorize the facts so you can answer the questions as quickly and accurately as possible. To memorize the facts and answer the questions follow these steps:

STEP 1 ==> MEMORIZE FACTS.

Read and study the five facts presented in the middle of the screen.

STEP 2 ==> VIEW QUESTIONS.

When you feel you have memorized the facts, point and click the 'VIEW QUESTIONS' button displayed in the middle left of the screen.

STEP 3 ==> ANSWER QUESTIONS.

Read each question. Choose the correct answer from the four (4) possible answers presented next to the question. To choose an answer, point and click at the appropriate indicator. Answer all five (5) questions.

STEP 4 ==> SUBMIT ANSWERS.

After choosing answers for all five (5) questions, point and click the 'SUBMIT ANSWERS' button displayed in the middle left of the screen.

Once the 'SUBMIT ANSWERS' button has been pressed, the next set of facts will be presented.

APPENDIX F

Instruction Packet: Fact Recall Task with Earcon

The following pages contain the instruction packet given to subjects using the crisis control system with the fact recall sub-task and a 'earcon' auditory warning signal. The instructions include a description of the general steps of the experiment, instructions on how to complete the fact recall task and a detailed description of the crisis control system.

GENERAL INSTRUCTIONS

PLEASE READ THESE INSTRUCTIONS COMPLETELY BEFORE YOU BEGIN.

Your objective is to complete a fact recall task while monitoring the Crisis Control System. All information necessary to complete your task will be displayed on a single computer positioned directly in front of you.

STEP 1

Read the instructions for the Crisis Control System.

STEP 2

Complete the practice session on the Crisis Control System. The practice session will last approximately three minutes; several alarms will occur. Use this time to familiarize yourself with the screen, practice reacting to an alarm and practice memorizing facts and answering questions.

The lab instructor will start the practice session. The lab instructor will indicate when it is time to end the practice session. At that time, you will be instructed to press the 'x' in the top right corner of the screen to close the practice screen.

STEP 3

When the practice session has ended, the lab instructor will start the actual Crisis Control System.

STEP 4

Answer the questions about your general experience. Use the mouse to select answers and press the 'Submit' button.

STEP 5

Begin the fact recall task and start monitoring the Crisis Control indicators.

STEP 6

The lab instructor will indicate when it is time to end the monitoring session. At that time, press the 'x' in the top right corner of the screen to close the monitoring screen and stop the Crisis Control System.

PLEASE NOTE:

This study assumes that you have no outside assistance in completing your tasks. The instructions have been designed so that questions should not be necessary.

THE CRISIS CONTROL SYSTEM

This system is a simulation of an industrial power plant that houses three water tanks. In this simulation, it is extremely important that the temperature, volume and pressure of each tank stay within a safe range. It is your responsibility to see that corrective action is taken if any of these water tanks reaches an unsafe level.

The system monitor displays nine indicators that represent the attributes (temperature, volume and pressure) of the three water tanks. You will need to monitor the indicators to ensure all levels remain within the safety range. In the event of an alarm situation in which an indicator has fallen out of its safety range, you will be expected to correct the problem as quickly and accurately as possible.

In addition to tank information, the Crisis Control System also displays facts and questions about well-known people. The facts are presented five (5) at a time. Your task is to memorize the five fact statements and then recall these facts by answering a set of five (5) questions based on these facts. Note that whether or not these fact statements are true is irrelevant to your task. You are simply to memorize the statements and then answer the questions as accurately and quickly as possible.

SCREEN LAYOUT

The computer screen has been divided into four (4) general areas. The top portion of the screen includes nine (9) indicators, three (3) for each of the three (3) water tanks. The indicators for Tank 1 are in the top left corner of the screen. The indicators for Tank 2 are in the top middle of the screen and the indicators for Tank 3 are in the top right corner. Each set of indicators is ordered as follows: temperature (labeled T), volume (labeled V) and pressure (labeled P). The bottom of the screen includes the buttons used to correct an alarm situation. The middle portion of the screen contains the area where the fact statements and questions are displayed. The diagram below shows the layout of the screen.

Crisis Control Indicators

Tank 1 T ___ V ___ P ___ Tank 2 T ___ V ___ P ___ Tank 3 T ___ V ___ P ___

Study facts displayed to the right. Press button when ready to view questions.

| View Questions |

Molly Smith's favorite color is green.

Pete Wilson is a good water skier.

Sammy Davidson likes Oreo cookies on his pizza.

Laura Walkman rides a bike to work.

Brittney Lopez likes to play Rummicube.

Controls

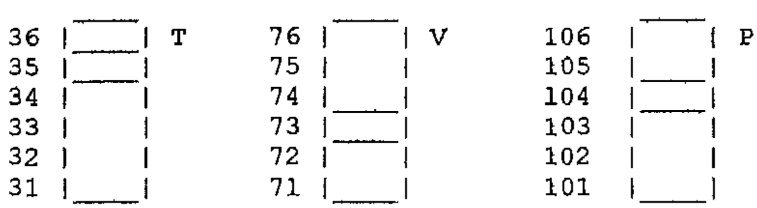
Tank |* 1|* 2|* 3| Attribute |* T|* V|* P| Change |* U|* D| |Submit|

DESCRIPTION OF INDICATORS

Each attribute (temperature, volume and pressure) should always fall within its assigned safety range:

	Low	High
Temperature	32	35
Volume	72	75
Pressure	102	105

The safety ranges are marked on the right hand side of each indicator; you will, therefore, not need to memorize the values. An example of each type of indicator follows:



The height of the solid bar or slider indicates the current value of the indicator. The above indicators are all within the safety range. It is acceptable for the bar to meet the safety marker; AN ALARM CONDITION OCCURS ONLY WHEN THE INDICATOR BAR GOES BEYOND THESE SAFETY MARKERS.

AUDITORY WARNING SIGNAL

Three (3) different types of auditory alarms are used to signal that a tank has reached an unsafe level. The sounds were chosen to signal the problem at hand - this should help you distinguish which indicator needs to be corrected.

ATTRIBUTE		AUDITORY SIGNAL
Temperature	==>	High pitched whistle
Volume	==>	Tone changing in pitch (siren)
Pressure	==>	Popping sound

Each warning signal lasts approximately one (1) second. The signal will occur only once for each alarm situation.

CORRECTING AN ALARM CONDITION

Four steps must be taken to correct an alarm condition in which an indicator has gone beyond its safety range. Any incorrect keys that are pressed will have no effect on the indicator's current value. As each of the following steps are correctly taken, the value of that step is displayed in the appropriate box at the bottom of the screen. Note, the phrase 'point and click' refers to using the mouse attached to the computer you are working on to direct the cursor to point at an area on the screen and then using the left mouse button to activate or select that area.

STEP 1. CHOOSE TANK.

TANK 1 ==> Point and click on '1' indicator
TANK 2 ==> Point and click on '2' indicator
TANK 3 ==> Point and click on '3' indicator

STEP 2. CHOOSE ATTRIBUTE.

TEMPERATURE ==> Point and click on 'T' indicator
VOLUME ==> Point and click on 'V' indicator
PRESSURE ==> Point and click on 'P' indicator

STEP 3. CHOOSE CHANGE.

INCREASE VALUE ==> Point and click on 'U' indicator
DECREASE VALUE ==> Point and click on 'D' indicator

STEP 4. SUBMIT ANSWER.

Point and click on 'SUBMIT' button in bottom part of the screen.

MEMORIZING FACTS AND RECORDING ANSWERS TO QUESTIONS

While you are monitoring the Crisis Control indicators, the system will present a series of facts and questions. Your objective is to memorize the facts so you can answer the questions as quickly and accurately as possible. To memorize the facts and answer the questions follow these steps:

STEP 1 ==> MEMORIZE FACTS.

Read and study the five facts presented in the middle of the screen.

STEP 2 ==> VIEW QUESTIONS.

When you feel you have memorized the facts, point and click the 'VIEW QUESTIONS' button displayed in the middle left of the screen.

STEP 3 ==> ANSWER QUESTIONS.

Read each question. Choose the correct answer from the four (4) possible answers presented next to the question. To choose an answer, point and click at the appropriate indicator. Answer all five (5) questions.

STEP 4 ==> SUBMIT ANSWERS.

After choosing answers for all five (5) questions, point and click the 'SUBMIT ANSWERS' button displayed in the middle left of the screen.

Once the 'SUBMIT ANSWERS' button has been pressed, the next set of facts will be presented.

APPENDIX G

Demographic Screen Diagram

The following page contains a layout of the screen used to capture demographic information about each subject. This screen was presented after the practice session and prior to each trial. Subjects were instructed to enter the information and press the 'Submit' button to begin the trial. To ensure complete information was captured, appropriate error messages were associated with each demographic question. If a subject pressed the 'Submit' button and one or more questions had not been entered, the system prompted the subject to enter an answer.

```
 ____________________________________________________________________
|Please answer the following questions about your experience         |
|                                                                    |
|What is your age in years?                                          |
|   ___                                                              |
|  |___|                                                             |
|                                                                    |
|What is your gender?                                                |
| o Female                                                           |
| o Male                                                             |
|                                                                    |
|Which of the following best describes your experience with crisis   |
|control situations?                                                 |
| o Experienced    o Intermediate                                    |
| o Novice         o No experience                                   |
|                                                                    |
|Which of the following best describes your vision?                  |
| o Nearsighted with contacts o Nearsighted with glasses             |
| o Farsighted with contacts  o Farsighted with glasses              |
| o Normal                    o Other                                |
|                                                                    |
|Are you having any problems with your hearing?                      |
| o No   o Yes                                                       |
|                                                                    |
|Are you right-handed, left-handed or ambidextrous (using both hands |
|with equal ease)?                                                   |
| o Right-handed   o Left-handed   o Ambidextrous                    |
|                                 _____                              |
|                                |     |                             |
|What color is square 1?  -->    |     | < display red >             |
|                                |_____|                             |
| o Blue     o Grey                                                  |
| o Red      o Yellow                                                |
| o Green    o Other                                                 |
|                                 _____                              |
|                                |     |                             |
|What color is square 2?  -->    |     | < display blue >            |
|                                |_____|                             |
| o Blue     o Grey                                                  |
| o Red      o Yellow                                                |
| o Green    o Other                                                 |
|                                 _____                              |
|                                |     |                             |
|What color is square 3?  -->    |     | < display yellow >          |
|                                |_____|                             |
| o Blue     o Grey                                                  |
| o Red      o Yellow                                                |
| o Green    o Other                                                 |
|   ______                                                           |
|  |Submit|                                                          |
|  |______|                                                          |
|____________________________________________________________________|
```

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