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Kenneth H. Funk, II

Research in the aviation domain, driving distractions, anesthesia administration, and nuclear power plant control rooms show that Concurrent Task Management (CTM) is a process that every human operator performs when interacting with complex environments. The need for understanding concurrent task management in a broader perspective more applicable and generalizable to different domains, led to the development of the Augmented Stage Model (ASM) of human information processing and the development of a test bed where hypotheses deriving from the augmented stage model can be tested. The ASM is an elaboration of the current Stage Model attempting to explain CTM in terms of those basic stages of human information processing and drawing on relevant, recent psychological research. One question that arises from the creation of the augmented stage model is to what degree the augmented stage model can be justified by actual human CTM performance. A corollary of this question is to what degree can CTM performance be explained by performance in simple tests that are derived directly from the stages of the model. To answer this question, 94 participants were tested on several standard cognitive tests suggested by the ASM: i.e. simple and complex reaction time, decision making, working memory, and intelligence. Performance in the cognitive tests was compared to participants' CTM performance in a multitasking simulator called the Task Management Environment (TME). The findings indicated that basic cognitive abilities, except for working memory, do not correlate significantly with CTM performance as calculated by the TME. Performance on three working

memory tests was shown to predict up to 47% of the variation in CTM performance. This suggests that simple cognitive abilities do not predict CTM performance. Although, cognitive abilities might be a component of CTM, a combination of them might prove to better predict CTM performance.

The Augmented Stage Model of Human Information Processing: How Well Do Cognitive Abilities Drawn from the Stages in the Model Predict Concurrent Task Management Performance?

By

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Roberto Javier Nicolalde Flores, Author

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Continued)

The Augmented Stage Model of Human Information Processing: How Well Do Cognitive Abilities Drawn from the Stages in the Model Predict Concurrent Task Management Performance?

1 INTRODUCTION

1.1 Introduction

Concurrent Task Management (CTM) is the process that human operators of complex systems, for example pilots, drivers, surgeons, and anesthesiologists, perform to allocate their attention among multiple, concurrent tasks.

Complex systems, such as aircraft cockpits, control rooms in nuclear power plants, operating rooms, automobiles, and tanks, among others, impose a high resource demand on the limited capacity of the human operator, and as predicted by Adams, Tenny, and Pew (1991) these complex systems have matured to the point that they "support, complement, and extend the capabilities of their human operators". However, this has also brought the proliferation of problems and disasters associated with the use of these complex systems.

Psychologists have studied CTM in the context of the dual-task paradigm, in which participants are challenged to perform two independent tasks simultaneously, in a laboratory setting. However, real world environments often present to the human operator more than two tasks, and the nature of the tasks is often more different than those used in the dual-task experiments. Tasks in the real world can be modified, delegated, or temporarily ignored, and the human operator determines priorities, coordinates and keeps track of their goals and subgoals, looks after tasks in a queue, and manages interruptions. Funk (1991) coined the term Cockpit Task Management to refer to the process by which pilots initiate, monitor, prioritize, interrupt, resume, and terminate tasks. Several other researchers have studied this process in the aviation domain (Dismukes, Young, & Sumwalt, 1998; Hart, 1989; Latorella, 1996; Loukopoulus, Dismukes, & Barshi, 2001).

In an effort to better understand the nature of CTM, Colvin and Funk (2000) conducted two part-task flight simulator studies to determine what factors affect the CTM process. They found that task importance, status, urgency, and display salience, among others, were significant factors that influence pilots CTM. However, problems exist with the current approach to study CTM. Findings from experiments in specific domains, such as aviation, are not generalizable to other domains, and experiments in specific domains require participants with very specific skills and experience, which make it difficult and expensive to run these experiments. An imperative need for a cross-domain framework and tools to study CTM is emergent.

This study introduces the Augmented Stage Model which is an elaboration of the current Stage Model of Human Information Processing (Wickens, 2000) in an attempt to frame CTM behavior. The ASM could provide a structural framework for future research in CTM in which new hypotheses can be formulated and tested.

1.2 Research Objectives

The main objective of this study was to investigate to what degree the ASM could be validated by actual human CTM performance, in other words, to what degree cognitive abilities drawn directly from stages in the model predict CTM performance.

1.3 Organization of the Thesis

Chapter 2 introduces the Augmented Stage Model of human information processing. It starts with an overview of the current Stage Model and, based on findings from cognitive research and engineering human performance research, it expands its capabilities to frame human information processing in the context of multiple concurrent task environments.

Chapter 3 introduces the research hypothesis for this study.

Chapter 4 introduces the Task Management Environment, which is an abstract multitasking environment. It introduces the psychological tests, and describes the research methodology and procedures of this study.

Chapter 5 presents the transformations, results and statistical analysis of the data gathered in this study.

Chapter 6 discusses the main findings and significance of this research. It also discusses the limitation of this study, and presents recommendations for future research.

2 LITERATURE REVIEW

2.1 Understanding the Advanced Multiple Task Environment

2.1.1 Introduction

The process by which people attend to multiple concurrent tasks has been studied for almost a century. McQueen (1917) performed a series of experiments in an attempt to identify the mechanism(s) by which people cope with more than one task presented at the same time. He concluded that "when two disparate operations are simultaneously performed, introspective evidence obtained under experimental conditions is brought forward in proof of the occurrence of all four possibilities: (1) the attention alternates from one to the other; (2) one of the tasks becomes automatic, and drops out of consciousness, occasionally even both; (3) the processes combine into a psychical fusion, an easy form of fusion being through the medium of rhythm, though the rhythmisation may be unconscious; (4) there may be simultaneous attention to the two tasks as separate." He further argued that simultaneous attention to two tasks is very rare and that more likely conscious attention is directed to only one of the tasks while the other is being performed automatically.

Since then, psychologists and human factors specialists have been puzzled with the nature of a multi-tasking ability and the factors that influence it. Research in the area of multi-task performance has followed two approaches; the first in the area of psychology, in which theories of attention based on measurements of human performance on dual-task situations in laboratory settings have been developed. The second approach is in the engineering domain where complex measures of workload and computational models of human behavior have been developed (National Research Council, 1998).

The rapid technological developments after the Second World War transformed the nature of most complex working environments. In the earlier stages of aviation, driving, and nuclear power plants, most of the numerous and frequent accidents were attributed to machine factors. The operator's tasks in these early complex environments were mainly manual and required a great deal of dexterity and skill. With the incorporation of computers, electronic sensors, and automated systems, the number of accidents has dropped and stabilized significantly, and machines are no longer the major cause of the majority of accidents. Instead, the human operator has been challenged with the incorporation of numerous new devices, displays and equipment into his environment and his role has shifted from being an active controller to being more of a monitor of multiple systems working concurrently, and this has become a major factor accounting for recent accidents.

"Human error is the term used to describe the failure of the human operator to work with the machine in the manner expected by its designer" (Adams, Tenny and Pew, 1991). Human error research has been broadly studied in the field of aviation, surface transportation and more recently in the health care environment, specifically in operating rooms and anesthesia administration. Operators in these complex systems are confronted with a number of tasks, each of them with its own priorities, time constraints, and subtasks.

The shift in the human operator's role in modern complex multiple concurrent task systems has encouraged a paradigm shift in the approach psychologists and engineers use to study concurrent task performance. Adams et al. (1991) proposed this paradigm shift in their comprehensive review of the existing psychological literature, which will be later summarized. They proposed an integrative conceptual framework for understanding multitasking and task management, which they called Strategic Workload, and the Cognitive Management of Advanced Multi-Task Systems. Other researchers have proposed a similar perspective to study multi-task performance (Wickens, 1992; Funk, 1991).

This review will focus on expanding and complementing Adams et al.'s (1991) approach to study human multi-task performance. A review of the psychology literature and its relevance to multi-tasking will be presented. A review of the more relevant models of human behavior in the engineering domain will be described. Some of the questions posed by Adams et al. (1991) will be addressed by an analysis of the most up-to-date research. Further, an integrative model of human information processing in the context of multiple concurrent tasks will be introduced, along with an abstract multi-tasking simulator in which hypotheses about human concurrent task management (CTM) behavior can be studied.

2.1.2 Adams, Tenny and Pew Conceptual Framework

Adams et al. (1991) point out that fundamental to each of the psychological theories of attention shifting, perception, knowledge, memory and information processing, is the notion that behavior is "goal-driven". They argued that "the analysis of activities in terms of goal structures and hierarchy help conceptualize the psychological issues of multi-task management in ways that are more wieldy." Further, they argued that goal structure analysis "gives us a way of framing the inevitable instance-to-instance and person-to-person variations in task management." (Adams et al., 1991)

Adams et al.'s conceptual framework of multi-tasking assumes that tasks in a complex system are cognitively difficult and as a result, attention becomes modular, meaning that conscious attention can be applied to one task at a time while queuing the other tasks, and that the order in which the tasks are managed involves task prioritization. Task prioritization is the result of the "goal hierarchy" motivating the operator's actions, in which independent goals direct the operator's attention, guide her perception, and direct her information processing as well. For example, any person when getting ready to leave for a long vacation trip, is faced with an innumerable set of tasks that have to be performed in order to accomplish a final goal (be on his/her way to the destination). Each individual task has a subgoal as its motivator; for example, the action of putting clothes in the suitcase is motivated by the "get luggage ready" subgoal, and while attending to this goal other subgoals like "check safety of the house" have to be put in queue for later completion.

An eloquent summary of Adams et al. *conceptual framework* was presented by the National Research Council (1998).

Task management involves task prioritization. Task prioritization depends on situation awareness, which in turn depends on perception. Perception is schema based; that is, input information is interpreted in the context of structured expectations about situations and events. This implies that information used to update situation models must be anticipated and prepared for. Long-term memory is a connectionist, associative structure, and the attentional focus corresponds to areas of long-term memory activation. Multitasking in turn depends on attentional shifts, which are cognitively difficult and take measurable time. Human behavior is goal driven and goals help determine how and where attention will be shifted. A goal hierarchy comprising goals and subgoals is the basis for task ordering or prioritization when simultaneous performance of all tasks is impossible. Tasks correspond to knowledge structures in long-term memory (one structure per task, though certain structural elements are shared across tasks). Since information processing is resource limited, the human can allocate conscious mental effort to only one task while queuing others. This is the motivation for task prioritization.

There is a tendency to process only that incoming information which is relevant to the task currently being attended to. If incoming information is not relevant to that task, the human must interrupt it to determine which queued task (if any) the information concerns. Such information tends to be "elusive'' and subject to neglect, since there is no schema-based expectation or preparation for it. However, noticing and processing a stimulus or event implies interrupting the ongoing task. Humans resist interruptions and can even become irritable when they occur. Tasks associated with lower-level (more specific) goals are more resistant to interruption. But interruptions do occur; fortunately, memory for interrupted tasks is highly persistent.

Task management further involves task scheduling. The ability to schedule depends on the individual's understanding of temporal constraints on goals and tasks. Subjects in task-scheduling studies are capable of responding appropriately to task priority, but scheduling performance may break down under time pressure and other stressors. Task management itself is an information processing function, and it is most crucial when information processing load is at highest, for example, when there are more tasks to manage. Therefore, task management is a significant element of human behavior.

2.1.3 Statement of the Problem

The need for a comprehensive and validated model of concurrent task management is imperative for a better understanding of multi-tasking ability across domains. Several models of concurrent task management for specific task environments have been developed for the aviation, driving, and anesthesia administration domains; similar approaches can be used to develop a general human model of multi-tasking.

Adams et al. (1991) integrated what was known about models of attention and multi-tasking in the field of psychology and proposed an understandable conceptual framework on managing real world concurrent task systems. The psychology literature is filled with studies of attention, perception, decision making, working memory, resource allocation, motor performance, long term memory, scheduling and other general models of cognition. However, since Adams et al.'s *conceptual framework,* no study has attempted to put these cognitive models into a comprehensive model that may explain multitasking behavior in different domains.

In contrast, the engineering human factors literature is vast in the attempts to model human multi-tasking behavior using approaches such as queuing theory (Carbonell, 1966; Carbonell et al. 1968), control and estimation theory (Tulga & Sheridan, 1980; Pattipati & Kleinman, 1991), and fuzzy logic (Chen & Funk, 2003). Human Factors specialists have also introduced some theories of task management (Funk, 1991; Wickens, 1994). However, one of the deficiencies of such models is that they forget that humans work in a very heuristic fashion, which is difficult to model with strict rational and algorithmic models. The failure to recognize the widely spread individual differences in cognitive abilities of operators makes these models impractical.

Often psychology and engineering literature disagree with each other due to the different nature of the experiments used in the fields. A large number of studies related to multi-tasking in psychology make use of the dual-task paradigm, and these experiments are run in a laboratory setting with unrealistic tasks. The psychology literature argues that people can switch between very dissimilar alternatives in attending to tasks with almost no cost in performance (Jersild, 1927), and can switch attention between two different sensory channels within a few tenths of a second

(Gopher, 1982; Sperling & Dosher, 1986). The engineering literature argues that there is a cost for switching between tasks, and there is a tendency to continue performing a lower-priority task longer than the optimal in the case that a higher priority task suddenly appears (Wickens, 2000).

Understanding complex human multi-tasking behavior requires the integration of existing psychological theories and models of attention, resource allocation, multi-tasking, memory, and information processing, with engineering theories of concurrent task management in complex real-world environments. The construction of a comprehensive model of human behavior in multi-tasking environments complemented with a test bed, in which human multi-tasking behavior can be studied, might help psychologists and engineers to come to a merging point, where new hypotheses can be made and tested. The closest approximations available are applications of varying degrees of specificity that are adapted to particular environments.

2.1.4 Overview of the Thesis

In this study, I will introduce an Integrated Model of Concurrent Task Management that has as a foundation the current model of human information processing. I will explore the influence of basic cognitive abilities such as: reaction time, working memory, decision making, and verbal intelligence over performance in the Task Management Environment which was developed (Shakeri, Funk, 2003) as a test bed that simulates an abstract multiple concurrent task environment in which the tasks' parameters (importance, behavior, correction rate, deterioration rate) can be manipulated.

The remainder of this chapter will focus on the development of an Integrated Model of Concurrent Task Management. A detailed description of the TME and its relation to cognitive abilities will be described in following chapters.

2.1.5 Why an Integrated Model of Concurrent Task Management?

Hart (1989) recognized the inappropriateness of the psychology approach to study multiple concurrent task management. She argued that in typical laboratory experiments, tasks impose homogeneous demands in specific time intervals, tasks force participants to respond in specific ways to the stimulus, and they push the participants to their limits, which is not a realistic managing strategy. Moreover, laboratory experiments last just a few minutes, in contrast to real-life complex concurrent task environments where tasks can last hours, and may include sequential and overlapping demands; tasks may follow complex schedule rules, and unexpected events may occur. For example, in the case of our vacationer, the completion of his/her final goal can take up to a few hours.

From a more general perspective towards attending to multiple concurrent tasks, Hart argued that people "actively manage their time, energy, and available resources to accomplish tasks on time and with adequate performance and, at the same time, to maintain a comfortable level of workload. To do so, they dynamically modulate their priorities, strategies, focus of attention and effort..." Hart used the term "Strategic Workload Management" to refer to this process.

Klein and Klinger (1991) also discussed the failure of laboratory tasks to capture the most important characteristics of real-world complex systems. Complex concurrent task environments often present poorly defined goals and even poorly structured tasks. They present uncertain, ambiguous, and missing data scenarios, shifting and competing goals, dynamic and continually changing conditions, and feedback reactions to changes in the system. These complex environments may impose time stress on the operators, high risks, multiple players, and organizational goals and norms (Klein & Klinger, 1991). In the case of our vacationer, she might be stressed by a deadline to depart, and many of the tasks that have to be performed before departing might or might not have a well-defined structure. For example organizing clothes in the suitcase does not have any well-defined structure or rule.

In the engineering approach to concurrent task management, several researchers have studied processes by which operators of complex systems allocate their attention among multiple concurrent tasks. Funk (1991) termed this process, in the context of aviation, Cockpit Task Management (CTM). He defined CTM as the process by which pilots initiate, monitor, prioritize, interrupt, resume, and terminate cockpit tasks. Other researchers have studied this process in the aviation domain as well (Hart, 1989, Latorella, 1996, Dismukes, Young, & Sumwalt, 1998, Loukopoulos, Dismukes, & Barshi, 2001). Colvin and Funk (2000) identified factors that affect task prioritization in the operational context of the flight deck, and concluded that factors such as task status, task importance, and task urgency are important in the pilot's decision to attend to a task. However, the inappropriateness of the engineering approach to understand concurrent task management lies in the failure to account for the cognitive differences among humans, and the failure to generalize concurrent task management to many other complex systems.

Psychologists and engineers have studied CTM from different perspectives, which in both cases made their findings an incomplete puzzle that omitted important factors that influence CTM. The failure to study CTM as an integrative process calls for the development of an integrative model of human behavior in multiple concurrent task environments that can be applicable and generalizable to any domain. The focus of the remainder of this chapter will be to develop an augmented integrative model of human information processing in the context of multiple concurrent task environments, and describe requirements for an abstract simulator, that will expand CTM research capabilities beyond the dual task paradigm.

2.1.6 Why Study Concurrent Task Management?

The development of a comprehensive and valid large-scale model of concurrent task management that can explain an operator's behavior in complex concurrent task systems, in which tasks partially overlap and follow complex schedules, and in which goals may change dynamically, has three major advantages. First, complex systems with tasks such as those described above leave the operator highly vulnerable to commit task management errors that lead to accidents (Chou et al. 1996). Understanding the cognitive and environmental factors that influence concurrent task management will lead designers of complex systems to account for limitations and vulnerabilities in the human operator, and will provide them with tools for evaluation of system design.

Second, much of the psychology literature has focused on dual-task experiments rather than on real world multiple concurrent task environments. Little is known about how humans deal with more than two tasks concurrently. Concepts such as task switching, goal shifting and congruent task processing have not been entirely investigated as to their influence on concurrent task management in complex real world environments.

Third, fully understanding human behavior in real world complex concurrent task environments will lead to the development and implementation of effective training programs, which may help prevent many of the accidents resulting from task management errors.

Fourth and finally, a large scale model of human behavior in complex environments will facilitate the development of thorough computational models of human behavior that in turn may be useful in training operators, and would also lead to the development of artificial intelligence systems with aims for automation.

2.1.7 Organization of this Review

The goal of this review is to bring together findings in the areas of psychology and engineering to develop a comprehensive model of human behavior in real world complex concurrent task environments. To achieve this goal, this review will start by discussing the psychological implications of CTM and the most relevant models of time-sharing, focused attention, single channel and multiple channel capacity, decision making, working memory and long term memory, goal shifting, and task switching. The engineering approaches to model human behavior, to measure workload, and to describe human strategies for prioritizing tasks in CTM environments are discussed. Finally, an integrated model of human behavior in CTM environments will be introduced and discussed.

2.2 Psychological Issues in Concurrent Task Management

Operators of complex systems, when interacting with the system, are challenged with a number of tasks that can be modified, delegated, or temporarily ignored, and the operator determines priorities, coordinates and keeps track of his goals and subgoals, looks after tasks in a queue, and manages interruptions. When attending to multiple concurrent tasks that are competing for operators' resources, prioritization plays an important role. Prioritization depends on the current importance, status and urgency of the task (Colvin & Funk, 2000) dictated by the system's present and future goals. In complex systems, tasks may have dynamic goals (i.e. immediate goals, mission goals) that may change from moment to moment. The operator's ability to prioritize tasks depends on his situational awareness, and in turn his situational awareness depends on his perception, interpretation, and responses to events in the environment. Psychology research describes and helps us understand the mechanism by which humans perceive the world.

The stage model of information processing, shown in Figure 2.1, shows the major processing stages of psychological processes used by humans when interacting with the environment (Wickens, 1999). Each stage in the model performs a transformation on the information coming from the environment or memory storage. It is important to notice that this system has a feedback loop which implies that the information processing can start anywhere in the loop.

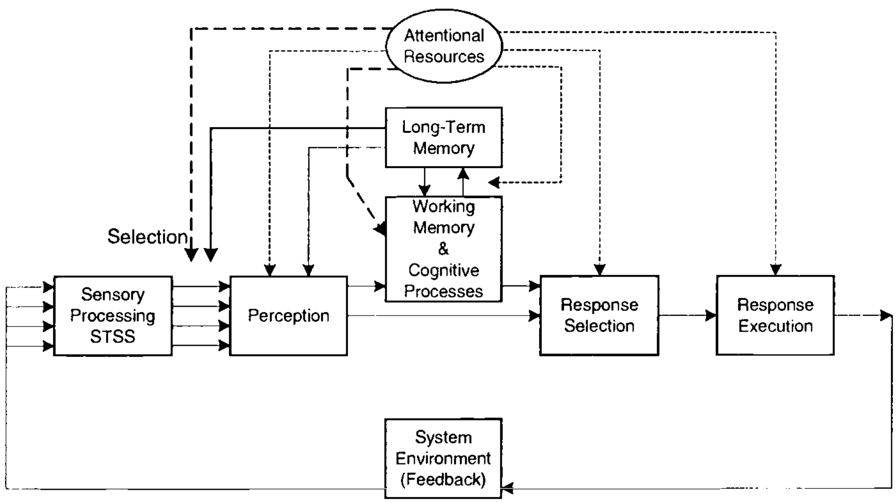

Figure 2.1 A model of human information processing (from Wickens & Hollands, 1999)

Consider the example of our vacationer in which the person is presented with a large number of immediate subgoals and future subgoals in order to successfully complete the final goal of "departing for vacation". She has to maintain highly accurate situational awareness of the state of the process on a moment-to-moment basis. This process requires the processing and transformation of incoming information from the environment (state of stove in the house, incoming phone calls, children calling for attention and so on) and information stored in memory (location of suitcase, documentation, and so on). In the pages following, functions and operations performed at each stage in the human information processing model will be described, and relevant augmentations to the model will be explained.

2.2.1 Sensory Processing

The sensory processing stage represents the short-term sensory storage (STSS) in which color, sound, and tactile sensation are stored for a few seconds. The best example of this sensory storage is when we perceive a lighted cigarette rotating at high speed as a continuous circle of light. The sensory stage receives information from our visual, auditory and tactile registers. Each sensory register's anatomy affects the characteristics of the stimuli that pass through them, and poses some limitations on the amount and quality of stimuli that can be perceived. Describing these sensory characteristics are beyond the interest of this review; for further reference see Wickens, Gordon, & Liu (1997).

The relevance of the sensory processing to multi-tasking lies in the questions relating to how many stimuli we can perceive at once, and to how many sensory channels we can pay attention to at the same time. These questions have been addressed thoroughly by the hundreds of dual-task experiments in psychology, which have explored the many different dichotomies in sensory processing. The result of these experiments were integrated by Wickens (1980, 2002) in his multiple resource theory, that has the "ability to predict dual task interference levels between concurrently performed tasks, to be consistent with the neuropsychological mechanisms underlying task performance" (Wickens, 2002). Multiple resource theory gives to the human information processing model the multiple modality dimension of sensing stimuli. In the vacationer example, Wicken's model can be used to predict interference between performing manual tasks, such as packing clothes in the suitcase and talking with a family member at the same time. Figure 2.2 represents the incorporation of the multiple modality concepts to the stage model.

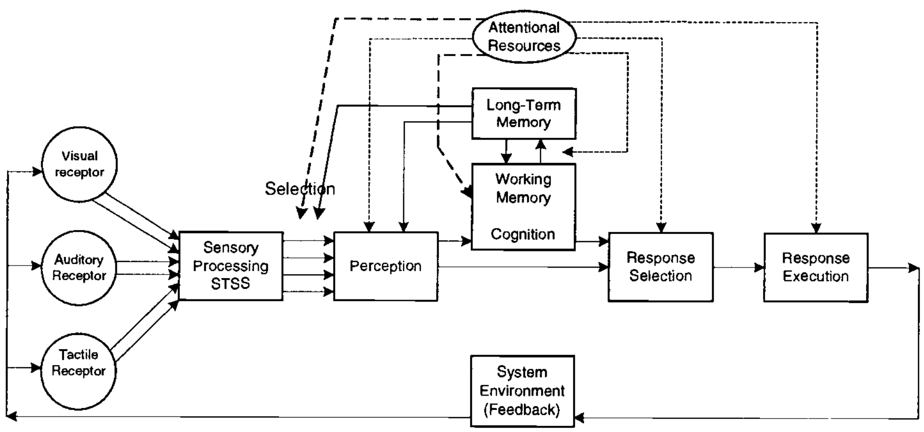

Figure 2.2 Multiple resource theory augmented to the stage model.

2.2.2 Perception

Perception is the process by which we give meaning to raw stimuli. Without perception, the different colors in a stoplight would not have any meaning. Perception is a very fast mechanism that requires little conscious attention and it is driven by incoming stimuli and by information stored in our long-term memory in the form of schemata and/or schemata active in working memory.

Perception in multiple concurrent task environments is an important factor that influences performance. In such environments, the overabundance of incoming information from the sensory receptors and from memory can cause misinterpretations of important information, and even confusion and loss of situational awareness. Accurate interpretation of the incoming information depends on past experiences stored in long-term memory in the form of schemata, and on activation of this information in short-term memory ruled by the operator's awareness of the current events in that particular environment. Consider our vacationer example. She might be searching and retrieving important documents from a drawer, at the same time a family member might start talking to her, and in the back of her head she might be thinking about the next thing to prepare for the trip. In this case, the overabundance of information could saturate her perception and cause some actions to occur without conscious perception, and a few minutes after completing the tasks she might not remember if all the documents were placed in the suitcase, and she is forced to go back and double check. In order to better understand the perceptive mechanisms we have to refer to the current theories of perception. The most relevant approach to understand perception was proposed by Gibson, and it will be discussed next.

Figure 2.3 introduces situational awareness to the stage model and shows the connections between situational awareness, long-term memory and perception (Situational awareness will be discussed as a component of short-term memory).

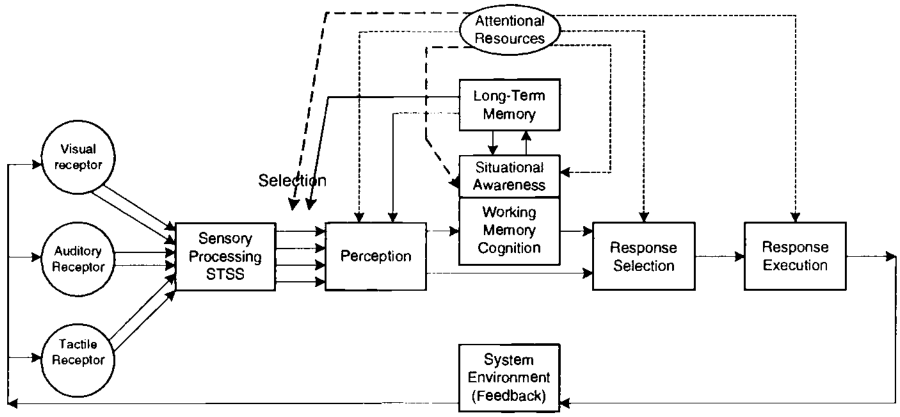

Figure 2.3 Situational Awareness added to the stage model.

2.2.2.1 The Ecological Approach to Perception

Gibson (1966-1979) proposed the ecological approach to perception based on his studies of human perceptual behavior in real world activities (driving automobiles and landing airplanes) as consequence to the inadequacy of the current approaches at the time. In his approach, Gibson, argues that the perceptual system comprised of human senses is "selective and even economical", opposite to the belief that the sensory system was passive, and collected all available sensations. He further explains that our perceptual system "seeks information so as to notice only those features of a thing or situation which distinguish it from other things or situations that it is not". This implies that our perceptual actions must be guided by our preexisting knowledge about the structure and dynamics of the world. However, there is a problem with this implication: the knowledge about the world is dependant on our perceptual experience of the world. To solve this dilemma Gibson argued that what was learned "was not particular responses to particular stimuli, but rather patterns of stimulation." What was learned, he stated, were "invariant relationships and distinguishing features of an object or situation that set it off, in appearance, behavior, and significance, from the rest of the world". With repeated encounters with the stimulus, the specificity and span of what is attended will increase. The span of attention can be incremented in scope and in time. This implies the chunking of information and episodes into larger pieces, in both the spatial and temporal dimensions. This explains the ability of pilots to keep track of a number of instruments in the cockpit. (Gibson, 1966). By repeated interactions with a specific multiple concurrent task environment the operator can make sense out of the overabundant number of tasks by grouping tasks into more complex tasks and adapting her attention in order to manage the system. This process of repeated experience with the environment creates metal structures to represent concepts and events; these structural models are what are known as *schemas*. On the other hand, the retrieval of information from memory to interpret incoming stimuli is associated with preexistent schemata of the world and their activation depends on the individual's situational awareness.

In the case of our vacationer, her situational awareness determines the information that she will pick up from the environment. If information is irrelevant to the ongoing task it might be ignored; this is known as perception tunneling. For example, if she is engrossed with checking documentation to take on the trip and the phone starts ringing, which does not fit into the active schema, the ringing might not be perceived.

One of the problems that can result as a consequence of the operator's increase of attentional span is that conscious recollection of completed tasks can be lost when interruptions occur, like our vacationer who had to go back and double check if the task of placing documents in the suitcase had been performed satisfactorily.

2.2.2.2 Schemata Theories of Comprehension

Schemata theories of comprehension help us understand how operators in complex multiple concurrent task environments comprehend information coming from the environment and from memory storage.

Schemata theory has several proponents, including Freys (1987), Gibson (1969), Mace (1977), MacLeod & Pick (1974), Reed (1988), Shaw & Bransford

(1977), Turvey (1990), and Yates (1985). Schemata theory is based on Gibson's ecological approach to perception. The ecological theory of perception is the top-down mode of information processing of the whole schemata theory of comprehension, in which the operator searches for information in the environment to fit and partially satisfy higher-order schemata. Schemata are "descriptions of a particular class of concepts or events and are composed of a hierarchy of schemata embedded within schemata."(Adams et al. 1991) The other part of schemata theory is the bottom-up mode of information processing in which the operator receives the information at the lowest, best fitting schema. In turn this lower level schema activates and converges into higher-level schemata. However, the processes by which schemata are activated in short-term memory are not yet well understood. This process of schema activation is what is known today as situational awareness. There is evidence that suggests that operators with higher situational awareness outperform those with lower awareness in complex systems such as aircraft cockpits (Wickens, 1994).

One of the obvious problems that arises from the schemata theory is, how do people form new schemata? If we have no schemata about a particular object, event or action, how do we perceive information from the environment? This problem relates back to theories of learning, knowledge, and memory. Such theories can help us understand the mechanisms by which knowledge about a thing or event is interpreted and stored in memory. They can help us understand the mechanisms by which knowledge about new things is processed and stored in our memory.

2.2.3 Cognitive and Memory Systems

Cognitive and memory systems are the mechanisms responsible for the complex interactions that we engage within the environment. What we learn from observations and prior interactions with the environment helps us develop knowledge, which is stored in memory, and is linked to a goal structure. If any future goal partially or completely maps with these goals and actions stored in memory, it will trigger new interactions with the environment and through perceptual and attentional mechanisms, new knowledge is formed.

2.2.3.1 Knowledge, Perception and Attention

The endless human perceptual cycle that involves bottom-up processing and top-down perception, in other words perceiving and learning and then learning influencing perception, has been described by Neisser as being centered in the interactions that occur between the environment and the human. "The [human] organism's active schema orients its responses to its environment [top-down]; the organism's responses to the environment change and reselect the information in attention; these changes serve, in turn, to modify [learn] and thus reorient [focus attention on] the prevailing schema [bottom-up]; and so on."(Adams et al., 1991). However, there is a central problem with Neisser's view: where does the cycle start? To answer this question we can refer to the Miller, Galanter, and Pribram's view.

> Once the biological machine starts to run, it keeps running twenty-four hours a day until it dies. The dynamic "motor" that pushes our behavior along its planned grooves is not located in our intentions, or our Plans, or our decision to execute Plans—it is located in the nature of life itself. As William James says so clearly, the stream of thought can never stop flowing. We are often given our choice among several different Plans, but the rejection of one necessarily implies the execution of some other (Miller et al., 1960, p64).

Miller at al.'s view brings into the picture the concept of plans, which intrinsically include the concept of goals. Every plan is motivated by a goal; i.e., the goal to acquire food induces a plan and the plan motivates an action. In the case of a newborn, the plan is to cry, which in this basic case is an instinct, and the action is the actual crying. Further, the environment's response to that action (being fed by the mother) induces learning behavior; in the case of the newborn, he learns that by crying he will be nourished. This learned behavior would influence other plans. In the future when the infant finds new needs, he will use the same learned behavior to try to fulfill his need. It is common to see toddlers crying to obtain candy or toys, until new behavior is learned by repetitive feedback from the environment (bottom-up processing), the previous behavior will be triggered by the same class of goals. This endless human learning cycle, molded by feedback from the environment, does not end until our biological machines shut off.

In the context of complex multiple concurrent task environments, behavior will be determined by the current goals of the operator, which in turn are influenced by his/her learned models of the environment, which are the product of past experiences of interaction with that environment. These past experiences will trigger actions and responses that have been activated by similar objects or events in the past. According to Neisser, past experiences and mental models stored in memory determine the information that is attended and picked up by the operator. Thus, if no schema exists for any given stimulus, the stimulus does not trigger any action. Neisser's view suggests "the scope or extent, patterns, and even combinations of information to which people are at once receptive may be strictly a matter of learning. Perhaps, people have trouble managing multiple tasks only because, for lack of experience and necessity, they have not learned to do so." (Adams et al. 1991). However, this approach is very simplistic and does not account for situations in which people are capable of interpreting cognitively complex events, for which no concrete or complete schema exist in memory. Considering our vacationer, it could be that this is the first time that she is going on a long trip, and no prior experience in preparing for it exists; however, she can extract information from observations or similar events that partially map to the current goal. She might have had the opportunity to take her documents to a lawyers office, or to a credit company and that experience helps her know how to go through similar procedure for a different goal (going on a long trip). Connectionist theories of memory provide means that help us understand this phenomenon.

2.2.3.2 Connectionist Theories of Memory

As described by Adams et al., "within connectionist theories, knowledge about any given object, concept, or event is reduced in memory to an extended array of primitive units while its structure is preserved through interconnections among them." This concept of memory being connectionist and associative helps us understand circumstances in which an unexpected action or behavior is performed, and helps us understand how actions are linked with goal structures in our memory. In our vacationer example, when she is finally driving away from home what triggers the wondering, "are all the burners off on the stove?" If all our actions are driven by goals, as argued above, and memories connected in a structured way, the fact that we may be unconsciously thinking about the safety of our belongings might trigger connections in memory that lead us to wonder if every burner was turned off. This might happen even if there is no prior experience of an event of that kind or any physical clue present in the environment. For further explanations about connectionist theory refer to the work of Hintzman, 1986; Rumelhart & McClelland, 1986.

Another phenomenon that can be explained on the basis of connectionist theories of memory is the fact that highly recurring information may map easily with well established memory structures, requiring less effort to be interpreted, and triggering almost automatic responses (Schneider & Shiffrin, 1985). On the other hand, novel perceived information would not find structures in memory, requiring higher effort, time and attention to be interpreted, and to construct new memory structures. This might be a way to interpret the ease with which pilots perform a large number of tasks in a normal flight, but in non-normal situations, when no prior experience of a given non-normal event exists, pilots performance decreases. This could be due to the fact that in such abnormal situations the pilot's attentional demand increases, leaving him/her more vulnerable to commit task management errors.

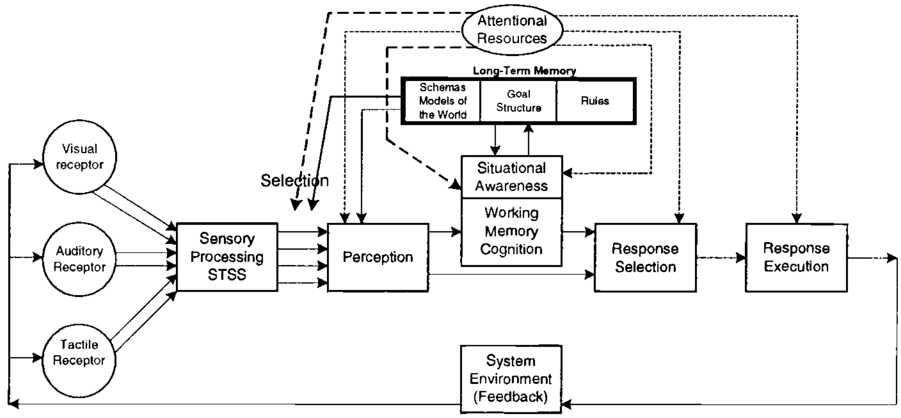

Figure 2.4 Long-Term memory structures added to the stage model.

2.2.3.3 Sanford and Garrod Working Memory Model

Working memory is the mechanism or entity that helps us perform a sequence of related actions without losing awareness of what we have just done and what has to be done immediately after. In the case of our vacationer, it helps her to remember that she has already packed her clothes, and at the same time helps her remember that she is going on a trip and more actions have to be performed.

It was earlier believed that working memory consisted of a single storage with limited capacity. Sanford and Garrod (1981) proposed a different structure for working memory. They argued that an individual's working memory consists of two different containers that they called "bins". One is called explicit focus and the other is called implicit focus.

In Sanford and Garrod's model, explicit focus corresponds to the short-term memory in the older models of memory, and the implicit focus is a new mechanism which supports information in explicit focus with knowledge about the current situation stored in long term episodic memory.

In Sanford and Garrod's model of memory, explicit and implicit focus are not distinct memory buffers, "instead they correspond to more and less activated fragments of long-term memory."(Adams et al.)

Adams et al. extrapolated from the literature to predict how operators would "anticipate some of the parameters that will control the ease or probability with which a given datum is properly processed by the manager of real-world information."(Adams et al, 1991) They explained that for information learned by experience to be more relevant with the current task, it will map easily to information currently in explicit focus. Information that is less relevant to the current task will map to implicit focus. According to Adams et al., mapping information to implicit focus will take longer than mapping information to explicit focus. When incoming information does not map directly to schemata in explicit or implicit focus, the system then searches for schema knowledge stored in long-term memory. It would first search for information in episodic memory relevant to the current working environment, requiring more effort, time and attention. If schemata information is not found in episodic memory, semantic memory will be activated, requiring even more effort, time and attention.

The Sanford and Garrod (1981) model of working memory, the Adams et al. model of complex information processing (1991) and the Adams, et al.'s goal approach to concurrent task management can help us understand an operator's behavior in complex concurrent task management environments. Within this context, it becomes evident that the operator's implicit focus depends on the operator's current goals for the system. Thus, if for our vacationer one of his current implicit goals when leaving his/her house is safety, the fact that he is leaving for a long period might trigger thinking about the status of the stove, even though the stove is not explicitly linked with the current action at that moment (driving). Another implication within this context is that explicit focus as well as implicit focus depends on the operator's situational awareness of the current environment, which in turn is highly related to the operator's episodic memory. Finally, the last implication within this context is that explicit focus depends on the information that can be perceived and interpreted from the environment in the different sensory modalities, which is linked to the multiple resource theory proposed by Wickens (1984).

The nature of situational awareness is still unclear. Within Sanford and Garrod's view, situational awareness can be interpreted as the implicit focus of their model of working memory, which is a link between long-term memory and explicit focus, where schemata associated with the moment are activated. From the perspective of other psychologists such as Wickens, it can be seen as a different mechanism residing in working memory. Nevertheless, the incorporation of situational awareness in the human information-processing model can provide a conceptual framework to study its nature. Figure 2.5 shows the different memory mechanisms that affect concurrent task management and shows how they are linked to one another, and to prior information transformation processes.

Figure 2.5 also accounts for Baddeley's (1986, 1990) model of working memory, in which the "central executive acts as an attentional control system that coordinates information from the two 'storage' systems." The two storage systems are the visiospatial sketch pad and the phonological loop; these storage systems are the same as the visual and verbal modalities in the multiple resource theory proposed by Wickens (1980, 1984, 1992).

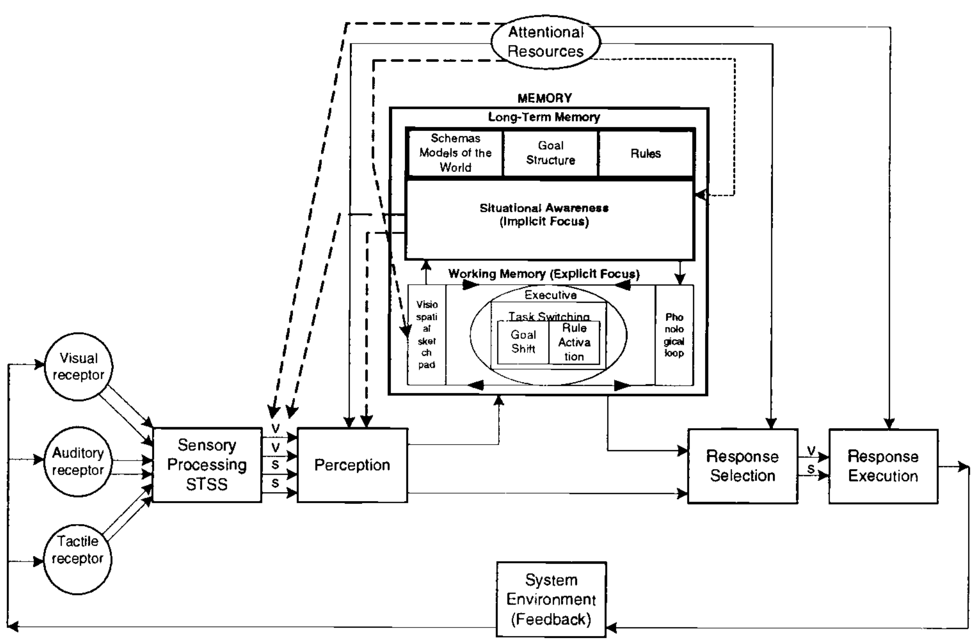

Figure 2.5 Working memory structure added to the stage model.

2.2.4 Theories of Attention

Attention is the mechanism that allows us to concentrate all of our cognitive conscious resources to a specific event or task. In the context of multiple concurrent task environments attention is the limiting factor that determines how many tasks we can attend to concurrently. In the case of our vacationer when she is driving away from home, how many things can she perform concurrently before becoming overloaded, and commit errors? She might be able to drive, think about the burners at home, interact with other passengers, and look for a street intersection; however, when approaching the intersection in heavy traffic, (hypothetically) all the other tasks will have to be interrupted and attention will focus on driving.

To account for the human ability to, in many cases, perform more than two tasks simultaneously, Wickens (1980, 1984, 1992) proposed the Multiple Resource Theory which is contrary to the prior single channel/resource theory of attention proposed by Broadbent (1958), which assumes the human information processing system is a single pool of attentional resources. In Wicken's theory the human information processing system consists of multiple attentional resources. Multiple resource theory accounts for most of the dichotomies explored in the dual-task experiments (Wickens 2002), in which performance in the primary task is not affected by increasing difficulty in the secondary task. However, in the context of multiple concurrent task environments, how does multiple resource theory explain performance in more than two simultaneously occurring tasks? In such a case, the human operator cannot be conceived as an infinite channel information processing system. Instead, the limited resources have to be managed. The issue of managing tasks brings us back to the concepts of task prioritization and goal structure, earlier discussed.

Task prioritization is a mental process that requires mental effort and resources just as perception processes and response processes do. The operator of complex concurrent task environments is challenged with the difficulty of performing all these tasks concurrently and the only way to accomplish all of them is to switch his/her attention and effort back and forth among them. For example, our vacationer has to switch her attention between the multiple tasks that have to be performed to accomplish the final goal of leaving on vacation. Little is known about how operators of complex systems switch their attention and effort among concurrent tasks, and what mechanisms account for task prioritization. Some efforts in the aviation domain are the only attempts to understand task prioritization (Colvin and Funk 2000, Wickens 1994), and they will be explained later. However, some research has been done in psychology in the area of task switching.

2.2.5 Strategic Task Switching

In the context of our traveling example, it is important to understand the mechanisms which she utilizes to switch from one task to another, and how difficult it is to do so. Some of the questions that came about from the Adams et al. (1991) review related to allocation of attention were: how do people shift their attentional resources among the multiple concurrent tasks in complex systems? What mechanisms influence operators to switch attention to one task and not another? What characteristics of the task prompt operators' attention?

The National Research Council (1993) reviewed the literature and introduced the term *strategic task switching* to describe the mechanisms by which people, on a daily basis, switch from one task to another making us appear as "a collection of special-purpose machines [luggage packing machine, clothing inventory machine, driving machine], capable of changing from one to another on a moment's notice."

The term "strategic" can be defined as "an optional organization of cognitive processes that is designed to achieve some goal in a particular task environment." (Logan, 1985; Logan and Zbrodoff, 1982; Logan et al., 1983) It is important to notice that the concept of goals is brought back into the context of managing multiple tasks in complex environments, as the most important motivator for our actions. According to Logan and Zbrodoff (1982), operators can "adopt the required attention very rapidly (within a half second) if they are motivated to do so, and they will choose one strategy or the other on the basis of the probability that it will best serve their performance (final goal) (Logan et al., 1984; Zbrodoff and Logan, 1986). Nevertheless, recent research with a multi-tasking simulator (Shakeri and Funk, 2003) showed that operators often do not adopt the optimal strategy to switch from task to task, and their performance is highly related to their training and current perception of the goal. So, how do people perceive goals, and how does the goal structure influence task prioritization, and attention allocation? Research in the area of goal structure is sparse. Funk (1991) studied task prioritization and goal structure in the aviation domain; his efforts will be described later in the "engineering theories of concurrent task management" section of this chapter.

In the psychology literature, the most relevant theory in the area of task switching and task prioritization is "action identification theory" proposed by Vallacher and Wegner (1987). Action identification theory assumes that actions are "organized hierarchically and concerns itself with discovering the level at which actions are constructed and the circumstances under which people shift the level at which they describe their action."

Action identification theory might help us account for the inaccuracy with which people perceive task characteristics such as importance, status, and urgency. Vallacher and Wegner (1987) argued that people would engage in action descriptions and analysis at the highest level possible until something goes wrong. They gave an example, in which they argued that we think that we are calling a friend (goal) until we find out that the number was not dialed correctly. Then we pay attention to button pressing (sub-goal) to find out what went wrong. In the context of complex concurrent task environments operators would not engage in detailed analysis and description of the task until something goes wrong and their performance decreases; moreover, their perception of their performance is highly influenced by their goal. Thus, if the goal is to maintain performance of the system at 80% of the maximum possible performance the operator will accommodate their task management behavior to accomplish this goal. However, if the goal changes to 90% and the goal is not achieved, the operator might go back and pay more detailed attention to the nature and functioning of the task to accommodate for this new goal requirement. The questions that rise from these discussions are: how accurate are operators at perceiving tasks that differ in nature (data-limited or resource-limited tasks)? (Norman and Bobrow, 1975) How accurate are operators in perceiving the workload demand of multiple concurrent tasks so as to be able to accommodate strategic switching to accomplish the current goal? How do operators switch their attention between tasks of different importance, urgency and status? How good are operators in perceiving task characteristics such as deterioration rate, correction rate, and goal status (achieved, in progress)? To be able to answer some of these questions an experimental tool bed is needed to explore all these questions in the context of multiple concurrent tasks.

Within the dual task paradigm in psychology, Wickens et al. (1985) "found that subjects can shift resources from one task to another within a few seconds, in response to a sudden increase in resource demand (difficulty) imposed by one of the tasks." Jersild (1927) conducted a series of studies to determine the time that it would take participants to alternate between similar and dissimilar strategies. He found that operators can switch between very dissimilar strategies without a cost. In the area of multiple resource theory Gopher (1982), and Sperling & Dosher (1986), found that people could switch attention between processing channels in a very short time, in the range of a few tenths of a second. They further argued that differences in switching time between two auditory channels are valid predictors of difference in performance in complex environments such as driving and aviation. However, the questions that raise from these findings in the dual-task paradigm, are: Do operators shift their attention in similar ways, as in dual-task environments, in multi-task environments? Are there different mechanisms by which operators manage tasks in real-world concurrent task environments, where the nature of the task is different?

The psychology literature argues that the time to stop a task or change from one task to another is low. Logan found that simple or complex actions can be stopped within 200 to 400 milliseconds (Logan and Cowan, 1984), and that the time required for stopping actions increases as the difficulty of performing that action increases (this is part of the stop-signal paradigm). The literature also suggests that the time to switch from one task to another is longer when the stopping of the current ongoing task is the clue to start the next task, and it may be due to "residual effect of the inhibited response to the first task." If the residual effect is removed satisfactorily, the new response can begin without interference. However, this is not the case in most complex real world systems, in which operators, more likely have continuous episodic awareness of the immediate, short-term and long-term goals of the system. Awareness presumably produces a great deal of retroactive interference between the first task and the next task(s) to be attended. This is reflected by research done by Moray (1886), Sheridan (1972), Jersild (1927), and Rogers & Monsell (1995), which suggests that there is a cost in switching between tasks, and so there is a tendency to continue performing a lower-priority task longer than optimal if the need to perform a higher priority task arises. Some literature in aviation psychology reveals the failures in task management and timely switching to high-priority tasks (Schutte & Trujillo, 1996), some of which occur in ways that can lead to aircraft incidents and accidents (Chou, Madhavan, & Funk, 1996). Colvin and Funk's (in review) studies revealed that task interruptions contribute significantly to the occurrence of task management errors and accidents.

The model in Figure 2.6 is the result of incorporating some of the most relevant models of human cognition into the stage model of human information processing. This Augmented Stage Model of human information processing can serve as the theoretical framework for the formulation of new hypotheses about human performance in multiple concurrent task environments. Of course, this stage model is based on the assumption that human concurrent task management behavior can be modeled as a rational process. However, other researchers in the area of multi-tasking had proposed a more reactive approached to concurrent task management (Dismukes et. al, 1998), in which human behavior cannot be modeled in a rational sequence and interaction of cognitive process, rather in a more probabilistic and heuristic combination of such processes.

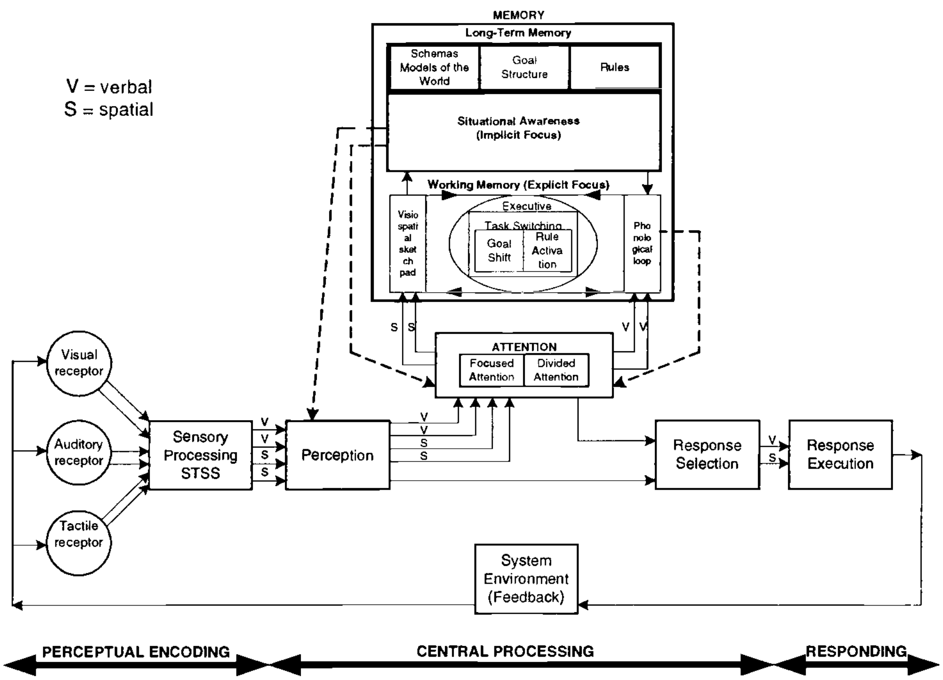

Figure 2.6 Augmented stage model of human information processing.

2.3 Engineering Theories of Concurrent Task Management

The approach that engineering theories of concurrent task management take is different from the psychology theories in that the former is concerned with overall human behavior and not the cognitive or psychomotor mechanisms that account for it.

One of the earliest engineering attempts to model human multi-tasking behavior was done by Carbonell and colleagues (1966, 1968). They used queuing theory to model pilots' visual scanning behavior in extracting information from a set of displays in the cockpit. Their approach describes the human operator as a server that has to provide service to a queue of customers that in this case were instruments displaying flight related information. This approach to concurrent task management allowed researchers to calculate probability distributions of service time to different tasks. It also allowed them to calculate mean waiting time that the task would be in the queue, and finally it allowed them calculate mean task execution time. However, implicit within queuing theories is the concept that a task, after being attended, no longer requires attention, and resources are allocated to the next task in the queue. The nature of this task does not represent the real attentional demand of dynamic concurrent tasks in complex environments such as an aircraft cockpit, where the operator has to dynamically shift his attentional resources among multiple, unending concurrent tasks, and often shifts back and forth among the same group of tasks.

In an attempt to model optimal behavior in environments with dynamic tasks, researchers have applied control and estimation theory (Tulga and Sheridan, 1980; Pattipati and Kleinman, 1991). In this approach to concurrent task management, each task has a decision state that is determined by the time it will take to accomplish the task, the time available to perform the task, and the state of the other concurrent competing tasks. This model calculates decision variables that predict which task will be attended to next based on the task parameters. One limitation with this approach is that it considers all tasks as demanding manual work, and in real world environments, some tasks require more mental effort than manual work.

Moray et al. (1991) used scheduling theory to study human strategic decision-making and predicting the optimal sequence in which human operators should attend to number of concurrent tasks. In this view, the operator is seen as a single machine and the tasks are seen as jobs. The operator's objective under this model is to maximize the number of tasks accomplished by their due date. One major problem with this perspective is that the nature of the tasks was not dynamic, meaning that each task had a completion state, which is not the case for some tasks in real world environments. For example, in an aircraft cockpit, altitude control is a never-ending task and requires attention during all phases of flight.

Shakeri (2003) used a similar approach to that of Moray et al. (1991) to study concurrent task behavior, in which the operator is a single machine that can attend to tasks. The difference from the previous approach lies in that the objective in Shakeri's approach was to maximize the "aggregated quality" of task performance rather than to maximize the number of tasks accomplished. Shakeri developed an algorithm based on a technique called tabu search that calculated a near-optimal performance. True optimal performance could not be calculated with common operations research tools due to the computational complexity of the mathematical model. But the near-optimal performance of Shakeri's algorithm in multiple concurrent tasks was compared to the performance of real humans on a multi-tasking simulator. Shakeri's research brought about three important findings. First, he found that participants could not beat the near-optimal solution predicted by his model. Second, performance of the best performers in each of the different trials were in some cases even 99% of the near-optimal performance, and the average performance for all participants was between 71-87%, implying that participants could have beaten the near-optimal performance with additional practice and experience. Finally, he found that participants in the earlier trial over-reacted to penalization (failure) of tasks and attempted to manage too many tasks even though it produced low overall system performance.

Shakeri's research is an important contribution to the study of multiple concurrent tasks, which includes many of the characteristics of real world tasks, such as the dynamic nature, ill structured goals, undefined deadlines, and varying task importance. However, the issue of goal structure and strategies for task prioritization were not addressed in his research. Nevertheless, his approach and tools can be expanded to study how different *goal sets* and *structures* would influence performance in the context of multiple dynamic concurrent tasks.

Finally, a fuzzy model of concurrent task management was introduced by Chen and Funk (2003). In their study, they attempted to determine how importance, status and urgency of each task affect task prioritization. To accomplish this goal several fuzzy models of human prioritization using different combinations of the task characteristics (status, importance and urgency) were developed and compared to real human data on a multi-tasking simulator. The most important of their findings was that models incorporating all of the three task characteristics predicted human behavior better than those using just one or two of the task characteristics. However, no single model accurately predicted all human behavior. In the case of the best performing participant, the best models predicted performance 78% of the time, and in the case of the worst performer, the models predicted human behavior only 25% of the time.

2.4 Real-World Constraints on Information-Processing and Action

Few studies have explored task management strategies in complex concurrent task environments (Adams et al, 1991). Puffer (1989) studied students' strategic management of several courses over the length of a semester. Chou and Funk (1990) performed some experiments to examine task scheduling and shedding in high-workload simulated aviation environments. Segal and Wickens (1990) also performed a series of experiments to investigate the degree to which operators optimally employed task priority to schedule tasks. In this section individual attempts to identify task prioritization factors in the aviation domain will be discussed.

2.4.1 The Goal Structure in Cockpit Task Management

Funk and colleagues (1990, 1996) developed a preliminary normative theory of cockpit task management to describe the process that flight crews use to prioritize, initiate, execute and terminate multiple concurrent tasks. According to Funk's normative theory of cockpit task management, pilots engage in the following processes:

- Assessing the current situation or task set
- Activating new tasks in response to recent events

- Assessing task status to determine whether each task is being performed satisfactorily
- Terminating tasks with achieved or unachievable goals
- Assessing task resource requirements
- Prioritizing active tasks
- Allocating resources to tasks in order of priority (initiating, interrupting, and resuming them, as necessary)
- Updating the task set

Further, Funk argued that goals are the basis for the accomplishment of tasks, and he divided up the general concept of goals into a hierarchy of super-goals, goals, and lower-level goals, reflecting the "action identification theory" proposed by Vallacher and Wegner (1987) and the strategic task management approach proposed by Adams et al.

Funk's normative theory of CTM and his description of the goal hierarchy in the aviation domain can help us understand and frame the behavior of our vacationer in the example described earlier. At any moment in time, every human has a complex set of super-goals comprised of goals and sub-goals that direct his behavior toward any given action. We can argue that our vacationer, in that particular moment (driving away from home) had a set of super-goals, among those: to maintain safety of her belongings, to maintain safety of her family, to go on vacation, to get promoted next year, and so on. In the same way, each of these super-goals contains a set of lower-level goals. For example, the "to go on vacation" goal, could have a set of subgoals such as: to choose a destination, to buy air tickets, to choose a date to depart, to depart, and so on. All of these goals motivate actions, for instance, the "to depart" goal triggers actions such as load the car, close the house, start driving, arrive at the airport, and so on. While performing any of these lower level actions, like driving away, our vacationer could "assess her current situation" and this could imply checking her higher level super-goals related with the action that she is performing in that moment. Just as Sanford and Garrod argued in their model of working memory, the vacationer will access supporting information from her implicit focus. In this case, a supporting goal for "going on vacation" could be "to maintain safety of belongings and family". This goal would "activate a new task" in the vacationer, for example, to perform a mental checklist of things that could jeopardize safety, and this in turn would lead to "assess the status" of the stove at home. Based on the acknowledgment of status of the stove, the vacationer will "terminate the task" if the safety goal is achieved, or if it is not achieved she might start a new action depending on the "priority" that the goal has over the other current on-going actions. If the safety goal has a higher "priority", the vacationer will start investing more resources (drive back to home) into satisfying that goal. Once the goal is satisfied, the driver will resume the interrupted actions (going on vacation) and the task set and goal set will be updated, and the cycle starts again.

As shown in the previous example, Funk's normative theory of CTM, description of goal structure, and cognitive theories of working memory and situational awareness can help us *explain* complex human behavior. However, an important question remains unsolved: do these theories allow us to *predict* human behavior? The problem lies in that every individual may have a different set of goals, and even the structure of this set of goals might be different. Predicting actions resulting from these goal sets is impossible without precisely knowing each individual's set and goal structure. The research question that rises from the previous discussion is: Can we train operators of complex concurrent task systems to create a specific structure and goal sets? How do different structure and goal sets influence performance in complex systems? To what degree do goal sets and goal structures influence task prioritization?

2.4.2 Strategic and Tactical Task Management Theory

Rogers (1996) expanded Funk's normative theory and proposed a preliminary set of discrete flight deck CTM processes. These processes according to Rogers occur in the following order:

- Assess situation
- Identify tasks

- Prioritize tasks
- Assess resources
- Allocate resources
- Schedule tasks
- Perform tasks
- Monitor tasks
- Manage interruptions

It is important to notice the differences in Funk's normative theory. The latter incorporates the concept of task interruptions and task scheduling in a more explicit way as opposed to Funk's theory, which includes them implicitly. The concepts of task interruptions and task scheduling link these theories with other approaches to model human behavior in complex systems such as the one proposed by Shakeri (2003), in which the tasks have to be scheduled and interrupted strategically, and also with psychology research in the area of strategic task switching.

Rogers also presented three important conclusions relevant to the nature of CTM. First, he argued that CTM has two *modus operandi*, strategic and tactical. Strategic CTM refers to phases of operation in which there is little time pressure. In this case, the operator will create a strategy and a plan to perform the tasks in order to avoid high workload moments. The tactical mode of CTM refers to moments of high workload and time pressure. In these cases, the operator will act in a more reactive manner extracting skill based knowledge from memory in case that one exists for the present tasks. In addition, the operator might opt to shed some of the tasks, reflecting what was found in Shakeri's (2003), and in Chen and Funk's (2003) experiments. Shakeri found that subjects that selected a strategic approach to manage the simulated tasks, obtained higher scores in the overall system performance, and those who were more reactive to the system showed lower overall scores. Second, Rogers argued that CTM is time-driven, meaning that the primary task characteristic that influences task prioritization is urgency, which was defined by Funk as the ratio of the time that it would take to complete the task or bring it to a satisfactory state to the time remaining before its deadline. Finally, Rogers argued that tasks are categorized into "discrete real-time tasks, discrete pre-planned tasks, and continuous or repetitive tasks." He further argued that discrete tasks are "ordered along a priority or time dimension and continuous tasks are interleaved with discrete tasks but not explicitly ordered."

Raby and Wickens (1994) conducted a study involving 30 pilots to answer two questions: "when do people choose to perform tasks and how do they choose to adapt to high-workload periods?" They concluded that tasks with higher priority were attended at the optimal time in the flight phase. In other words, tasks that were initiated later than they should have been were the ones that account for a decrease in flight performance even though they were performed properly. These findings support earlier findings by Lauderman and Palmer (1993), and Fischer et al. (1993) who found that those pilots "who performed better on their overall flight path accuracy tended to perform most of the discrete tasks significantly earlier in the flight." However, it is difficult to discriminate if this behavior is due to actual task management strategy or just proficiency of flight skills.

2.4.3 Workload, Task Management and Situational Awareness

Schutte and Trujillo (1996) proposed a different perspective to CTM. They argued that CTM is made of two distinct activities, which they called personal workload management and monitoring of the current situation. What is important from their approach is that they described monitoring the current situation as containing the "assess current situation" and "assess progress and status of active tasks" concepts from Funk's normative theory, which in turn relates to current concepts of situational awareness.

In an attempt to better understand human behavior in complex systems, other researchers have started subdividing the concept of situational awareness. Wickens (2002) divided situational awareness into subcategories like spatial awareness, system awareness, and task awareness. He further argued that all these components have real-world implications. For more detail, see Wickens (2002).

2.5 Summary

Psychology research has introduced a number of theories and models of human perception, human information processing, working memory, long-term memory, attention, situational awareness, and psychomotor skills. On the other hand, engineering research has created useful models of human behavior in multiple concurrent tasks environments. Funk's (1991) normative theory of cockpit task management can be extrapolated to create a valuable framework to explain and predict to some extent human performance in multiple concurrent environments, as we saw in the example of our vacationer. From the integration of these different approaches to study multi-tasking behavior, the Augmented Stage Model of Human Information Processing was introduced to provide a comprehensive framework to better understand factors involved in multi-tasking, and to support the formulation of new hypotheses that may fuel research in the area of CTM.

3 RESEARCH HYPOTHESIS

Research in the aviation domain, driving distractions, anesthesia administration, nuclear power plant control rooms, and even cooking at home show that Concurrent Task Management (CTM) is a process that every human operator performs when interacting with complex environments. As described in Chapter 2, psychologists have been studying multi-tasking in a wide variety of dual task experiments. On the other hand, engineers have studied concurrent task management performance in very specific domains, such as aviation. However, the need for understanding concurrent task management from a broader perspective, more applicable and generalizable to different domains, led to the development of the Augmented Stage Model of human information processing (Figure 2.5) and led to the development of a test bed where hypotheses deriving from the augmented stage model can be tested.

The stage model, as presented in Figure 2.1 is a widely accepted representation of human information processing (Smith, 1968; Sternberg, 1969; McClelland, 1979; Wickens, 1984). The Augmented Stage Model as presented in Figure 2.6 is merely an elaboration of that model attempting to explain CTM in terms of those basic stages of human information processing and drawing on relevant, recent psychological research. One of the most significant questions that arise from the creation of the Augmented Stage Model is to what degree the augmented stage model can be validated by actual human concurrent task management performance. A corollary of this question is to what degree can CTM performance be explained by performance in simple tests that are derived directly from the stages of the model, for example, tests of working memory, and reaction time.

The original stage model of human information processing (Figure 2.1) was derived from a vast amount of psychological research originating from Broadbent's (1958) model of attention that attempted to relate cognition to human performance. Experiments of simple and complex reaction time, and memory search (Sternberg, 1969, 1975) provided strong support for the stage model, confirming that information passes through those cognitive stages after entering the human sensory system and before exiting the system in the form of responses. Other experiments in simple tasks provided ground for the development of theories of working memory and justified the introduction of this mechanism in the stage model. The Augmented Stage Model was developed taking as starting point this simpler stage model and integrating recent and relevant psychological research in each of the information stages, and focusing on their relation to CTM performance. The purpose of this research was to investigate if simple cognitive abilities draw from stages in the model can predict performance in CTM.

The research hypothesis for this study was: cognitive abilities drawn from the ASM predict Concurrent Task Management performance. More formally, if correlation between cognitive abilities and CTM performance are significant and high, then cognitive abilities predict CTM performance.

To test this hypothesis, several psychological tests that quantify cognitive abilities were selected, and performance in these tests was compared to CTM performance. CTM performance was measured in a computer program, developed as a test bed, called the Task Management Environment.

Tests of simple and complex reaction time similar to the ones used by Hick (1952) and Hyman (1953), a test of working memory (Baddeley, 1992), a test of declarative memory or verbal intelligence (Anderson, 1976, 1983; Anderson and Bower, 1973; Kintch, 1974; Norman and Rumelhart, 1975), and a test of decision making strategy, were used to quantify basic cognitive abilities.

The next chapter describes each of the tests that were used for this study, the research methodology, and the analysis performed on the data collected from the different tests.

4 RESEARCH METHODOLOGY

4.1 Research Methodology Overview

This chapter is divided into three parts. First, a general description of each of the cognitive and neuropsychological tests, including how participants interacted with each of the tests, is provided. A detailed description of the TME and its components, including how participants interacted with its interface, is explained in the second part of the chapter. Finally, experimental procedures are explained in the third part of the chapter. This includes information on experimental design, collection of participants' demographics, multi-tasking scenarios, task management performance measures in the TME, performance measures on the cognitive tests, and testing procedures.

4.2 Cognitive and Neuropsychological Tests

The cognitive and neuropsychological tests used for the study were a battery of widely used tests described in the literature (e.g., Lezak, 1995; Spreen & Straus, 1991; Graf & Uttl, 1995; Uttl, Graf, & Cosentino, 2000). These tests can be classified into two categories: computer based tests, and pencil and paper tests. Computer based tests were developed by Dr. Bob Uttl, at the Oregon State University Psychology Department, and were programmed with the C language. A single personal computer workstation was used to run the tests and display information to the participants.

4.2.1 Computer Based Psychological Tests

4.2.1.1 Simple Reaction Time

The speed of simple reaction (an important component of Response Execution in Figure 2.6) was assessed by means of a task that requires pressing a key in response to a simple stimulus displayed on a computer screen. (see Graf & Uttl, 1995; Uttl, Graf, & Cosentino, 2000 for details and normative data). Four blocks of 25 trials were given. On each trial, a clearly visible stimulus (e.g., a large letter X) was displayed in the center of a computer screen, and the participant responded to this stimulus by pressing a key on the keyboard, as quickly as possible. Appendix 1 shows the program's interface.

4.2.1.2 Card Sorting

Selective attention, decision-making time, and visual search ability were assessed by means of a simulated card-sorting task (see Graf & Uttl, 1995; Uttl, Graf, & Cosentino, 2000 for details). For this task, computer displays, each resembling a playing card, were presented on the computer monitor. Each card had either 1, 5 or 9 different letters on it, and one of the letters on each card was either an A or B. The participants' task was to sort the cards into two groups, by separating cards marked A from cards marked B by pressing two different keys on the keyboard. Participants were given this task three times and each time the task had 53 sorting trials. Appendix 2 shows the program's interface.

4.2.1.3 Coordination and Switching

To assess motor functions, visual search ability, attention, coordination and switching, and working memory capacity, a widely used test was implemented. The test is called the Path Finding Test (Uttl, Graf, Santacruz, 2000). The PFT included several conditions. For each condition, a target was displayed on the screen, and the task was to locate the target, and click on it with the computer mouse as quickly as possible. In the first condition, a single target had to be located on the screen (e.g., a large letter X inside a circle). In the second condition a sequence of numbers/letters was displayed. The task was to locate them and click over them, as fast as possible, in ascending order (e.g., a sequence such as 1, 2, 3 and so on, or A, B, C and so on). In the third condition two different sequences were displayed on the screen. The task was to locate them and click over them in ascending order, alternating between the two sequences (e.g., a sequence such as 1, A, 2, B, 3, C and so on). In the fourth and fifth conditions, three and four different sequences were displayed on the screen, respectively. The task was to locate them and click over them in ascending order alternating between the sequences (e.g., fourth condition 1, 9, 18, 2, 10, 19 and so on; fifth condition 1, A, 7, G, 2, B, 8, H and so on). Appendix 3 shows the interface for the PFT.

4.2.2 Paper and Pencil Based Psychological Tests

4.2.2.1 Computer Experience Questionnaire

The purpose of the computer experience questionnaire was to get information about participants' experience using computers, their comfort level, and their computer knowledge. The questionnaire consisted of 7 multiple choice questions such as "How long have you been using a computer?" with possible answers such as: a) never, b) less than 6 months, c) 1 to 3 years, d) 4 to 6 years, e) 7 years or more, as well as 6 questions such as "How many hours per week do you use computers? Information from this questionnaire was used to determine if experience in operating computers was a significant factor in performance on the other computer based tests. Appendix 4 shows the questionnaire.

4.2.2.2 Decision Making Questionnaire (Mann, Leon, et al. 1997)

The decision-making questionnaire was a 22-item scale that measures a participant's agreement with statements such as "I do not make decisions unless I really have to". The level of agreement to the statement is measured in a 1 to 5 rating scale, 5 being the highest level of agreement to the statement. The scale is divided into 4 factors, Buck-Passing (items 1, 3, 7, 12, 16, 19), Vigilance (items 2, 5, 8, 11, 13, 17), Procrastination (items 9, 10, 15, 21, 22), and Hyper-vigilance (items 4, 6, 14, 18, 20). Appendix 5 shows the questionnaire.

4.2.2.3 Vocabulary Test (Uttl, B., 2000)

The vocabulary test recorded an index of participants' verbal intelligence and semantic memory. This test was a multiple choice vocabulary questionnaire with 84 items. Three pages of printed words in capital letters, followed by four words or phrases were given to the participant. For each capitalized word, the participant had to circle the word or phrase that was closest in meaning to the capitalized word. If the participant could not identify which of the four words was closest in meaning to the capitalized word, he/she was asked to make a guess. Working in order, from the first word to the last, and not skipping any words was important for this test. Following is an example of an item on the test.

1 UNASSUMING A) endowed B) gripping C) self-effacing D) dearest

4.3 The Task Management Environment (TME)

The TME is a computer program that simulates an abstract system composed of simple dynamic subsystems. The TME is written in the Microsoft Visual Basic 6.0 programming language and runs under the Windows 2000 operating system. The TME serves as an abstract multi-tasking environment, in which the behavior of the multiple subsystems (deterioration/correction rates from/to their satisfactory status), importance of the subsystem, number of subsystems, and duration of the experiment can be set by the experimenter. This program gave the experimenter the ability to assess and quantify cognitive attributes such as the participant's allocation of attention to concurrent dynamic subsystems.

Each TME subsystem has a single state variable, called status, that ranges from 0% to 100%. A subsystem's status is represented by a blue vertical bar in the interface (Nicolalde, Funk and Uttl, 2003) (see Figure 4.1). If the participant does not attend to a subsystem, its status goes down from the fully satisfactory status level (100%) at a constant rate. On the other hand, the participant can improve the status of each subsystem toward the desired state by pressing the button underneath each subsystem using the mouse. While attending to a subsystem by keeping the left mouse button pressed, the participant can move the cursor around the screen, and the level of the bar will keep increasing until the mouse button is released. This characteristic is intended to compensate for the time it takes to move the mouse from one subsystem to another.

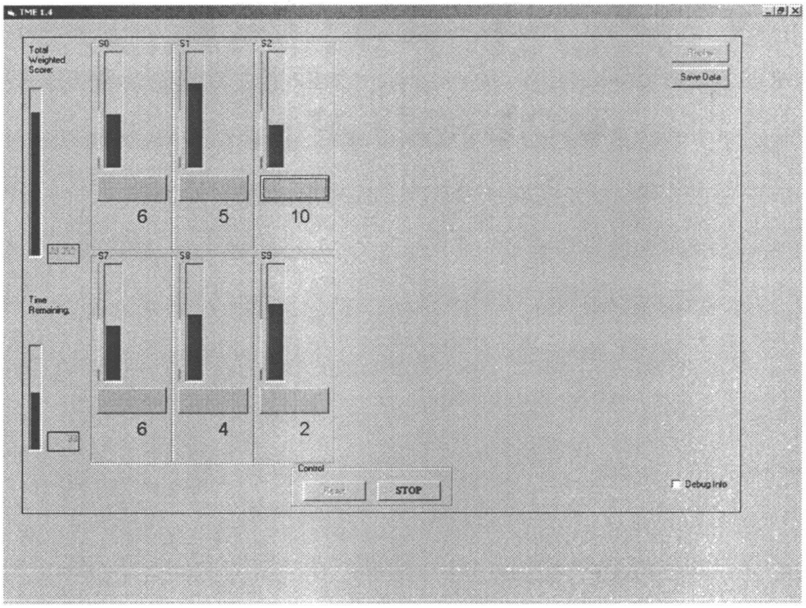

Figure 4.1 Subsystems' position for practice trials and TME easy

There are two types of subsystems, continuous and discrete. The normal behavior of a continuous subsystem, unattended by the operator, is for its status to decrease at a constant rate, called the Deterioration Rate (DR), until it reaches and remains at 0%. When the participant operates a continuous subsystem by clicking the computer's mouse on the button below the subsystem's status bar, its status increases at a constant rate, called the Correction Rate (CR), until it reaches 100%. When the operator releases the button, the status begins decreasing again.

The behavior of a discrete subsystem is very similar, except that its status normally remains at 100%, even without the participant's attention, until a random "failure" event occurs. At that time, its status decreases at a rate of DR until the operator clicks the subsystem's button. The decrease halts for a predetermined period, during which the subsystem's button disappears. After the period, the button reappears and the status continues decreasing at the DR until the operator clicks the button again and the decrease again pauses. This continues for a predetermined number of cycles, after which the status is restored to 100% and stays there until another random "failure" event occurs.

Each subsystem presents the participant with a simple control task. A continuous TME control task simulates a continuous control task in a real domain, where, for example, a pilot tries to control the aircraft so as to precisely maintain a specified altitude (corresponding to 100% in the TME task). A discrete TME task simulates a discrete task in a real system where, for example, the pilot must perform a series of discrete actions to restart an engine that has stopped in flight and restore it to normal operation (100% in the TME task). As in the real world, where the operator can often perform just one task at a time due to personal and technical limitations, the TME allows the participant to perform just one control task (operate just one subsystem) at a time.

To start the TME the participant presses the "Start" button at the bottom of the screen. Immediately after the "Start" button is pressed the level of each subsystem starts dropping from the 100% level. The participant's task is to try to keep all of the subsystems at satisfactory status levels. The TME computes a performance measure based on this objective. Each subsystem has three zones, green (100% to 50%), yellow (50% to 10%) and red (10% to 0%). These zones determine the status of the subsystem. Thus, green means satisfactory status, yellow means unsatisfactory status, and red means unacceptable status. The instantaneous score for a subsystem at any time is qi. The variable q is a qualitative transform of the subsystem's current status level; q = +1 if the subsystem's status is satisfactory, q = 0 if its status is unsatisfactory, and q = -1 if its status is unacceptable. The variable i is the subsystem's importance, the number appearing directly below the subsystem's status bar in the interface. The cumulative score for the subsystem is the mean instantaneous score starting at the beginning of the run. The total weighted score (TWS) is the summation of all subsystems' cumulative scores, and reflects an overall task management performance measure, weighted according to subsystem's importance.

4.4 The Experiment

4.4.1 Experimental Design

The general approach to design and conduct an experiment is called the strategy of experimentation or experimental design (Montgomery, 1997). There are numerous strategies that an experimenter could use in implementation of the experiment to attain his/her objectives. The experimental design used to conduct this study is described in the following section.

4.4.1.1 General Description

The second objective of this study was to investigate to what degree the Augmented Stage Model could be justified by actual human concurrent task management in simple tests that are derived directly from the stages of the model. In order to attain this objective, performance in the psychological tests used to assess cognitive abilities was correlated with performance in the TME. The Pearson Product-Moment Correlation Coefficient was used as a measure of the degree of relationship between mean performance in each psychological test and performance in the TME. It is suggested in the literature (Howell, 1997), that when the sample size is small relative to the population, the sample correlation will be a biased estimate of the population coefficient. To correct for this factor the adjusted correlation coefficient (r_{adj}) should be calculated. The adjusted r was calculated.

The multiple correlation coefficient, often denoted $\boldsymbol{R}_{0,1,2,3,\ldots p}$, was also calculated. $\boldsymbol{R}$ is defined as the correlation between the criterion, in this case performance in the TME, and the best linear combination of the predictors which for this experiment are each of the psychological tests (Howell, 1997).

Performance on the TME in each of the difficulty levels was defined as the dependant variable. Mean performance in each of the psychological tests was defined as the independent variables or predictors. Table 4.1 presents a list of all variables and how they were accounted for in this study.

Table 4.1 Variables list.

Variable	Cognitive Ability	Type
Y – Performance in TME	CTM	Dependant
AG – Age	NA	Independent
SX – Sex	NA	Independent
EY – Education Years	NA	Independent
EL – Education Level	NA	Independent
BP – Buck-Passing	Buck-Passing	Independent
VI – Vigilance	Vigilance	Independent
PR – Procrastination	Procrastination	Independent
HV – Hyper-vigilance	Hyper-vigilance	Independent
RT – Reaction time performance	Reaction time	Independent
CS – Card Sorting Performance	Decision Time	Independent
PF – Path Finding Performance	Working Memory Time	Independent
PC – Computer Experience	NA	Independent
VT – Vocabulary Test Score	Verbal Intelligence	Independent
TP – TME Training Performance	Learning Effect	Independent
E – Residual Error	NA	Independent

4.4.1.2 Participants

Ninety-four college students from Oregon State University participated in the experiment. The participants were recruited through the use of posters posted in the Psychology Department and in the Industrial and Manufacturing Engineering Department, (Appendix 6), and through word of mouth. Participants received credit in their respective psychology or engineering classes for their participation.

4.4.1.3 TME Scenarios

TME scenarios are planned combinations of the different parameters that can be changed by the experimenter in the TME program. These parameters include number of subsystems, importance, i, of each subsystem (represented by the number underneath the buttons), behavior of each subsystem (continuous or discrete), deterioration/correction rates, and run time of the scenario.

For this experiment, three different scenarios were created. One scenario was designed for practice purposes; the other two scenarios were experimental tests, in order to determine if there was a significant difference between two different combinations of parameters.

4.4.1.3.1 TME Practice Scenario

The practice scenario was developed so that the participants could become familiar with the TME. This practice scenario, as seen in Figure 4.2, was two minutes long, and was run five times by each participant. Another important reason for having a practice scenario was to allow participants to try different strategies for attending to the multiple concurrent control tasks. A small pilot study showed that the time required by participants to learn to manage the TME was approximately ten minutes.

This scenario consisted of six subsystems, S0, S1, S2, S7, S8, and S9, three located in the upper half of the TME interface and the other three underneath the first three. In the TME, the importance of the subsystem is given by the number underneath its button, the bigger the number the more important the subsystem is. For this scenario, the importance values, i, were [6, 5, 10, 6, 4, 2] starting from the upper left subsystem to the right and then down. All of the subsystems except the one (S7) located at the lower left corner, which was discrete, were continuous in behavior. The maximum score possible for the scenario was 33. The deterioration and correction rates, subsystem importance, and behavior for the subsystem are given in Table 4.2.

Table 4.2 TME practice scenario subsystems' behavior.

Task Number	Deterioration Rate	Correction Rate	Task Importance	Behavior	Number of Steps
S0	2	9	6	Continuous	NA
S1	1	5	5	Continuous	NA
S2	3	8	10	Continuous	NA
S7	3	8	6	Discrete	2 or 3
S8	4	9	4	Continuous	NA
S9	2	13	2	Continuous	NA

4.4.1.3.2 TME Easy Scenario

This scenario consisted of six subsystems in the same positions as in the practice scenario, (Figure 4.2). The parameters for this scenario are presented in Table 4.3. This scenario was the same as the practice scenario except that it was ten minutes long. The maximum score possible for the scenario was 33. Subsystem S7 was discrete.

4.4.1.3.3 TME Difficult Scenario

This scenario consisted of eight subsystems in the positions shown in Figure 4.3. The parameters for this scenario are presented in Table 4.4. This scenario was also ten minutes long. The maximum possible score was 37. Subsystem S7 was discrete.

Table 4.3 Subsystems' behavior for TME difficult.

Task Number	Deterioration Rate	Correction Rate	Task Importance	Behavior	Number of Steps
S0	2	9	6	Continuous	NA
S1	1	5	5	Continuous	NA
S2	3	8	10	Continuous	NA
S3	3	9	1	Continuous	NA
S7	3	8	6	Discrete	2 or 3
S8	4	9	4	Continuous	NA
S9	2	13	2	Continuous	NA
S10	1	6	3	Continuous	NA

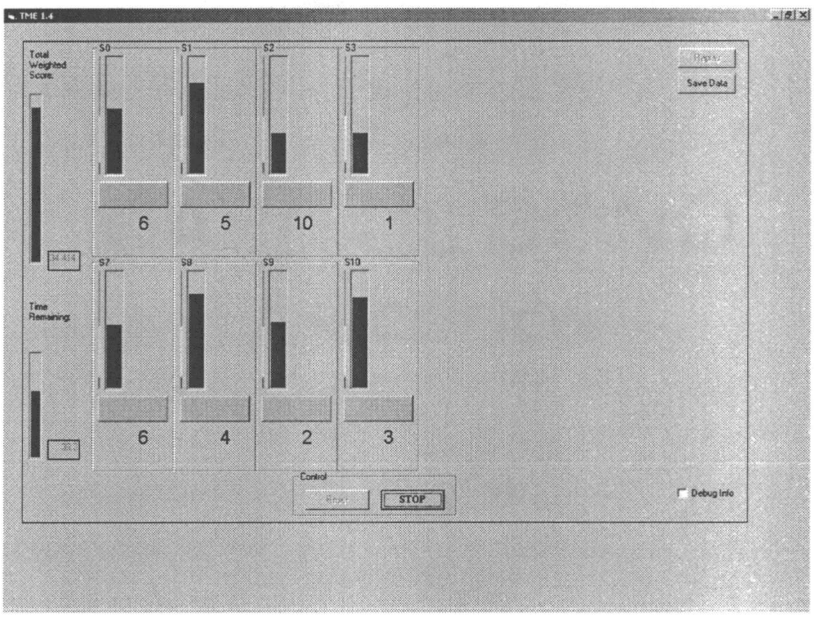

Figure 4.2 Subsystems' positions for TME difficult.

4.4.2 The Measures

The measures that were taken from this experiment can be classified into two groups, independent measures and dependant measures. Independent measures are associated with each of the independent variables, and the dependent measures are associated with the dependant variables.

4.4.2.1 Independent Measures

The performance measures for the independent variables are the measures taken from the psychological tests, reaction time, card sorting, path finding, and index of verbal IQ; and the measures taken from the questionnaires, computer experience, personal information, and decision-making (buck-passing, procrastination, vigilance, and hyper-vigilance).

4.4.2.1.1 Reaction Time Measures

From the three blocks of twenty-five trials of the reaction time test, an average of simple reaction time was calculated. Reaction Time (RT) is defined as the elapse time (in milliseconds) between the presentation of the visual stimulus on the center of the computer screen, and the hit of the specific key in the keyboard by the participant.

4.4.2.1.2 Card Sorting Measures

The card sorting tests consisted of one practice block of 53 trials and three experimental blocks of 53 trials. All blocks were identical; each was comprised of a combination of trials showing cards with one, five, or nine letters. On each card a letter A or a B was presented. In the trials with five and nine letters, the remaining letters (different then A or B) were distractions. The measures from these tests were three different Card Sorting (CS) time numbers, each representing the mean CS time for the different kinds of trial (1 letter trials, 5 letter trials, and 9 letter trials). CS time was defined as the elapsed time (in milliseconds) between the presentation of the stimulus (each card) in the center of the computer screen, and the pressing of the corresponding correct key by the participant. Incorrect hits were not included in the calculations.

4.4.2.1.3 Path Finding Measures

The Path Finding test presented the participant with four different conditions, the first condition was a tracking test in which the target appeared on the computer screen in different random positions. The second condition was comprised of three different sequences; a sequence of numbers (1, 2, 3, and so on), a sequence of letters (A, B, C, and so on), and a combined sequence of numbers and letters (1, A, 2, B, and so on). The third condition had a sequence of three numbers (1, 9, 18, 2, 10, 19 and so on), and a sequence of three letters. Finally, the fourth condition had three different sequences comprised of four items each; a sequence of numbers (1, 7, 14, 20, 2 and so on), a sequence of letters (A, G, N, T, B, and so on), and a combined sequence of numbers and letters (1, A, 7, G, 2 and so on). Each of the different sequences was presented twice to the participant.

For each of the different sequences an average of the time required to complete the sequence was calculated between the two repetitions. This time was called the Path Finding time (PF).

4.4.2.1.4 Vocabulary Test Measure

The Vocabulary Test (VT) presented to the participant a word in capital letters, followed by four potential synonyms from which just one was a correct choice. The scored resulting from this test was an average proportion of correct responses, ranging from 0 to 1.

4.4.2.1.5 Buck-Passing, Vigilance, Procrastination, and Hyper-Vigilance Measures

Each of these measures is an average of the chosen values for each of the questions that correspond to each of the categories (BP, VI, PR, and HV) on the Decision Making Questionnaire. The possible scores range from 1 to 5. A higher score value represents a higher presence of that characteristic in the participant.

4.4.2.1.6 Computer Experience Measure

The computer experience (PC) score is a compound score. It is formed by the multiplication of the "frequency using computers" in hours per week, and the category number of the number of years using computers. This information was compiled from questions one and three on the computer experience questionnaire.

4.4.2.1.7 Age, Sex, Education Level, and Education Years Measures

This information was obtained verbally from the participant at the beginning of the session. Age (AG) is presented in years; sex (SX) is a Boolean variable (m=male, f=female). Education level (EL) was recorded as a category (1 to 5): 1 represents High-school level, 2 represents bachelors level, 3 represents Masters level, 4 Medical doctor level, and 5 represents Ph.D. level. Finally, number of education years was the amount of time spent by the participant in formal education.

4.4.2.2 Dependant Measures

The performance measures for the dependant variables were the measures taken from the TME scenarios. The TME records three types of files per scenario; one file is a text document that displays all the information concerning the scenario, and can be opened with any word processor or spreadsheet (Appendix 7). The other two files are data files compatible with SPSS or other statistical packages. One file has extension .TM1; this file records the characteristics of each subsystem, for example, subsystem number, correction and deterioration rates, behavior, and information about the subject, test time and date, scenario length, and total weighted score (see appendix 7). The last file has extension .TM2; this file records all the raw data from each subsystem. The raw data consists of subject ID, test time, time increments and the corresponding status of the subsystem, as well as the number of the subsystem that was attended in that specific time increment (see appendix 7).

For the TME easy and difficult scenarios, three different measures of performance were computed, the Task Management Error Time (TMET), the Raw

Total Weighted Score (RTWS), and the Total Weighted Score (TWS) which was the score presented to the participant while running each scenario. For the practice trials, only the total weighted score was computed.

Data files recorded by TME were processed to SPSS compatible files by a Python program. Appendix 8 shows the program.

4.4.2.2.1 Task Management Error Time (TMET)

The concept of a Task Management Error is defined in the literature (Funk, 1991) as "attending to a lower priority task when a higher priority task is in a critical state". This concept was expanded for this study to the task management error time as "the amount of time that a lower priority subsystem (in terms of importance) is being attended when a higher importance subsystem is in a critical state". This score was calculated from the raw data file with extension .TM2 by means of a computer program developed in the Python programming language. Appendix 8 shows the program's code. The program checks the value of each bar in every instance of time in order to determine in what region the bar is. Each bar in the TME is divided in 1000 intervals, if the bar lies between 1000 to 500 the bar is in the green area (satisfactory status), between 499 to 100 the bar is in the yellow area (unsatisfactory status), and between 99 to 0 the bar is in the red area (unacceptable status). If a bar is under 500 the program assigns a value of 1 to that task in that particular time instance, this value means that the subsystem should be attended to because it is in the unsatisfactory or unacceptable zones. If a bar is over 500 the program assigns a value of 0 to the subsystem in that particular instance of time, zero value means that the subsystem does not need to be attended since it is in the satisfactory range. For every time instance, this value (1 or 0) is multiplied by the variable i (importance of the subsystem) represented by the number underneath each bar. The program compares the results for each subsystem and the subsystem with the higher product is the subsystem that should be attended to in that particular instance of time. Then, the program checks if indeed that subsystem was attended. If the subsystem was not attended, the program marks that time instance as an error. Finally, the program adds up all the time instances marked as errors and calculates the proportion of TMET over the total time that the scenario ran for. In the case of discrete tasks an error is marked only if the subsystem is in the unsatisfactory or unacceptable zones and the button for that subsystem is active.

4.4.2.2.2 Raw Total Weighted Score (RTAS)

This number was calculated from the raw data file .TM2. A different Python program was developed for this purpose (see Appendix 8). The program calculates the instantaneous score for a subsystem at every time instance by multiplying the raw position of the bar, x, (0 to 1000) times the importance, i, of the subsystem. The product is xi. The cumulative raw score for the subsystem is the mean instantaneous score since the beginning of the run. The raw total weighted score is the summation of all subsystems' cumulative scores. This measure was introduced to capture participants' ability to prioritize tasks based on their importance (i) value.

4.4.2.2.3 Total Weighted Score (TWS)

The total weighted score is the same score that was presented to the participant, as was previously described. The instantaneous score for a subsystem at any time is qi. The variable q is a qualitative transform of the subsystem's current status level; q = +1 if the subsystem's status is satisfactory, q = 0 if its status is unsatisfactory, and q = -1 if its status is unacceptable. The variable i is the subsystem's importance, the number appearing directly below the subsystem's status bar in the interface. The cumulative score for the subsystem is the mean instantaneous score since the beginning of the run. The total weighted score (TWS) is the summation of all subsystems' cumulative scores and reflects an overall task management performance measure, weighted according to subsystem importance.

4.4.3 Testing Procedure

Participants were tested individually, each in a single session lasting approximately 2 hours, in one of two rooms located in Moreland Hall and Covell Hall at Oregon State University. After signing the informed consent form, subjects completed the battery of psychological tests, filled out the two questionnaires, and performed 7 runs on the TME. The order of presentation of the tests was as follows: computer experience questionnaire, simple reaction time test, card sorting test, path finding test, 5 TME practice scenarios, decision making questionnaire, first TME scenario, vocabulary test, and second TME scenario. Half of the participants ran TME easy as the first scenario and TME difficult as the second scenario. The other half of the participants ran the TME difficult as the first scenario and the TME easy as the second scenario. Appendix 9 shows the detailed testing protocol and the consent form.

4.5 Data Analysis Procedure

The second objective of this study was to investigate if basic cognitive abilities (see table 4.1) drawn directly from stages in the augmented stage model (Figure 2.6) can explain CTM performance scores in the TME. In order to accomplish the objective a correlation analysis was performed between the cognitive measures and performance scores in the TME easy and difficult scenarios. A widely used statistical software package called SPSS was used for the analysis. SPSS allows the user to create syntax files to perform transformations and analysis on the data. A syntax file was created for the analysis of data in this experiment. The SPSS syntax file caused SPSS to calculate the scores from the raw data files for each of the tests, both cognitive tests and TME scenarios. It also normalized the scores for each test score, performed tests of normality, performed treatment for outliers, calculated descriptive statistics and frequency distributions, created plots, and finally it performed parametric correlation analysis and multiple regression. Appendix 10 shows the SPSS syntax files.

4.5.1 Data Normalization

Normalization is a technique used "to adjust a series of values using a transformation function in order to make them comparable to some specific point of reference. Data normalization is required when there is an incompatibility of the measurement units across variables that might affect the result of operation between the variables." (statsoft.com) For example, when a measurement of time is expressed in minutes and another in seconds, and operations between the two are going to be performed, normalization is needed. Data normalization is also important to represent results from two or more variables in meaningful and compatible units.

In this study, data normalization was necessary because performance scores in the TME scenarios and in the vocabulary test had different scales; by normalizing these scores they were brought to one single scale ranging from 0 to 100. Scores in the simple reaction time test, card sorting test, path finding test, and decision-making questionnaire did not need normalization. Time scores in the simple reaction time test, card sorting test and path finding were presented in milliseconds. Scores in the decision-making questionnaire were presented in a 5-point scale.

Vocabulary test scores were normalized from a [0, 84] scale to a [0, 1] scale. Scores in the TME easy and practice scenarios were transformed from a [0, 33] scale to a [0, 1] scale. Finally, TME difficult scenario scores were transformed from a [0, 37] scale to a [0, 1] scale.

4.5.2 Tests of Normality

A common application for distribution fitting procedures is to verify the assumption of normality before using parametric tests. Varieties of procedures for testing normality are available including the Kolmogorov-Smirnov test for normality, the Shapiro-Wilks' W test, and the Lilliefors test. "Additionally, probability plots and normal probability plots to assess whether the data are accurately modeled by a normal distribution can be reviewed."(statsoft.com)

In this experiment the Shapiro-Wilks' W, and the Kolmogorov-Smirnov tests for normality were performed for each distribution. The null hypothesis for these tests was that the scores in each individual test follow a normal distribution.

4.5.3 Descriptive Statistics

Descriptive statistics computed were univariate statistics, including mean, standard deviation, minimum, and maximum for all the measures, and confidence intervals for the mean of each measure.

4.5.4 Frequency Distributions

Frequency distribution tables were computed for each of the measures. Extreme values, under which 10%, 25%, 33%, 66% and 75% of the participants fell, were computed.

4.5.5 Plots

Histogram plots were generated to investigate frequency distributions for the measures. Other types of graphics were generated for analysis and comparison between measures.

4.5.6 Parametric Correlation

The Pearson product-moment correlations were calculated with their respective levels of significance for each pair of variables. See section 4.4.1.1

4.5.7 Multiple Regression

A multiple regression model was introduced to explore what combination of independent variables would best predict the dependant variable. The forward method for adding independent variables into the model was used. Residual analysis was also performed.

4.5.8 TME Practice Trials Analysis

The average performance score for each of the five practice trials was calculated for all the participants, resulting in five average scores, one per trial. The following tests were performed over these scores.

4.5.8.1 Learning Curve

To test if the average performance scores per trial followed an ideal learning curve in which final scores reached the asymptotic mode, the average scores were plotted by presentation order (see results chapter). A t-test was performed between the last two consecutive practice trials in order to verify if learning reached a stable state. If no significant difference between them exists, it can be inferred that learning reached a plateau and no significant learning should occur after that point.

4.5.8.2 Correlation among Trials

The Pearson product-moment correlations were calculated between the different consecutive practice trials, in order to test for a learning effect from trial to trial. Small correlations between the trials would imply no learning effect.

4.5.9 Gender Difference Analysis

Data analysis by gender was performed in order to test for possible differences in performance in the TME between males and females. The data was split according to gender for these purposes. T-tests were performed to compare mean TME performance between males and females.

4.5.10 Presentation Order in TME Analysis

Half of the participants ran the TME easy scenario first and the difficult scenario second. The other half ran the scenarios in reverse order. The data set was split based on this criterion to explore the effect that scenario presentation order might have had over the correlational analysis. The initial hypothesis was that scenario order would not have an effect on the results.

5 RESULTS AND ANALYSES

5.1 Overview of Results and Analyses

This chapter presents the results of the analyses described in the last part of chapter 4. It contains descriptive statistics, normality tests, outlier treatment, and summaries of the data gathered from the personal information questionnaire, computer experience questionnaire, simple reaction time test, card sorting test, path finding test, vocabulary test, and TME scenarios.

5.2 Results

The following are the results and analyses performed on the different tests. Because of the individual nature of each test, some operations may or may not apply to a specific test.

5.2.1 Demographics

Ninety-four Oregon State University students were tested in this study. All the participants were healthy adults from 18 to 51 years of age that participated to receive extra credit in certain classes in the Psychology, and in the Industrial and Manufacturing Engineering departments. The average age was 21.48 years with standard deviation of 5.91, and the average number of education years was 15.13 with standard deviation of 2.19. Sixty participants were female and thirty-four were male.

Table 5.1 presents descriptive statistics for the participants' demographics, including education level, number of years of education, and age distributions sorted by gender.

Table 5.1 Participants' Characteristics by Gender

Group	n[a]	M(SD)	Range min(max)
Men	34		
Age (years)		22.6(5.80)	18(49)
Education (years)		16.15(2.28)	13(22)
Level			
Highschool	25		
BS/BA	8		
Masters	1		
Ph.D	0		
Women	60		
Age (years)		20.85(5.93)	18(51)
Education (years)		14.55(1.93)	12(20)
Level			
Highschool	53		
BS/BA	5		
Masters	2		
Ph.D	0		

[a] Number of observations

5.2.2 Computer Experience Questionnaire

The purpose of the computer experience questionnaire was to get information about participants' experience using computers, comfort level, and computer knowledge. Information from this questionnaire was used to determine if experience in operating computers was a significant factor in performance on the computer-based tests.

The first question recorded the amount of time participants have been using computers. The results showed that 11 participants had been using computers for a period of 1 to 3 years, 30 participants for a period of 4 to 6 years, and 53 participants for a period of 7 or more years.

The second question recorded the different places that participants usually used computers, for example home, work, school, public places, or other. For purposes of analysis, each place counts as one point towards a total number of the different places that participants might use computers. Table 5.2 shows the number of participants that use computers in 1, 2, and so on number of places.

Table 5.2 Number of different places that participants use computers at.

Number of Places	Number of Participants
1	10
2	31
3	37
4	14
5	2

The third question recorded the amount of time that participants used computers per week. The mean time that participants used computers per week was 14.0 hours with standard deviation of 9.44 hours. The range of computer use per week was from 1 to 40 hours.

The fourth question recorded specific unusual difficulties that each participant might have using computers. This question was used for analysis of outliers with respect to scores on the computer-based tests. The results showed that no participant presented an impediment in using computers to the level of interfering with performance on the other computer tests.

The fifth question recorded the number of different applications that participants gave to computers, for example participants may have used computers for education, work or business, typing documents, accessing email, internet search, accounting, finances, or other. Each different kind of application that participants used computers for counts as one point towards a total number of applications for computers. Table 5.3 presents the number of participants that used computers for 1, 2 and so on different number of applications.

Table 5.3 Number of different uses of computers per number of participants.

Number of Different Use for Computers	Number of Participants
1	2
2	7
3	7
4	33
5	33
6	8
7	3
8	1

Question six recorded the computer comfort level that participants feel when using computers. Comfort level was measured using a five point scale where 1 represented very comfortable and 5 very uncomfortable. Table 5.4 presents the results.

Table 5.4 Participants' comfort level using computers

Confort Level	Number of Participants
Very comfortable	40
Somewhat comfortable	45
Neither comfortable nor uncomfortable	8
Somewhat uncomfortable	1
Very uncomfortable	0

Question seven recorded the satisfaction level of the participants with their computer skills. Satisfaction level was measured with a five point scale where 1 represented very satisfied and 5 very unsatisfied. Table 5.5 presents the results.

Table 5.5 Participants' computer skill satisfaction level.

Satisfaction Level	Number of Participants
Very satisfied	11
Somewhat satisfied	65
Neither satisfied not unsatisfied	15
Somewhat unsatisfied	3
Very unsatisfied	0

Questions eight, nine and eleven (see appendix 4) were not tallied in this study because they provided little information.

Question ten measured if participants play video games. Sixty-four (68%) participants play video games, and 34 (32%) participants do not play video games.

Question twelve measured if participants drive automobiles. Eighty (85%) participants drive and 14 (15%) participant do not drive. Eighty-eight (93.6%) participants have been driving less than 9 years. The average of years that participants have been driving is 5.5. This was measured by question 13.

5.2.3 Normality Test

The Kolmogorov-Smirnov, the Shapiro-Wilks' W, and the Lilliefors test for normality were performed for all the variables. If the W statistic in the case of the Shapiro-Wilks's W test and the D statistic for the Kolmogorov-Smirnov test are significant, then the hypothesis that the respective distribution is normal should be rejected. A statistic is said to be significant when its value is equal to or smaller than the significance level. Table 5.6 presents the values for the W and D statistics with their respective significance levels for each of the variables.

Table 5.6 Normality Test Results

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Variables	Statistic D	df	Sig.	Statistic W	df	Sig.
Buck-pasing	0.11	88	0.02	0.98	88	0.11
Vigilance	0.10	88	0.05	0.97	88	0.03
Procastination	0.15	88	0.00	0.94	88	0.00
Hyper-vigilance	0.10	88	0.04	0.98	88	0.22
Vocabulary (%)	0.08	88	0.20*	0.99	88	0.44
SRT (s)	0.11	88	0.01	0.96	88	0.01
CRT (s)	0.12	88	0.00	0.95	88	0.00
PF No Sequence (s)	0.10	88	0.02	0.92	88	0.00
PF 1 Number Sequence (s)	0.08	88	0.20*	0.97	88	0.02
PF 1 Letter Sequence (s)	0.08	88	0.18	0.95	88	0.00
PF 2 Numbers Sequence (s)	0.10	88	0.03	0.91	88	0.00
PF 2 Letters Sequence (s)	0.11	88	0.01	0.95	88	0.00
PF 2 Number & Letter Sequence (s)	0.09	88	0.06	0.96	88	0.01
PF 3 Number Sequence (s)	0.13	88	0.00	0.88	88	0.00
PF 3 Letter Sequence (s)	0.12	88	0.00	0.92	88	0.00
PF 4 Number Sequence (s)	0.11	88	0.02	0.94	88	0.00
PF 4 Letter Sequence (s)	0.12	88	0.00	0.94	88	0.00
PF 4 Number & Letter Sequence (s)	0.12	88	0.00	0.90	88	0.00
TME-Easy RTWS (%)	0.11	88	0.02	0.96	88	0.01
TME-Easy TWS (%)	0.15	88	0.00	0.88	88	0.00
TME-Easy TMET (%)	0.09	88	0.07	0.93	88	0.00
TME-Difficult RTWS (%)	0.08	88	0.19	0.98	88	0.31
TME-Difficult TWS (%)	0.12	88	0.00	0.93	88	0.00
TME-Diffiecult TMET (%)	0.13	88	0.00	0.95	88	0.00

* This is the lower bound of the true significance

[a] Lilliefors Significance Correlation

Table 5.6 shows that all the variables passed the normality tests. For most of the variables, statistics W and D showed to be bigger than the significance level, not allowing the rejection of the null hypothesis (Ho: Variables = normally distributed). For those other variables (vocabulary test, TME-Difficult RTAS score, PF 1 Number Sequence and PF 1 Letter Sequence test) in which the statistics were not bigger than the significance level, the significance level did not provide confidence over 80% to reject the null hypothesis.

5.2.4 Outlier Treatment

Treatment for outliers was performed over the total set of data after normality tests were performed, and before any other analysis was done. Outliers were transformed to the nearest real value inside the mean plus/minus two interquartile ranges. Table 5.7 presents a list of the variables that presented outliers, shows the extreme valid value inside the allowed range to which outliers were transformed to, and the number of outliers present in each variable.

Table 5.7 Outliers values for each of the variables.

Variables	Extreme Values	Number
Vocabulary (%)	NA	0
SRT (s)	0.301	2
CRT (s)	0.771	4
PF No Sequence (s)	22.503	6
PF 1 Number Sequence (s)	43.141	1
PF 1 Letter Sequence (s)	48.646	3
PF 2 Numbers Sequence (s)	67.754	3
PF 2 Letters Sequence (s)	107.216	2
PF 2 Number & Letter Sequence (s)	73.093	2
PF 3 Number Sequence (s)	93.660	6
PF 3 Letter Sequence (s)	189.944	1
PF 4 Number Sequence (s)	124.676	3
PF 4 Letter Sequence (s)	186.866	3
PF 4 Number & Letter Sequence (s)	141.240	3
TME-Easy RTWS (%)	41.886	5
TME-Easy TWS (%)	18.490	3
TME-Easy TMET (%)	85.036	2
TME-Difficult RTWS (%)	29.920	1
TME-Difficult TWS (%)	NA	0
TME-Diffiecult TMET (%)	NA	0

5.2.5 Descriptive Statistics

Table 5.8 presents descriptive statistics for all the variables after treatment of outliers. The statistics include: mean (M), standard deviation (SD), standard error of the mean (Std.E), minimum value (min), maximum value (max), and number of cases for each variable. Some variables may have a smaller number of cases due to missing data.

Table 5.8 Descriptive statistics for all the variables.

Variables	n	M	Std.E	SD	min	max
Buck-pasing	94	2.51	0.08	0.75	1.00	4.17
Vigilance	94	4.12	0.05	0.47	2.67	5.00
Procastination	94	2.41	0.07	0.70	1.00	4.80
Hyper-vigilance	94	2.84	0.06	0.63	1.40	4.20
Vocabulary (%)	94	60.11	1.29	12.55	27.38	86.90
SRT (s)	94	0.254	0.002	0.021	0.206	0.315
CRT (s)	94	0.636	0.008	0.073	0.490	0.906
PF No Sequence (s)	93	19.040	0.177	1.709	15.551	22.503
PF 1 Number Sequence (s)	93	30.565	0.543	5.241	20.682	43.141
PF 1 Letter Sequence (s)	93	32.151	0.677	6.531	20.269	48.646
PF 2 Numbers Sequence (s)	93	44.528	0.950	9.164	27.316	67.754
PF 2 Letters Sequence (s)	93	67.695	1.722	16.610	37.334	107.216
PF 2 Number & Letter Sequence (s)	93	46.897	1.046	10.089	27.058	73.093
PF 3 Number Sequence (s)	93	61.372	1.608	15.505	31.634	93.660
PF 3 Letter Sequence (s)	93	93.890	3.047	29.384	43.401	189.944
PF 4 Number Sequence (s)	93	77.956	2.275	21.936	39.260	124.676
PF 4 Letter Sequence (s)	92	108.738	3.230	30.979	53.890	186.866
PF 4 Number & Letter Sequence (s)	92	81.100	2.570	24.654	37.839	141.240
TME-Easy RTWS (%)	90	60.86	1.07	10.20	29.96	81.88
TME-Easy TWS (%)	90	64.47	2.11	19.98	7.44	89.58
TME-Easy TMET (%)	90	63.10	0.89	8.45	47.96	85.04
TME-Difficult RTWS (%)	93	55.65	1.24	11.98	25.53	80.43
TME-Difficult TWS (%)	93	52.57	2.40	23.18	2.79	86.73
TME-Difficult TMET (%)	93	73.03	0.97	9.38	51.46	93.28

It is important to notice from table 5.8 that TWS scores in TME easy and difficult scenarios present high variability (SD = 19.98, SD = 23.18) respectively.

5.2.6 Frequency Distributions

Table 5.9 shows the upper limit for the percentile ranges for each of the variables. The percentile ranges that were calculated were 10, 33.3, 66.7 and 75. These values mean that 10%, 33.3%, 66.7% and 75% of the population scored below the calculated value for each of the variables, respectively. For example, 10% of the population scored 42.26% or less on the vocabulary test.

Table 5.9 Frequency distribution for all the variables.

			Percentiles			
Variables	**Valid**	**Missing**	**10**	**25**	**33.3**	**66.7**
Buck-pasing	94	0	1.667	2.000	2.167	2.833
Vigilance	94	0	3.667	3.833	4.000	4.333
Procastination	94	0	1.600	2.000	2.000	2.600
Hyper-vigilance	94	0	2.100	2.400	2.527	3.200
Vocabulary (%)	94	0	42.262	51.190	55.952	65.155
SRT (s)	94	0	0.233	0.241	0.244	0.259
CRT (s)	94	0	0.555	0.590	0.594	0.656
PF No Sequence (s)	93	1	16.702	17.987	18.395	19.598
PF 1 Number Sequence (s)	93	1	24.370	26.663	27.506	32.502
PF 1 Letter Sequence (s)	93	1	24.286	27.738	28.879	34.258
PF 2 Numbers Sequence (s)	93	1	34.555	37.434	38.916	47.190
PF 2 Letters Sequence (s)	93	1	47.439	55.763	57.843	72.331
PF 2 Number & Letter Sequence (s)	93	1	36.802	39.624	41.255	50.531
PF 3 Number Sequence (s)	93	1	44.011	50.612	52.166	66.568
PF 3 Letter Sequence (s)	93	1	61.571	69.316	76.839	105.732
PF 4 Number Sequence (s)	93	1	50.738	59.672	66.919	89.373
PF 4 Letter Sequence (s)	92	2	76.269	84.503	91.529	119.511
PF 4 Number & Letter Sequence (s)	92	2	54.034	62.034	65.106	89.695
TME-Easy RTWS (%)	90	4	45.301	56.841	58.827	65.712
TME-Easy TWS (%)	90	4	29.486	53.464	61.800	75.841
TME-Easy TMET (%)	90	4	53.539	56.741	57.842	66.687
TME-Difficult RTWS (%)	93	1	37.146	48.204	51.925	60.555
TME-Difficult TWS (%)	93	1	11.655	38.689	45.581	67.554
TME-Diffiecult TMET (%)	93	1	62.286	66.097	67.786	76.442

5.2.7 Plots

Histogram plots showing the frequency distribution for scores in each of the tests, including dependant and independent variables, were generated.

5.2.7.1 Histograms

Histograms were generated for each of the tests to graphically represent the frequency distribution of the measures for all the participants. The horizontal axis represents uniform ranges of possible scores for each of the variables, and the vertical axis or height of the bar represents the number of participants that scored within each range. Figure 5.1 presents the histogram plots for the TME-Easy RTWS, and the TME-Easy TWS. Histograms are useful in comparing frequency distributions of scores in different tests, or in similar tests when scores are calculated differently. For example, figure 5.1 shows the scores for the TME easy scenario for different methods of calculating the final score (see chapter 4 for detailed information of calculation scores). In figure 5.1a it becomes easy to identify that 14 participants performed to a 65% (RTWS) performance level and the distribution resembles a symmetrical normal distribution as shown by the curve, and figure 5.1b shows that 16 participants performed to a 75% (TWS) performance level, and that the distribution is skewed negatively as shown by the curve.

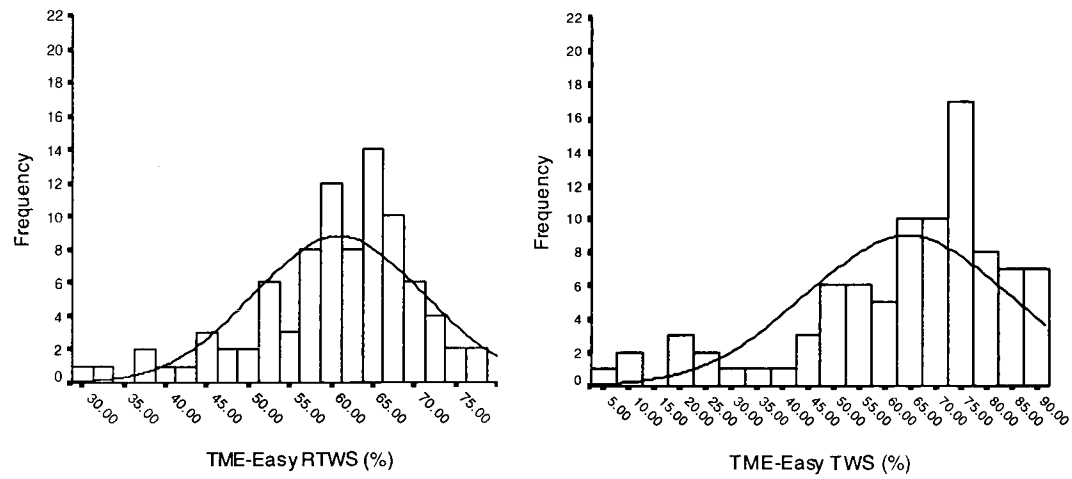

Figure 5.1 a) TME-Easy RTWS histogram. b) TME-Easy TWS Histogram.

For histograms of the rest of the variables refer to Appendix 11.

5.2.8 Parametric Correlations

Table 5.10 presents the correlation coefficients for each combination of variables. Significant correlations to a p value of 0.05 or smaller are bolded.

Table 5.10 Correlation Matrix.

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Age		**0.50**	-0.08	-0.03	0.07	-0.05	**0.32**	0.14	0.14	0.19	0.24	0.17	0.17
2	Years of Education			0.05	0.08	0.17	0.12	0.19	0.10	0.08	0.16	0.25	0.11	0.25
3	Buck-pasing				-0.16	**0.62**	**0.52**	0.09	0.05	0.06	-0.10	-0.03	-0.06	0.02
4	Vigilance					-0.15	-0.03	0.04	0.12	-0.02	0.16	0.12	0.05	0.13
5	Procastination						**0.57**	0.11	-0.02	0.02	-0.10	-0.05	0.01	0.15
6	Hyper-vigilance							-0.02	0.10	0.05	0.01	-0.04	-0.01	0.04
7	Vocabulary								0.02	-0.06	0.05	-0.09	-0.11	-0.15
8	SRT									**0.51**	0.12	**0.31**	**0.41**	**0.30**
9	CRT										0.20	**0.52**	**0.63**	**0.68**
10	PF No Sequence											**0.51**	**0.35**	**0.31**
11	PF 1 Number Sequence												**0.61**	**0.68**
12	PF 1 Letter Sequence													**0.66**

	Variables	14	15	16	17	18	19	20	21	22	23	24	25	26
1	Age	0.06	**0.28**	0.19	0.03	0.11	0.08	0.21	-0.11	-0.09	-0.07	0.00	-0.02	-0.05
2	Years of Education	0.02	0.09	0.22	-0.04	0.12	-0.04	0.04	-0.24	-0.21	-0.03	0.05	-0.08	-0.02
3	Buck-pasing	-0.16	-0.02	0.04	-0.11	0.02	-0.12	-0.03	0.05	0.12	-0.03	0.01	0.00	-0.06
4	Vigilance	0.16	0.05	0.05	0.02	0.15	0.03	0.13	-0.02	-0.04	0.18	0.17	0.04	0.15
5	Procastination	-0.05	0.11	0.08	-0.04	0.06	-0.06	0.06	0.17	0.16	0.10	0.12	0.08	0.05
6	Hyper-vigilance	-0.07	-0.08	0.02	-0.08	-0.13	-0.11	0.02	0.07	0.07	0.01	0.03	0.04	0.08
7	Vocabulary	-0.24	0.03	**-0.30**	-0.20	-0.11	-0.22	-0.16	0.04	0.06	0.08	0.12	-0.06	-0.03
8	SRT	0.25	**0.30**	**0.28**	0.14	0.27	0.23	**0.39**	-0.14	-0.11	-0.17	-0.14	-0.11	-0.12
9	CRT	**0.59**	**0.62**	**0.51**	**0.44**	**0.47**	**0.53**	**0.54**	-0.08	-0.09	-0.12	-0.11	0.09	-0.08
10	PF No Sequence	0.13	0.22	0.11	-0.01	0.14	0.02	0.11	0.09	0.09	0.04	0.05	0.23	0.11
11	PF 1 Number Sequence	**0.53**	**0.55**	**0.33**	**0.37**	**0.37**	**0.35**	**0.39**	0.00	-0.03	-0.02	0.00	0.23	0.05
12	PF 1 Letter Sequence	**0.63**	**0.62**	**0.36**	**0.43**	**0.50**	**0.53**	**0.44**	-0.09	-0.09	-0.15	-0.14	0.03	-0.11
13	PF 2 Numbers Sequence	**0.67**	**0.64**	**0.59**	**0.50**	**0.58**	**0.51**	**0.59**	-0.13	-0.13	-0.04	0.00	0.05	-0.05
14	PF 2 Letters Sequence		**0.72**	**0.52**	**0.69**	**0.46**	**0.69**	**0.64**	-0.12	-0.17	-0.13	-0.12	0.00	-0.12
15	PF 2 Number & Letter Sequence			**0.54**	**0.54**	**0.52**	**0.57**	**0.61**	0.08	0.04	-0.07	-0.05	0.13	-0.12
16	PF 3 Number Sequence				**0.55**	**0.58**	**0.54**	**0.65**	-0.09	-0.07	-0.11	-0.10	0.08	-0.17
17	PF 3 Letter Sequence					**0.49**	**0.68**	**0.58**	0.01	-0.07	-0.05	-0.11	0.04	-0.07
18	PF 4 Number Sequence						**0.50**	**0.54**	-0.26	-0.27	-0.20	-0.22	-0.07	-0.24
19	PF 4 Letter Sequence							**0.67**	-0.04	-0.06	-0.16	-0.17	0.02	-0.15
20	PF 4 Number & Letter Sequence								-0.05	-0.11	-0.06	-0.09	0.02	-0.15
21	TME-Easy RTWS									**0.93**	**0.51**	**0.47**	**0.69**	**0.48**
22	TME-Easy TWS										**0.42**	**0.46**	**0.58**	**0.39**
23	TME-Difficult RTWS											**0.93**	**0.50**	**0.84**
24	TME-Difficult TWS												**0.42**	**0.79**
25	TME-Easy TMET (%)													**0.57**
26	TME-Difficult TMET (%)													

Table 5.10 clearly shows that correlations between the TME measures have no significantly strong correlations with any of the cognitive measures, the personality decision-making test, or with the demographic information. Correlations between the different kinds of sequences in the Path Finding test are significant. These results were expected, given the fact that the scores were calculated by the same test; similar findings can be found in Uttl, Graf and Santacruz's (2000) study. In addition, correlations between the different measures of TME performance between the two different scenarios are significant. The highest correlations shown are between TME RTWS and TWS in each of the scenarios (r = .93); these highly significant correlations were expected since both scores are calculated from the same TME raw data files. Correlations between the RTWS and TWS for each scenario show to be significantly high with the TMET measure of "task management error" (Funk, 1991) introduced in this study. These correlations ranged from 0.57 to 0.84.

5.2.9 Multiple Regression

Stepwise multiple regression analysis was performed over the set of data. Independent variables were the psychological measures, the decision-making questionnaire, and the personal information questionnaire. Dependant variables were the TME scores for the easy and difficult scenarios. The forward stepwise method was used to introduce independent variables to the model, the significance level to introduce variables was 0.05 and the significance level to take variables out of the model was 0.10. Following are the results for the multiple regression models for each of the TME dependant variables.

5.2.9.1 Regression Model for TME-Easy RTWS

From the stepwise multiple regression analysis, four independent variables were found to influence variance in the dependant variable TME-Easy RTWS. Table 5.11 shows the amount of variance that can be explained by the independent variables for each model. A combination of three measures of working memory and number of years of education can contribute up to 47% of variance in CTM performance as computed by the TME-easy RTWS.

Table 5.11 Stepwise regression model for TME-Easy RTWS

	Regression Model for TME-Easy RTWS				
Model	r	r square	adjusted r square	Std.E	Durbin-Watson
1	0.26	0.07	0.06	10.01	
2	0.36	0.13	0.11	9.73	
3	0.42	0.18	0.15	9.53	
4	0.47	0.22	0.19	9.31	1.99

1 Predictors: PF 4 Number Sequence

2 Predictors: PF 4 Number Sequence, PF 2 Number & Letter Seq.

3 Predictors: PF 4 Number Sequence, PF 2 Number & Letter Seq. Years of Education

4 Predictors: PF 4 Number Sequence, PF 2 Number & Letter Seq. Years of Education, PF 2 Letter Seq.

5.2.9.2 Regression Model for TME-Easy TWS

The results of the regression analysis performed over the TME-easy TWS are consistent with the results of the regression analysis for the TME-easy RTWS. The same group of measures of working-memory and years of education predict scores in CTM performance to the same level as the previous regression model (47%).

Table 5.12 Stepwise regression model for TME-Easy TWS

	Regression Model for TME-Easy TWS				
Model	r	r square	adjusted r square	Std.E	Durbin-Watson
1	0.27	0.07	0.06	19.57	
2	0.34	0.12	0.10	19.21	
3	0.42	0.18	0.15	18.66	
4	0.47	0.22	0.18	18.27	2.22

1 Predictors: PF 4 Number Sequence

2 Predictors: PF 4 Number Sequence, PF 2 Number & Letter Seq.

3 Predictors: PF 4 Number Sequence, PF 2 Number & Letter Seq. PF 2 Letter Seq.

4 Predictors: PF 4 Number Sequence, PF 2 Number & Letter Seq. PF 2 Letter Seq, Years of Education.

5.2.9.3 Regression Model for TME-Easy TMET

The stepwise regression model for the "task management error" time (Funk, 1991), showed that 22% of TMET can be predicted by performance in one single measure of working memory as computed from the Path Finding test.

Table 5.13 Stepwise regression model for TME-Easy TMET

	Regression Model for TME-Easy TMET				
Model	r	r square	adjusted r square	Std.E	Durbin-Watson
1	0.22	0.05	0.04	8.34	1.60
1	Predictors: PF 1 Number Sequence				

5.2.9.4 Regression Model for TME-Difficult RTWS

No regression model could be calculated for the 0.05 significance level.

5.2.9.5 Regression Model for TME-Difficult TWS

Table 5.14 shows the results of the stepwise regression model performed over the TME-Difficult RTWS. Working memory performance as measured by one of the Path Finding sequences can predict scores of CTM performance up to 21%.

Table 5.14 Stepwise regression model for the TME-Difficult TWS.

	Regression Model for TME-Difficult TWS				
Model	r	r square	adjusted r square	Std.E	Durbin-Watson
1	0.21	0.05	0.03	22.99	2.29
1	Predictors: PF 4 Number Sequence				

5.2.9.6 Regression Model for TME-Difficult TMET

The same measure of working memory performance, as in the TME-Difficult TWS regression model, predicts CTM performance computed by the TME-Difficult TMET score.

Table 5.15 Stepwise regression model for the TME-Difficult TMET.

	Regression Model for TME-Difficult TMET				
Model	R	r square	adjusted r square	Std.E	Durbin-Watson
1	0.24	0.06	0.05	9.00	2.12
1	Predictors: PF 4 Number Sequence				

5.2.10 TME Practice Trials Analysis

The purpose of analyzing the scores from the practice trial was to make sure participants obtained a significant level of comfort running the TME and learned how to operate the simulator. The practice trial lasted 2 minutes, and for each of the trials the total weighted score (TWS) was calculated. This score was presented to the participants while running the trials. The mean scores and standard deviation for all the participants were calculated per trial. Table 5.16 shows the results.

Table 5.16 Means and standard deviations for TWS in the practice trial.

	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5
M	72.06	82.97	86.14	88.36	89.04
SD	14.47	11.28	9.95	8.65	8.76

5.2.10.1 Learning Curve

The learning curve was generated by plotting the mean performance values for each of the practice trials. Two-standard-deviation bars were plotted for the mean of each trial. Figure 5.2 presents the learning curve and it can be seen that an asymptotic mode was reached in the last two trials.

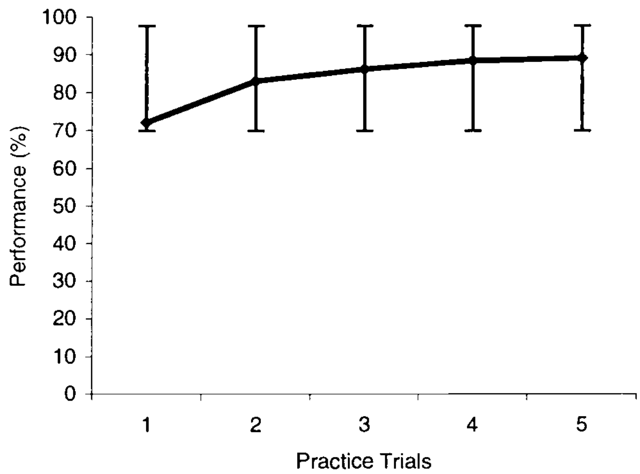

Figure 5.2 Learning curve for the TWS in the practice trial.

5.2.10.2 Correlation among Practice Trials

Table 5.17 presents the Pearson-correlation coefficients for each pair of practice trials. It can be seen that higher correlations appeared in consecutive ascending trials, the correlation between practice trial four and practice trial five being the highest of all.

Table 5.17 Correlation table for the TWS in the practice trials.

	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5
Practice 1		0.581124	0.552821	0.496306	0.461708
Practice 2			0.776267	0.725859	0.664047
Practice 3				0.827739	0.779206
Practice 4					0.865429
Practice 5					

5.2.10.3 T-test: Practice Trial Four and Practice Trial Five

A t-test was performed between the fourth and fifth practice trial to determine if participants learned to operate the TME. No significant difference, with a level p=0.05, was found between practice trial four and five. The t statistic was –1.21 and the two-tail critical t was 1.99. These values did not allow for the rejection of the null (means' difference = 0).

5.2.11 Analysis by Gender

Analysis by gender was performed to identify possible sex differences in CTM performance as computed by the TME. Table 5.18 presents demographic statistics by sex group.

Table 5.18 Demographic information by sex group.

Groups	*n*	*M*	*SD*
TME-Easy TWS			
Male	33	63.24	22.39
Female	57	65.19	18.61
Total	90	64.47	19.98
TME-Diff RTWS			
Male	34	51.89	24.03
Female	59	52.96	22.87
Total	93	52.57	23.18
TME-Easy TWS			
Male	33	60.98	11.57
Female	57	60.78	9.42
Total	90	60.86	10.20
TME-Diff RTWS			
Male	34	55.37	13.15
Female	59	55.82	11.37
Total	93	55.65	11.98
TME-Easy TMET			
Male	33	62.96	9.95
Female	57	63.18	7.54
Total	90	63.10	8.45
TME-Diff TMET			
Male	34	73.42	9.32
Female	59	72.81	9.50
Total	93	73.03	9.38

T-tests were performed to compare mean TME scores between females and males. No significant difference was found (p=.05) for any of the mean scores in any of the TME measures between females and males. Table 5.19 shows the results of the t-tests. Figure 5.3 shows a graphical representation of the mean scores for each of the TME measures, for both each of the sex groups and for the total sample.

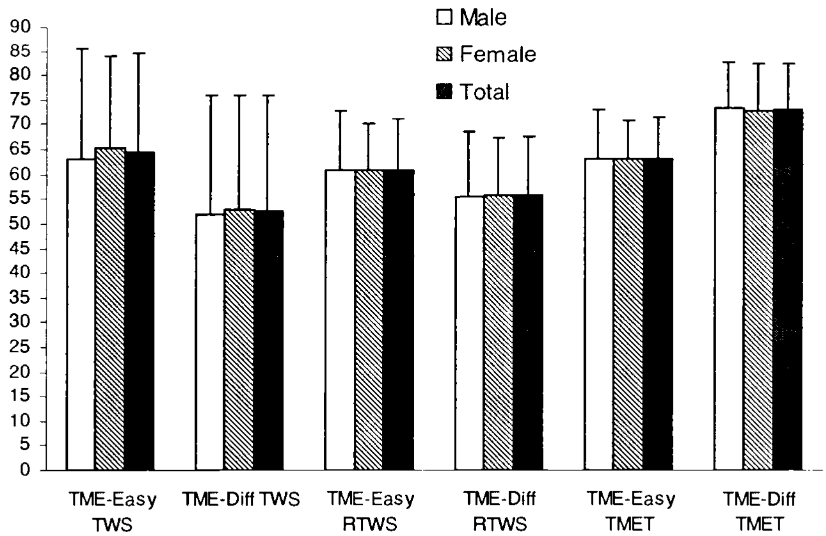

Figure 5.3 TME mean scores for total sample and by sex group.

Table 5.19 T-test results for TME scores between sex groups.

Variance Equality Assumption	*t*	*df*	Sig. (2-tailed)
TME-Easy TWS			
Equal	-0.44	88.00	0.66
Not Equal	-0.42	57.47	0.67
TME-Diff TWS			
Equal	-0.21	91.00	0.83
Not Equal	-0.21	66.19	0.83
TME-Easy RTWS			
Equal	0.09	88.00	0.93
Not Equal	0.08	56.53	0.93
TME-Diff RTWS			
Equal	-0.17	91.00	0.86
Not Equal	-0.17	61.11	0.87
TME-Easy TMET			
Equal	-0.12	88.00	0.91
Not Equal	-0.11	53.44	0.91
TME-Diff TMET			
Equal	0.30	91.00	0.76
Not Equal	0.30	70.07	0.76

5.2.12 TME Performance Analysis by Order

CTM performance, as computed by different TME measures, was analyzed for a possible scenario presentation order. The initial null hypothesis was that scenario presentation order between TME-easy and TME-difficult scenarios did not have an effect over performance measures in these scenarios. After the analysis, the opposite proved to be true. A significant effect on performance measures in TME by the order in which the scenarios were presented to the participants was found. Figure 5.4 shows a graphical representation of the mean scores for each TME measure sorted by scenario presentation order and for the whole sample.

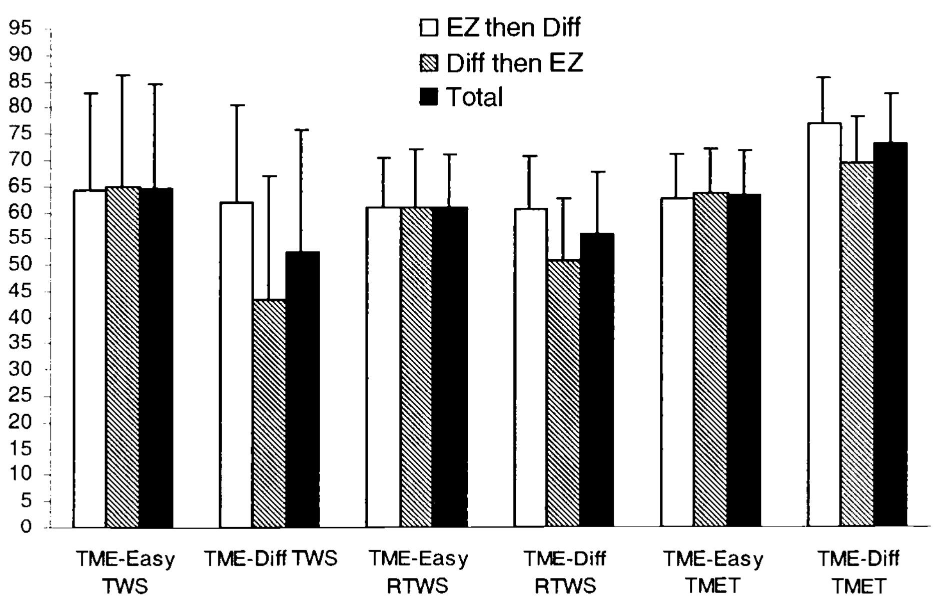

Figure 5.4 Mean TME scores by TME measure and by presentation order.

Table 5.20 shows the results of the t-tests performed over the different TME measures divided by presentation order. Significant differences were found ($p = .05$) on the mean scores for all the measures of TME difficult scenario between participants that ran this scenario first and participants that ran this scenario after the easy scenario. Participants that ran the TME easy scenario first outperformed those that did not.

Table 5.20 T-test results for scenario order effect

Variance Equality Assumption	*t*	*df*	Sig. (2-tailed)
TME-Easy TWS			
Equal	-0.14	88.00	0.89
Not Equal	-0.14	86.21	0.89
TME-Diff TWS			
Equal	4.17	91.00	0.00
Not Equal	4.16	85.50	0.00
TME-Easy RTWS			
Equal	-0.07	88.00	0.95
Not Equal	-0.07	86.29	0.95
TME-Diff RTWS			
Equal	4.22	91.00	0.00
Not Equal	4.21	88.57	0.00
TME-Easy TMET			
Equal	-0.64	88.00	0.52
Not Equal	-0.64	88.00	0.52
TME-Diff TMET			
Equal	4.10	91.00	0.00
Not Equal	4.10	90.98	0.00

6 DISCUSSION

This chapter discusses the meaning and significance of the findings in this study. The main objective of this study was to investigate if simple cognitive ability tests predict performance in CTM. Chapter 2 introduced the Augmented Stage Model of human concurrent information processing which is merely an elaboration of the Stage Model of human information processing originally introduced by Broadbent (1958) and revised by Smith (1968), Stemberg (1969), McClelland (1979) and Wickens (1984). Chapters 4 and 5 addressed the research methodology, and the results and analysis of the tests ran on 94 participants. To achieve the objectives for this study, performance in psychological tests that measure basic cognitive abilities such as reaction time, decision time, working memory performance, verbal intelligence and decision-making strategies were compared with performance in a multi-tasking simulator called the TME. Correlational analysis was performed between the cognitive measures and Concurrent Task Management (CTM) performance in the TME.

Table 6.1 shows a summary of the correlational analysis between the cognitive abilities tested in this study and CTM performance measured on the TME.

Table 6.1 Significant correlations between TME and cognitive abilities.

Variable	Cognitive Ability	Correlation with TME
Decision-Making (BP)	Buck-Passing	Not significant
Decision-Making (V)	Vigilance	Not significant
Decision-Making (P)	Procrastination	Not significant
Decision-Making (HV)	Hyper-vigilance	Not significant
Simple Reaction	Reaction time	Not significant
Card Sorting Time	Decision Time	Not significant
Path Finding Time	Working Memory Time	0.07- 0.22*
Vocabulary Test	Verbal Intelligence	Not significant

* Significant to a p=0.05

6.1 Findings

6.1.1 The Correlations

The findings indicate that basic cognitive abilities (the ones used in this study), except for working memory, do not correlate significantly with CTM performance as calculated by the TME. Working memory correlated with performance on the TME in the best of the cases $r = 0.22$ ($p=0.05$). From the literature review in this study, it was concluded that no previous research has tried to compare CTM performance with cognitive abilities drawn from the stages in the Stage Model, as done in this study. Ruchalla, Schalt, and Vogel, (1985) compared basic cognitive abilities such as simple and complex reaction time with different intelligence measures. They found small correlations between reaction time and performance in intelligence tests. Similar to intelligence, and as demonstrated in the second chapter of this thesis, CTM can be recognized as a complex mental process, for example, a pilot in an aircraft cockpit performs CTM when attending to numerous complex tasks simultaneously. This study found no significant correlations between simple reaction time and CTM performance. This suggests a significant measure of construct validity for the CTM measures recorded by the TME.

In terms of the original question (to what degree can the Augmented Stage Model be validated by actual human CTM performance?), the findings suggest that CTM is a cognitively demanding process that does not depend on fast human response in order to be performed satisfactorily. Instead, operators that take a longer amount of time to decide on the correct response to this complex environment may perform better than those that overreact to the system. This resembles findings from Shakeri's (2003) study in which he found that participants that attended to tasks in the TME in a more strategic manner outperformed those who were more reactive to the system. This conclusion is supported by the negative and non-significant correlations between CTM as measured by the TME and the simple reaction time measures.

The Fitts' Law paradigm can help us understand the non-significant correlation between simple reaction time and CTM. This theory states that a tradeoff exists between speed and accuracy of response, if one responds faster to stimuli, one is more likely to respond incorrectly, and if one concentrates on responding always correctly, one will take longer to respond. As discussed and concluded earlier, CTM is a complex mental process. Based on this conclusion it can be extrapolated that speed of reaction is not a significant factor when dealing with complex cognitive processes, as also found by Ruchalla, Schalt, and Vogel (1985) when they compared reaction time to intelligence measures. In this sense, the Augmented Stage Model does underline some of the basic mechanisms of complex cognitive human information processing. As explained by Welford (1976), "all skills involve all the major cognitive mechanisms, but different types of activities emphasize different processes". In the same way, CTM can involve all the major cognitive abilities, such as the ones used in this study, but CTM emphasizes different processes, like working memory. From the correlation analysis, CTM performance as measured by the TME correlates significantly with working memory performance, which is a central stage in the Stage Model.

Ruchalla et al., (1985) found that simple reaction and complex reaction time influence working memory performance. However, they found that simple or complex reaction time does not correlate significantly with complex cognitive processes such as intelligence. Similarly, this study found that performance in the path finding test, which records working memory performance, can be a significant predictor of CTM performance in the TME, and since working memory correlates with reaction time, as demonstrated by Ruchalla et al., simple reaction time could also influence performance in CTM, but perhaps to a lower degree. This could not be proved in this study, however, several correlations between simple reaction time and working memory were found to be significant, 0.30, 0.28, and 0.39 ($p=0.01$). Correlations between complex reaction time as measured by the card sorting tests were found to correlate significantly with all the measures of working memory as measured by the path finding test (see Table 5.10).

6.1.2 The Regression Model

The findings from the regression model suggest that different measures of working memory duration predict at best 21% to 47% of the variation in CTM performance. The highest prediction power of 47% was between the TME easy scenario and a combination of three different measures of working memory performance and number of education years (see tables 5.11 and 5.12). One measure of working memory (in the most difficult sequence, see tables 5.14 and 5.15) was found to be a significant predictor of CTM performance to maximum level of 21%, as measured in the TME-Difficult scenario. These differences in prediction power between the TME-Easy and TME-Difficult scenarios could have occurred because the TME easy scenario was similar to the practice scenario with the only difference being that it was 10 minutes long as opposed to the 2-minute practice trials. This suggests that participants might have had the chance to learn the quantitative dynamics of each subsystem, letting their cognitive abilities be a stronger determinant of their performance in this particular scenario. No significant difference in TME-Easy scenario performance was found between the participants that ran this scenario first or second, after the TME-Difficult Scenario.

However, participants that ran the TME-Difficult scenario first performed significantly worse, in this scenario, than those that ran it after running the TME-Easy scenario. This implies that participants that ran TME-Easy first had a chance to learn something else about managing concurrent tasks by running a longer scenario right after the practice trials, allowing them to adjust to the time increase and perform better in the TME-Difficult scenario. Those participants that did not run TME-Easy first did not have the opportunity to learn that additional skill, leaving them with only one alternative, to attend to the tasks in a more reactive manner masking the influence of their cognitive abilities in performance on the TME-

Difficult scenario. In summary, these findings are a significant indicator that learning was still occurring while running the experimental trials.

6.1.3 The Effect of Practice on the Experimental Trials

It is clear from the analysis of the data that those participants that ran the TME-easy scenario first, which was the same as the practice trials except that it was 10 minutes long, obtained higher scores in TME difficult scenario. However, participants that ran TME difficult scenario first did not obtain higher scores in the TME-easy scenario. This suggests that a significant learning effect was still occurring while running the experimental trials. This, in turn implies that every experimental scenario imposed a completely different set of attentional and cognitive demands for the participants, which were not learned or transferred from the practice trial. These findings leads to the hypothesis that CTM performance might be specific to a particular situation, and further, leads to the question if CTM could be trained in a different environment than the one in which it was applied. These questions could not be answered by this research. Adams et al. (1991) formulated similar question in their review: "Is strategic task management specific to each specific complex system?"

6.1.4 Gender Difference in CTM Performance

Findings in this study suggest that there is not a significant difference in performance in CTM between males and females. However, conclusive evidence cannot be claimed from this study. The sample was limited and not necessarily representative of the whole human population.

6.2 Study Limitations

Several limitations have to be considered in interpreting the results from this study. Although, the sample was large (94 participants), the sample is not representative of the human population; most of the participants were young adults, most of them 19 to 21 years old. Other limitations might have come from the assumption that scores in the TME, which were introduced here, are accurate, valid and reliable measures of concurrent task management performance.

Given the time constraints to run the experiment, short practice trials were used to familiarize the participants with the TME, however, the results showed that longer practice trials, similar in length to the experimental trial would have been better suited for this study.

The different sequence in presenting the experimental trial to the participants imposed higher variability to the total mean scores for each of the experimental trials. This contributed to low correlations found between the TME scores and the measures of the basic cognitive abilities used in this experiment. Variability of scores could have been controlled by increasing the sample size.

Several complementary analyses of the data set could have shown other interesting implications and relationships among the different tests. Due to time constraints for the completion of this study and the fact that the main objective of the study was to explore if cognitive abilities drawing from stages in the stage model could explain CTM performance in the TME, this main objective was fulfilled and no other analyses were performed.

6.3 Recommendation for Future Research

Based on the findings and conclusions, and experience gained conducting this study, there are two main recommendations to make. First, correlational studies, especially when not much is known about one of the variables in consideration, need a large sample size to account for possible variability that might result from the experimental design. In this study a larger sample size would have allowed the grouping of data among better performers and worse performers, in which case it could have decreased the variability in the scores and resulted in possibly higher correlations among the variables. Second, practice trials have to be as similar as possible to the experimental trial, especially when the experiment is trying to capture complex cognitive abilities such as CTM. In our study longer practice trials would have enabled the participants to explore different strategies in attending to the tasks in TME, and might have eliminated the learning effect that was occurring while the participants were running the experimental trials.

Further research is needed in the area of task prioritization related to goal structure. The TME presents a valuable tool to investigate the relationships between parameters that affect task prioritization, for example, importance of the tasks, urgency of the tasks, status of the tasks, salience of the task displays, among others, as well as their relationship with the operator's goal structure. Different sets of operators could be instructed to keep different goal structures while running TME and the effect of these structures could be compared to task prioritization behavior, and CTM performance. Salience of the subsystems in TME can be manipulated and the effect of this task characteristic over CTM performance, task prioritization, and goal structure can be studied.

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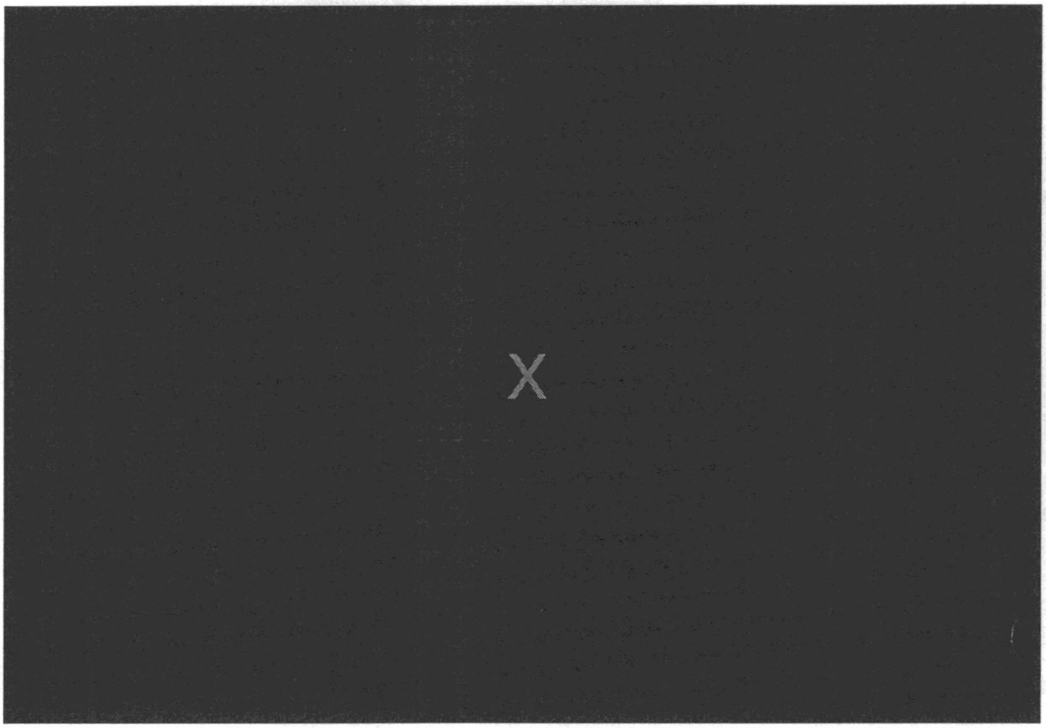
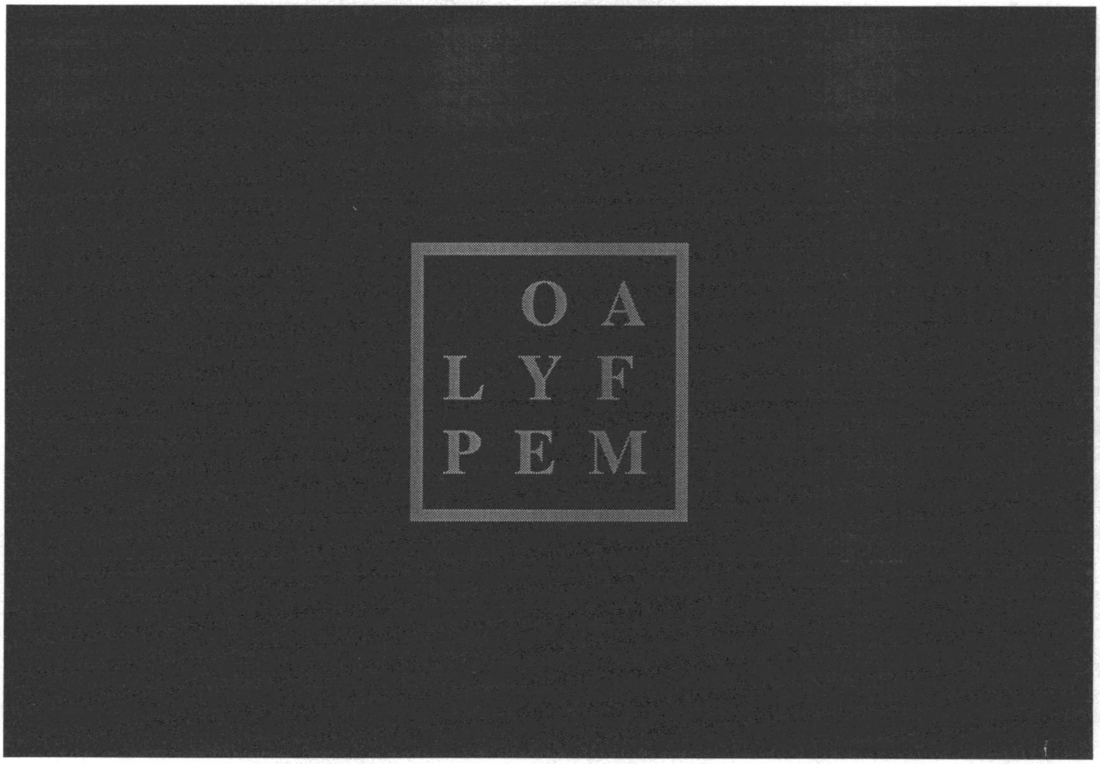
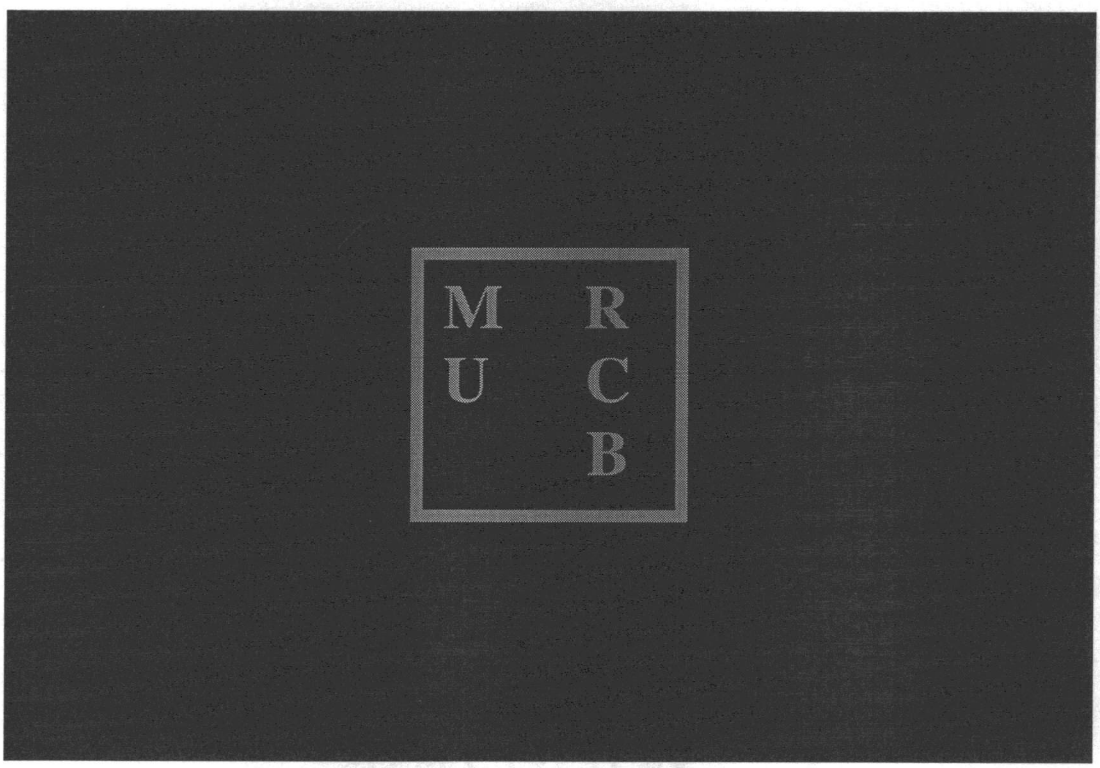
APPENDICES

Appendix 1 – Simple Reaction Time Interface

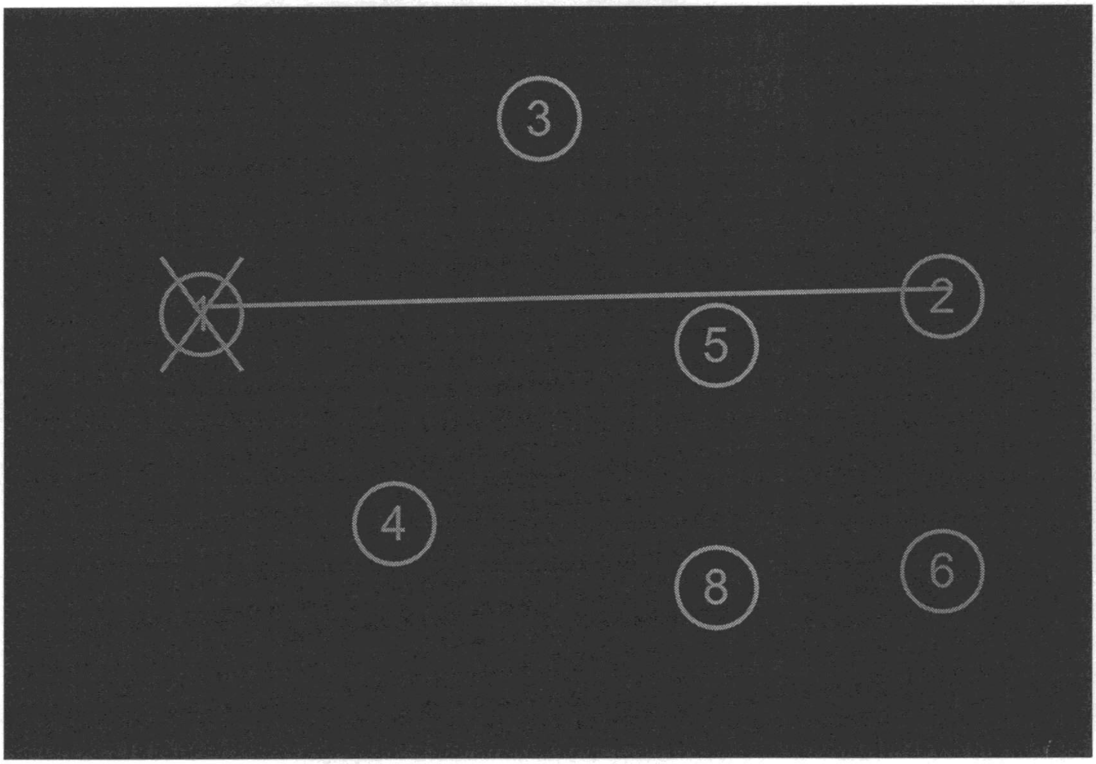


Appendix 2 – Card Sorting Interface


O A
L Y F
P E M


M R
U C
B

Appendix 3 – Path Finding Interface


3
1
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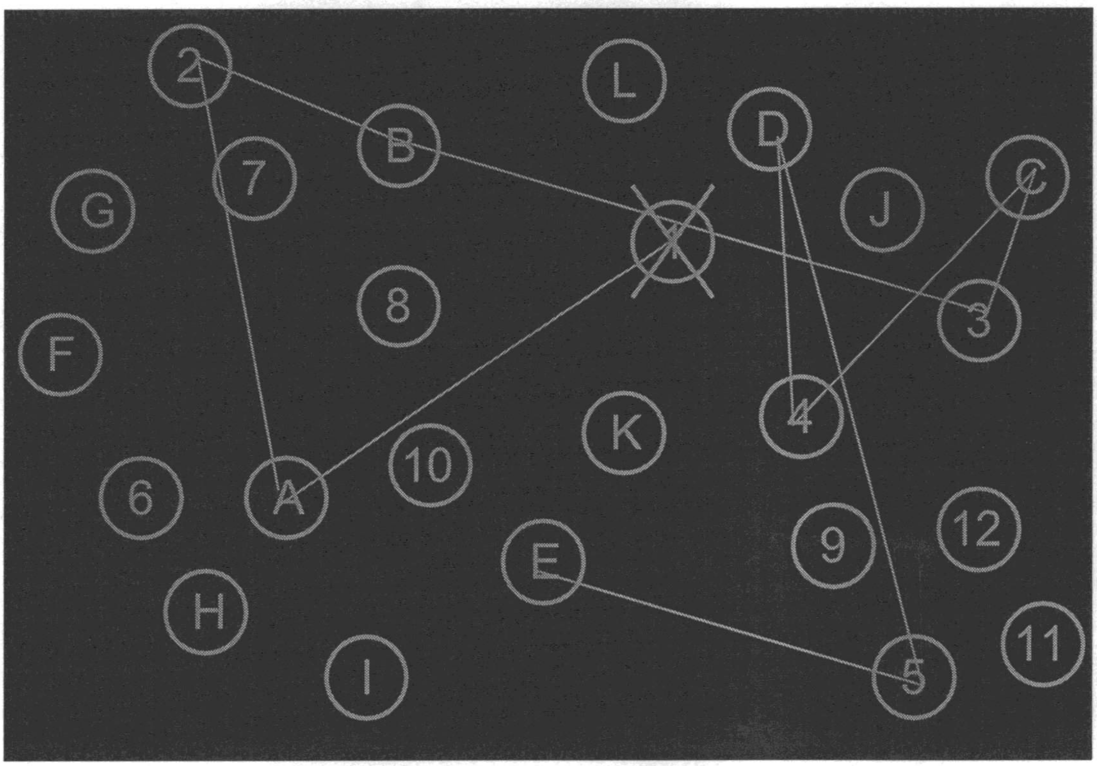
5
4
8
6


2
L
D
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7
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I

Appendix 4 – Computer Experience Questionnaire

Computer Experience Questionnaire

How long have you been using computers?

- Never
- Less than 6 months
- 1 to 3 years
- 4 to 6 years
- 7 years or more

Where do you usually use a computer? (Check all that apply)

- Home
- Work
- School
- Public Terminal (e.g. library, cybercafe, etc.)
- Other places

How many hours per week do you use computers? ____________________

What do you find to be the biggest problems in using computers? Explain:

What do you primarily use the computer for? (Check all that apply)

- Education
- Work/Business
- Typing documents
- Accessing your email
- Searching the Internet
- Accounting
- Finances
- Other _________________

How comfortable do you feel using computers, in general?

- Very comfortable
- Somewhat comfortable
- Neither comfortable nor uncomfortable
- Somewhat uncomfortable
- Very uncomfortable

How satisfied are you with your current skills for using a computer?
- Very satisfied
- Somewhat satisfied
- Neither satisfied nor unsatisfied
- Somewhat unsatisfied
- Very unsatisfied

What is the size of the monitor that you use most often?
- Under 10 inches
- 10-12 inches (most laptops)
- 13 inches
- 14 inches
- 16 to 18 inches
- 19-21 inches
- Over 21 inches
- Other____________________
- Don't know

What type of monitor & graphic do you have?
- Monochrome (e.g. Blank and White)
- Color-8 bit
- Color-16 bit
- Color-24 bit
- Color-but I am not sure of type
- Other____________
- Don't know

Do you play video games? If yes, how many hours per week? __________

What kind of video games do you play? Explain:

Do you drive? If yes, how many hours per week? ______________________

How long have you been driving? How many years? ____________________

Appendix 5 – Decision Making Questionnaire

THE MELBOURNE DECISION MAKING QUESTIONNAIRE

Here are a number of decision-making characteristics that may or may not apply to you. Please circle the response for each statemer that best describes the way you make decisions.

Circle	SD	if you ***strongly disagree*** or if the statement is definitely false.
Circle	D	if you ***disagree*** or if the statement is mostly false.
Circle	N	if you are ***neutral*** on the statement, you cannot decide, or the statement is about equally true or false.
Circle	A	if you ***agree*** or if the statement is mostly true.
Circle	SA	if you ***strongly agree*** or if the statement is definitely true.

Circle only one response for each statement. Please respond to all statements, making sure you circle the correct response.

SD	D	N	A	SA	I do not make decisions unless I really have to.
SD	D	N	A	SA	I consider how best to carry out a decision.
SD	D	N	A	SA	I avoid making decisions.
SD	D	N	A	SA	The possibility that some small thing might go wrong causes me to swing abruptly in my preference.
SD	D	N	A	SA	I like to consider all the alternatives.
SD	D	N	A	SA	After a decision is made, I spend a lot of time convincing myself it was correct.
SD	D	N	A	SA	I prefer to leave decisions to others.
SD	D	N	A	SA	I try to find out the disadvantages of all alternatives.
SD	D	N	A	SA	When I have to make a decision, I wait a long time before starting to think about it.
SD	D	N	A	SA	I delay making decisions until it is too late.
SD	D	N	A	SA	I try to be clear about my objectives before choosing.
SD	D	N	A	SA	I prefer that people who are better informed decide for me
SD	D	N	A	SA	I take a lot of care before choosing.
SD	D	N	A	SA	I cannot think straight if I have to make a decision in a hurry.
SD	D	N	A	SA	I put off making decisions.
SD	D	N	A	SA	I do not like to take responsibility for making decisions.
SD	D	N	A	SA	When making decisions, I like to collect a lot of information.
SD	D	N	A	SA	Whenever I face a difficult decision, I feel pessimistic about finding a good solution.
SD	D	N	A	SA	If a decision can be made by me or another person, I let the other person make it
SD	D	N	A	SA	I feel as if I am under tremendous time pressure when making decisions.
SD	D	N	A	SA	I waste a lot of time on trivial matters before getting to the final decision.
SD	D	N	A	SA	Even after I have made a decision, I delay acting upon it.

*Mann, Leon, et al. (1997). Modified

Appendix 6 – Sign up Sheets

STUDY ON

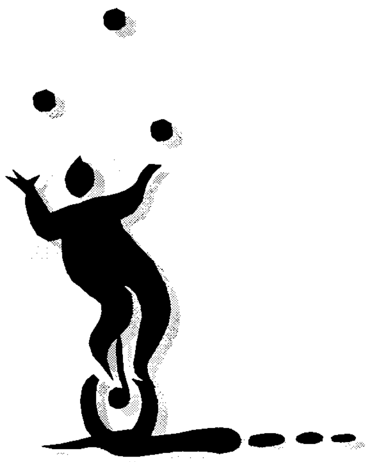
PERFORMING MULTIPLE TASKS SIMULTANEOUSLY

Experimenter: **Javier Nicolalde, Bob Uttl & Ken Funk**
Location: **MORELAND 118**
Phone: **737-1376 OR 737-5240**

You will be asked to complete a battery of cognitive psychological tests including tests of processing speed, decision-making, attention, concentration, and multi-tasking. Participation in this experiment REQUIRES ONE VISIT BETWEEN 90 TO 120 MINUTES LONG. In exchange, YOU WILL RECEIVE 2.0 HR PSYCHOLOGY EXPERIMENT CREDITS provided you complete the session. If you would like to participate, PRINT IN YOUR NAME AND PHONE NUMBER IN ONE OF THE AVAILABLE SLOTS (ONLY ONE PERSON PER SLOT) AND ARRIVE AT MORELAND 118 AT THE SELECTED TIME. If you have any questions regarding the experiment, please call the above phone number. **If you have participated in this experiment already, you are not eligible to participate.**

WEEK FROM JULY 15 TO JULY 19

SIGN-UP TIMES	July 15 MONDAY	July 16 TUESDAY	July 17 WEDNESDAY	July 18 THURSDAY	July 19 FRIDAY
9:00am	Only one person per cell **9:00AM 11:00AM**	Only one person per cell **9:00AM 11:00AM**	Only one person per cell **9:00AM 11:00AM**	Only one person per cell **9:00AM 11:00AM**	Only one person per cell **9:00AM 11:00AM**
9:30am					
10:00am					
10:30am					
11:00am	Only one person per cell **11:00AM 1:00PM**	Only one person per cell **11:00AM 1:00PM**	Only one person per cell **11:00AM 1:00PM**	Only one person per cell **11:00AM 1:00PM**	Only one person per cell **11:00AM 1:00PM**
11:30am					
12:00pm					
12:30pm					
1:00pm			Only one person per cell **1:00PM 3:00PM**	Only one person per cell **1:00PM 3:00PM**	
1:30pm	Only one person per cell **1:30AM 3:30PM**	Only one person per cell **1:30AM 3:30PM**			Only one person per cell **1:30AM 3:30PM**
2:00pm					
2:30pm					
3:00pm			Only one person per cell **3:00PM 5:00PM**	Only one person per cell **3:00PM 5:00PM**	
3:30pm	Only one person per cell **3:30PM 5:30PM**	Only one person per cell **3:30PM 5:30PM**			Only one person per cell **3:30PM 5:30PM**
4:00pm					
4:30pm					
5:00pm					
5:30pm					



A STUDY ON

PERFORMING MULTIPLE TASKS SIMULTANEOUSLY

Experimenter: **Javier Nicolalde, Bob Uttl & Ken Funk**
Location: **Covell Hall 040**
Phone: **737-5240 OR 737-1376**

You will be asked to complete a battery of cognitive psychological tests including tests of processing speed, decision-making, attention, concentration, and multi-tasking. Participation in this experiment REQUIRES ONE VISIT BETWEEN 90 AND 120 MINUTES LONG. If you would like to participate, PRINT YOUR NAME AND PHONE NUMBER IN ONE OF THE AVAILABLE SLOTS (ONLY ONE PERSON PER SLOT) AND ARRIVE AT COVELL 040 AT THE SELECTED TIME. If you have any questions regarding the experiment, please call the above phone number. **If you have participated in this experiment already, you are not eligible to participate.**

(Calendar Example, it will vary every week)

WEEK FROM NOVEMBER 12 TO NOVEMBER 16

SIGN-UP TIMES	**November 12 MONDAY**	**November 13 TUESDAY**	**November 14 WEDNESDAY**	**November 15 THURSDAY**	**November 16 FRIDAY**
9:00am					
9:30am					
10:00am			Only one person per cell 10:00AM 12:00PM		
10:30am					
11:00am					
11:30am					
12:00pm					
12:30pm					
1:00pm			Only one person per cell 1:00PM 3:00PM		
1:30pm	Only one person per cell 1:30AM 3:30PM				Only one person per cell 1:30AM 3:30PM
2:00pm					
2:30pm					
3:00pm			Only one person per cell 3:00PM 5:00PM		
3:30pm	Only one person per cell 3:30PM 5:30PM				Only one person per cell 3:30PM 5:30PM
4:00pm					
4:30pm					
5:00pm					
5:30pm					

Appendix 7 – TME Data Files

Files with extension .tm1

File Edit Format View Help

02P1	4/30/2002	4:46:11 PM	0	9	2	6	Continuous	00.6217	03.7300
02P1	4/30/2002	4:46:11 PM	1	5	1	5	Continuous	00.6158	03.0792
02P1	4/30/2002	4:46:11 PM	2	8	3	10	Continuous	00.6192	06.1917
02P1	4/30/2002	4:46:11 PM	3	9	4	0	Continuous	-00.7092	00.0000
02P1	4/30/2002	4:46:11 PM	4	4	1	0	Discrete	00.2658	00.0000
02P1	4/30/2002	4:46:11 PM	5	3	0	0	Continuous	01.0000	00.0000
02P1	4/30/2002	4:46:11 PM	6	4	1	0	Continuous	00.1658	00.0000
02P1	4/30/2002	4:46:11 PM	7	8	3	6	Discrete	00.2833	01.7000
02P1	4/30/2002	4:46:11 PM	8	9	4	4	Continuous	00.4850	01.9400
02P1	4/30/2002	4:46:11 PM	9	13	2	2	Continuous	00.5658	01.1317
02P1	4/30/2002	4:46:11 PM	10	6	1	0	Continuous	00.1658	00.0000
02P1	4/30/2002	4:46:11 PM	11	6	5	0	Continuous	-00.7675	00.0000

Files with extension .tm2

File Edit Format View Help

07P4	5/2/2002	2:25:01 PM	0		1000	1000	1000	100
07P4	5/2/2002	2:25:01 PM	0.1		998	999	997	996
07P4	5/2/2002	2:25:01 PM	0.2		996	998	994	992
07P4	5/2/2002	2:25:01 PM	0.3		994	997	991	988
07P4	5/2/2002	2:25:01 PM	0.4		992	996	988	984
07P4	5/2/2002	2:25:01 PM	0.5		990	995	985	980
07P4	5/2/2002	2:25:01 PM	0.6		988	994	982	976
07P4	5/2/2002	2:25:01 PM	0.7		986	993	979	972
07P4	5/2/2002	2:25:01 PM	0.8		984	992	976	968
07P4	5/2/2002	2:25:01 PM	0.9		982	991	973	964
07P4	5/2/2002	2:25:01 PM	1		980	990	970	960
07P4	5/2/2002	2:25:01 PM	1.1		978	989	967	956
07P4	5/2/2002	2:25:01 PM	1.2		976	988	964	952
07P4	5/2/2002	2:25:01 PM	1.3		974	987	961	948
07P4	5/2/2002	2:25:01 PM	1.4		972	986	958	944
07P4	5/2/2002	2:25:01 PM	1.5		970	985	955	940
07P4	5/2/2002	2:25:01 PM	1.6		968	984	952	936
07P4	5/2/2002	2:25:01 PM	1.7		966	983	949	932
07P4	5/2/2002	2:25:01 PM	1.8		964	982	946	928
07P4	5/2/2002	2:25:01 PM	1.9		962	981	943	924
07P4	5/2/2002	2:25:01 PM	2		960	980	940	920
07P4	5/2/2002	2:25:01 PM	2.1	8	958	979	937	916
07P4	5/2/2002	2:25:01 PM	2.2	8	956	978	934	912
07P4	5/2/2002	2:25:01 PM	2.3	8	954	977	931	908
07P4	5/2/2002	2:25:01 PM	2.4	8	952	976	928	904
07P4	5/2/2002	2:25:01 PM	2.5	8	950	975	925	900
07P4	5/2/2002	2:25:01 PM	2.6	8	948	974	922	896
07P4	5/2/2002	2:25:01 PM	2.7	8	946	973	919	892
07P4	5/2/2002	2:25:01 PM	2.8	8	944	972	916	888
07P4	5/2/2002	2:25:01 PM	2.9	8	942	971	913	884
07P4	5/2/2002	2:25:01 PM	3	8	940	970	910	880
07P4	5/2/2002	2:25:01 PM	3.1	8	938	969	907	876
07P4	5/2/2002	2:25:01 PM	3.2	8	936	968	904	872
07P4	5/2/2002	2:25:01 PM	3.3	8	934	967	901	868
07P4	5/2/2002	2:25:01 PM	3.4		932	966	898	864
07P4	5/2/2002	2:25:01 PM	3.5		930	965	895	860
07P4	5/2/2002	2:25:01 PM	3.6	9	928	964	892	856
07P4	5/2/2002	2:25:01 PM	3.7	9	926	963	889	852
07P4	5/2/2002	2:25:01 PM	3.8	9	924	962	886	848
07P4	5/2/2002	2:25:01 PM	3.9	9	922	961	883	844
07P4	5/2/2002	2:25:01 PM	4	9	920	960	880	840
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07P4	5/2/2002	2:25:01 PM	4.4	9	912	956	868	824
07P4	5/2/2002	2:25:01 PM	4.5	9	910	955	865	820
07P4	5/2/2002	2:25:01 PM	4.6	9	908	954	862	816
07P4	5/2/2002	2:25:01 PM	4.7	9	906	953	859	812
07P4	5/2/2002	2:25:01 PM	4.8	9	904	952	856	808
07P4	5/2/2002	2:25:01 PM	4.9	9	902	951	853	804
07P4	5/2/2002	2:25:01 PM	5		900	950	850	800
07P4	5/2/2002	2:25:01 PM	5.1	2	898	949	847	796
07P4	5/2/2002	2:25:01 PM	5.2	2	896	948	855	792
07P4	5/2/2002	2:25:01 PM	5.3	2	894	947	863	788
07P4	5/2/2002	2:25:01 PM	5.4	2	892	946	871	784
07P4	5/2/2002	2:25:01 PM	5.5	2	890	945	879	780
07P4	5/2/2002	2:25:01 PM	5.6	2	888	944	887	776
07P4	5/2/2002	2:25:01 PM	5.7	2	886	943	895	772
07P4	5/2/2002	2:25:01 PM	5.8	2	884	942	903	768
07P4	5/2/2002	2:25:01 PM	5.9	2	882	941	911	764

Appendix 8 – Python Programs

```
######################################################
# This program is property of Roberto J. Nicolalde #
######################################################

# Replaces space separators by tab separators in TME files with extension tm2.
# Marks non-attendance time with -1, and marks attendance to discrete subsystem.

import sys
import re
import os, string

filenames = ""
filenames = os.listdir("d:\\Data\\javier\\data\\tm2\\tm2P1")

#fileout = open("d:\\TME analysis\\tm1\\trans.dat", "w")

for file in filenames:
   filein = open(os.path.join("d:\\Data\\javier\\data\\tm2\\tm2P1", file))
   fileout = open(os.path.join("d:\\Data\\javier\\data\\tm2P1x", file),"w")
   cr1 = " "
   cr2 = " "
   cr3 = " "

   cr1 = filein.readline()
   cr2 = filein.readline()

   cr1=re.sub("                    ","      -1        ",cr1)
   cr1=re.sub("\s+","\t",cr1)
   tf1 = cr1.split()
   print >> fileout, "%s\t%s" % ( cr1, tf1[5] )

   cr2=re.sub("                    ","      -1        ",cr2)
   cr2=re.sub("\s+","\t",cr2)
   tf2 = cr2.split()
   print >> fileout, "%s\t%s" % ( cr2, tf2[5] )


   cr3=re.sub("                    ","      -1        ",cr2)
   cr3=re.sub("\s+","\t",cr3)
   tf3 = cr3.split()
   #print "%s\t%s" % ( cr3, tf3[5] )
   counter = 0
   while( cr3 != "" ):
      cr3=re.sub("                    ","      -1                        ",cr3)
```

```
    cr3=re.sub("\s+","\t",cr3)
    tf3 = cr3.split()

    if (counter > 2) and (tf1[13] > tf2[13])and( tf2[13]==tf3[13]):
      print >> fileout,  "%s\t%s" % ( cr3, "7" )
    else:
      print >> fileout,  "%s\t%s" % ( cr3, tf3[5] )

    tf1=tf2
    tf2=cr3.split()

    counter=counter+1
    cr3 = filein.readline()

filein.close()
fileout.close()

####################################################
# This program is property of Roberto J. Nicolalde #
####################################################

# Computes the Raw Total Weighted Score from TME files with extension tm2, after
they
# have been cleaned up.

from __future__ import division
import sys
import re
import os

inputfilenames = ""

inputfilenames = os.listdir("d:\\Data\\javier\\data\\tm2P1x")
fileout = open("d:\\Data\\javier\\data\\tm2\\AverageP1.dat", "w")

for inputfilename in inputfilenames:
  filein = open(os.path.join("d:\\Data\\javier\\data\\tm2P1x", inputfilename))

  records = filein.readlines()  # retrieve list of lines in file

  total = 0                     #resets total
  counter = 0                   #starts counter

  #loop to calculate average
```

```
   for line in records:
         fields = line.split()
         sum = int(fields[6])* 6 + int(fields[7])*5 + int(fields[8])*10 +
int(fields[13])*6                                    + int(fields[14])*4 +
int(fields[15])*2
         total= total + (sum/33)
         counter = counter + 1
   average = total/counter
   print >> fileout, inputfilename,
   #print total,
   print >> fileout, "%.3f" % (average/10)
filein.close()
fileout.close()

#####################################################
# This program is property of Roberto J. Nicolalde #
#####################################################

# Calculates the Task Management Error Time from TME files with extension tm2.

from __future__ import division        #imports division module
import sys                             #imports system module
import re                              #imports subtitution module
import os, string                      #imports operation system and string modules

def maximunValue(x, y, z, a, b, c):
   maximun = x
   if y > maximun:
      maximun = y
   if z > maximun:
      maximun = z
   if a > maximun:
      maximun = a
   if b > maximun:
      maximun = b
   if c > maximun:
      maximun = c
   return maximun

filenames = ""                                                #empties file
name list
filenames = os.listdir("d:\\Data\\javier\\data\\tm2P1x")      #creates a list of
the files in the specified directory
```

```
fileout = open("d:\\Data\\javier\\data\\tm2\\ErrorTimeTME_P1.dat", "w")
        #opens file for output

#loop for opening each file that is in the list of filenames got from the listdir commad

for file in filenames:
  totalerror = 0                                                    #resets the total
errors
  filein = open(os.path.join("d:\\Data\\javier\\data\\tm2P1x", file))          #appends
the path to the file name in the listdir
  records = filein.readlines()                    #creates a list of the lines in the file per
each file opened
  counter = 0
  for line in  records:
    task = line.split()     #divides the line in each value
    if int(task[6])< 500:
      importance6 = 1*6      #if is smaller than 500 assigns a value of importance
    else:                   #if not assigns 0 importance
      importance6 = 0
    if int(task[7])< 500:
      importance7 = 1*5
    else:
      importance7 = 0
    if int(task[8])< 500:
      importance8 = 1*10
    else:
      importance8 = 0
    if (int(task[13])< 500):
      importance13 = 0
    else:
      importance13 = 0
    if int(task[14])< 500:
      importance14 = 1*4
    else:
      importance14 = 0
    if int(task[15])< 500:
      importance15 = 1*2
    else:
      importance15 = 0

    #creates a list with the importance values for each task

        importance = [importance6, importance7, importance8, importance13,
importance14,           importance15]         #creates a list with the importance
```

```
        #calculates the maximun value among the critical tasks

        max = maximunValue(importance[0], importance[1], importance[2],
importance[3],

        importance[4], importance[5])

    if int(task[20]) == 0:
      att=6
    else:
      if int(task[20])==1:
        att=5
      else:
        if int(task[20]) == 2:
          att=10
        else:
          if int(task[20]) == 7:
            att=7
          else:
            if int(task[20])== 8:
              att=4
            else:
              if int(task[20]) == 9:
                att=2
              else:
                att= 0


    if (max > 0) and (att != max):
      error = 1
    else:
      error = 0
    #calculates total erro for the file
    totalerror = totalerror + error
    counter = counter + 1

    #print file,
    #print importance,
    #print max,
    #print att,
    #print error,
    #print totalerror
```

```
    print >> fileout, file, totalerror, counter

    filein.close()
fileout.close()
```

Appendix 9 – Testing Protocol and Consent Form

Oregon State University
Department of Industrial and Manufacturing Engineering
Informed Consent Document

I hereby give my consent to participate in a Masters Thesis research project conducted by Roberto Javier Nicolalde under the supervision of Dr. Ken Funk of the Oregon State University, Department of Industrial & Manufacturing Engineering, and Dr. Bob Uttl of the Psychology Department at Oregon State University.

Purpose. These studies are part of a thesis project that has as its objective to identify abilities required for attending to multiple concurrent tasks, for example how easy it is for me to drive, scan for my favorite radio station, and talk on my cell phone.

Procedure. The experimenter has explained the procedure for the experiment as follows: First I will be inducted, and trained for half hour on the computer-based tests. Then, after understanding the functionality of all the computer-based tests and gaining an acceptable level of competence determined by the experimenter, I will be asked to take each test one time, and answer a brief questionnaire after finishing the computer based tests. No information identifying me will be recorded. The total length of the experiment should not be more than three hours.

Risks I understand that the probability and magnitude of harm, inconvenience or discomfort anticipated in this study are no greater than those encountered in daily life. I also understand that Oregon State University does not provide compensation or medical treatment in the event that I am injured or harmed in any way as a result of participating in this experiment.

Confidentiality. I understand that the data collected in this study will be available to the research investigators, support staff, and any duly authorized research review committee. The data will be kept confidential to the extent permitted by law The data will be kept for 5-6 years following the publication of the results (usual time required for keeping original data and records).

I grant Oregon State University permission to reproduce and publish all records, notes, or data resulting from participation, provided there will be no association of my name with the collected data and that confidentiality is maintained unless specifically waived by me.

Benefits. I understand that my participation in this study is voluntary and I can withdraw from the experiment at any time without any kind of penalty. I understand that I will not be paid for my participation in this experiment. In exchange for completing the experiment, I will be given 2-hours experiment participation credits for class in the Psychology, and Industrial and Manufacturing Engineering Departments that accept them (not all professors accept experimental credits.) If I withdraw from the experiment prior to its completion, I will not receive any experiment credit hours for classes.

Questions. I understand that I will have the opportunity to ask questions and receive satisfactory answers from Javier Nicolalde. I understand any further question concerning this experiment should be directed to Dr. Ken Funk at (541) 737-2357 and/or Dr. Bob Uttl at (541) 737-1374.

If I have questions about my rights as a research subject, I should contact the IRB Coordinator, OSU Research Office, (541) 737-3437.

My signature bellow indicates that I have read and that I understand the process described above and gives my informed and voluntary consent to participate in this experiment. I understand that I will receive a copy of this consent form.

Signature of Subject ________________________ Date: ____________

Printed Name of Subject ____

Multi-task Psychology Battery Protocol

General instructions

- subject must not ever see your scoring sheets. If the subject sees your scoring sheets the testing becomes invalid.

Materials Required

- computer station (be careful in moving or relocating computer stations, if any equipment malfunction occurs let me know as soon as possible)
- table
- several pencils
- consent form

Make sure that you have these items prior to the subject's arrival.

Starting up the computer

1. Turn on the power by turning the power-bar switch
2. Wait until password prompt appears
3. Enter the password
4. Wait until you are giving a choice between the operating system (e.g., Windows NT, Windows NT VGA, and MS-DOS)
5. Use arrow key to select MS-DOS and hit <Enter>
6. Wait until you see "C:>" prompt
7. Enter cd cab <Enter> in order to move to test directory

Starting up CAB

1. To starting up CAB or Brains at Work Test, type cab <Enter> at the DOS prompt

- To fill subject's identification, press "i" character (highlighted in the menu) and fill in the ID (e.g. 1111)
- To select the test, press highlighted character in the menu

Starting up Laptop computer forTME

1. Turn on the power by turning the power-bar switch
2. Wait until password prompt appears
3. Enter the password
4. After Windows finishes loading, choose the folder TME from the Desktop and double click on either TME 1.4 EZ or TME 1.4 Diff, depending on which scenario is to be run.

Introduction, consent from, and study purpose

You already know that you came for 2 to 2.5 hours of cognitive testing. All tests which we will de today will be either paper and pencil test or they will be done on a computer.

First thing which I would like you to do is to look over this consent form, and once you have finished reading it, sign it and date it.
The two most important things to remember is that
1. you are free to discontinue testing for whatever reason at any time (although we prefer that you do not), and
2. your individual results are confidential (only people involved in research have access to them).

The main purpose of this study is to identify abilities required for attending to multiple concurrent tasks. For example how easy it is for you to drive, scan for your favorite radio station and talk on your cell phone.

Finally, many of the tests, which you will do today, are designed to stress the limits of your abilities- they will become intentionally very difficult. Thus, you should not find it distressing if you start making errors; what is important is that you try as hard as you can, your best.

<u>Simple Reaction Time (CAB)</u>

This test measures how quickly you can react to a stop light, to the brake-lights on the car in front of you, or to a child running in front of your car.

Start: from CAB menu
Subject: Keyboard (down-arrow key)
Experimenter: Mouse (left button= YES/Next, right button = NO)

This test measures how quickly you can react to a stop light, to the brake-lights on the car in front of you, or to a child running in front of your car.

For the main part of the test the computer screen will show you a letter --- an X— from time to time, and whenever the X appears, you must press the down-arrow key on the keyboard. The goal is to react as quickly as possible, as quickly as you would if a child ran in front of your car.

Let's practice this task. Place the index finger of your dominant/preferred hand on the down-arrow key, and when you are ready to begin, press that key. After a very brief period, an X will appear, and you press the down-arrow key again. Keep doing the same thing until the test is finished; keep concentrating and always respond as quickly as you can.

What you have done so far was only practice – now it counts. The test is exactly the same. The test begins when you are ready, and you press the down-arrow key. Keep concentrating and always respond as quickly as you can. This is the end of one block of trials. Now you can rest for a while. When you are ready for the next block of trial, we will continue.

<u>Decision Time</u>

This test measures how quickly you can make a simple decision, for example, whether to continue or to stop when a traffic light turns yellow.

Start: from CAB menu
Subject: Keyboard (left-arrow key = A, right-arrow key = B)
Experimenter: Mouse (left button = YES/NEXT, right button = NO)

This test measures how quickly you can make a simple decision, for example, whether to continue or to stop when a light turns yellow.

For the main part of the test, the computer screen will show you letters from time to time, either the upper-case A or the upper-case B. Whenever one of these letters appears on the screen, you must press one of the arrow keys: press the left-arrow key when the upper-case A appears on the screen, and the right-arrow key when the upper-case B appears on the screen. The goal is to make a CORRECT decision and to react as quickly as possible.

Let's practice this task. Place the index finger of your dominant/preferred hand on the left-arrow key and your middle finger on the right-arrow key. When the trial begins, the computer screen will show you a series of As and BS, in random order. You must press the left-arrow key when the upper-case letter A appears on the screen, and the right-arrow key when the upper-case B appears on the screen. The goal is to make a correct decision (to press the correct key), to react as quickly as possible without making any errors. A brief period after you make a decision, the nest letter will appear and you have to make another decision.

What you have done so far was only for practice--- now it counts. Everything is exactly the same. Keep concentrating, and making all your decisions as quickly and as accurately as you can.

This is the end of one block of trials. Now you can rest for a while. When you are ready for next block of trials we will continue.

Card Sorting

This test measures your ability to spot relevant letters among a varying number of other irrelevant letters—it is like scanning a crowd for your friend's face.

Start: from CAB menu
Subject: Keyboard (left-arrow key = A, right key = B)
Experimenter: Mouse (left button = YES/NEXT, right button = NO)

This test measures your ability to spot relevant letters among a varying number of other irrelevant letters—it is like scanning a crowd for your friend's face.

For the main part of the test, the computer screen will show you a series of cards, one at a time. Each card will have a target letter on it—either an A or a B; and there will be various other irrelevant letters. Your task is to check each card, to find out whether there is an A on a B on it: press the left-arrow key if an A is on the card, and press the right-arrow key if a B is on the card. The goal is to decide as quickly as possible whether there is an A or B on the card. Immediately after pressing one of the arrow-keys the next card will appear on the screen. Your task is always to check if there is an A or a B, and to do this as quickly as possible.

Let's practice this task. Place two fingers of your dominant hand in the left-arrow and right-arrow keys. When a card appears on the screen, check as quickly as possible whether there is an A or B on the card. Press the left-arrow key if there is an A on the card, and press the right-arrow key if there is a B on the card. The goal is to check quickly and correctly whether there is an A of a B on each card, to react as quickly as possible without making any errors. Immediately after you press one of the arrow-keys, the next card will appear on the screen and you have to check it again for a letter A or letter B.

What you have done so far was only for practice--- now it counts. Your task is exactly as you practiced. When a card appears on the screen, check as quickly as possible whether is an A or a B on the card, press the left-arrow key if there is an A on the card, and press the right-arrow key if there is a B on the card. Keep concentrating, and check each card as quickly and accurately as you can.

TME

This test measures how easy it is for you to take care of multiple tasks simultaneously, for example how easy it is for you to drive, scan for your favorite radio station and talk on your cell phone.

Start: from Windows Desktop
Subject: Mouse (left button to click over command buttons)
Experimenter: Mouse to set up environment and save the data after the test is done.

The test consists of 6/8 tasks, which are shown as bars. If you do not attend to a task, its status goes down from the satisfactory level at a constant rate. On the other hand, you can improve the status of each bar toward the desired state by pressing the button underneath each bar using the mouse. While attending to a task by pressing the left mouse button, you can move the cursor around the screen, and the level of the bar will keep increasing.

Let's practice the test, to start press the "Start" button in the bottom of the screen. You will see that the level of each bar will star going down. Your task is to try to keep all of them at the highest level possible. Your score will be determined by how well you do this task. Notice that each bar has three zones, green, yellow and red. These zones determine the status of the bars. Thus, green means satisfactory status, yellow means unsatisfactory status, and red means unacceptable status. Your score will take in consideration how long you stayed in each of these zones, being green the best zone. It is also important that you consider the importance of each bar, represented by the number underneath each button. The importance of the bar will be also considered in calculating your score. Keep doing the same thing until the test is finished; keep concentrating and always respond as quickly as you can. You are going to have five practice sessions.

What you have done so far was only practice – now it counts. The test is exactly the same. The test begins when you are ready, and you press the "Start" button. Keep concentrating and always respond as quickly as you can. This is the end of one block of trials. Now you can rest for a while. When you are ready for the next block of trial, we will continue.

<u>Vocabulary Test</u>

This test examines whether or not you know the word of phrase that is closest in meaning to a target word.

Start: paper and pencil test
Subject: paper and pencil
Experimenter: stopwatch and pencil

I will give you three pages of printed words in capital letters, followed by four word or phrases. For each capitalized word, circle the word of phrase that is closest in meaning to the capitalized word. If you cannot identify which of the four words is closest in meaning to the capitalized word, make a guess. Work in order, form the first word to the last, and do not skip any words.
Path Finding

Check Brightness And Contrast
Starting up the program
1. Turn on power (cables, power-bar switch, computer and monitor switches)
2. Wait until you see C:> prompt
3. enter CD \cab and you will see c:\cab> prompt
4. run PATH FINDING by entering pfind [subject number]<enter>
· subject number can be any digit string between 1 and 5 digit long
5. you will see PATH FINDING banner

general instructions
· the subject must use his/her dominant hand for controlling the mouse
· record which hand is subjects' dominant hand
· the subject should sit in front of a monitor in such a way that his/her line of vision is perpendicular (orthogonal) to the monitor surface and intersects monitor surface in the middle
· leaning to one or other side is not allowed
· the surface of the monitor needs to be kept clean

Overview

This test measures how quickly you can find targets – numbers or letters on the computer screen, and how quickly you can touch them with the mouse. This is a test for the same abilities as are needed for many everyday tasks such as making deposits and withdrawals from a bank machine or extracting information (e.g., weather forecast) via telephone.

The test is very demanding and it is designed to test the limits of your abilities. It is important that you try as hard as you can even though you may feel that it is too difficult or even though you may start making mistakes.

Stopping rules: On PATH FINDING trials, subject is given two trials at each difficulty/sequence type level. Whenever the subject fails to complete the trial (touches 5 wrong targets consecutively, he/she is automatically given one more trial. Thus, subjects may get up to 4 trials at each difficulty/sequence type.

1. If they fail all trials at a given item load (e.g., all 1-item load trials or all 2-item load trials) stop the test by hitting 'q' (lower case) while being on one of the sequence definition screens.
2. If they fail all trials at given item load/sequence type level, try to continue, and stop only if subject cannot be motivated to continue.

Tracking practice

In the first part of this test, the target – a letter X shown inside a circle – will appear on the screen. Your task is to locate the X on the screen and to touch it with the mouse as quickly as you can. When you touch the target, it will disappear and immediately pop-up in another location, and again you must locate and touch the target with the mouse as quickly as possible. Keep on this task until there are no more targets.

It is important that you touch each target as quickly as you can, but you must also be accurate. If you miss the target, that is, if you touch outside the target circle, the computer will beep briefly and wait until you actually touch the target.

Show the subject how to touch the screen during the first practice trial, including

- when you touch the target it immediately pops-up elsewhere
- when you miss the target computer beeps this way
- it is important that you touch the targets AS QUICKLY AS YOU CAN and continue doing so until there are no more targets
- use your dominant hand to control the mouse and touch the targets

Tracking critical trials

What you have done was for practice – now it counts. Your task is exactly the same. The target – a letter X shown in a circle will appear on the screen. Your task is to locate the target and to touch it with the mouse as quickly as you can. When you touch the target, it will disappear and immediately pop-up in another location, and again you must locate and touch the target as quickly as possible.

It is important that you touch each target as quickly as you can, but you must also be accurate. If you miss the target, that is, if you touch outside the target circle, the computer will beep briefly and wait until you actually touch the target.

Path finding practice

The next part of the test is a little different. This time, the computer will show you a full page of targets at the same time; moreover, the targets will be labeled either by numbers (1, 2, 3, ...) or by letters (A, B, C, ...). This time, your task is to touch the targets with the mouse, as fast and accurately as you can, in the order that is specified by the instructions for each test page.

To begin each test page, you will be shown a sequence, for example, 1, 2, 3, ..., and this sequence defines the order in which you are to locate/touch the targets on the following test page. When you touch the correct target in each sequence, the computer will draw a line between it and the just preceding target. When you touch an incorrect target or if your touch misses the target, the computer will beep to remind you to be more accurate. A deep sounding beep means you missed the circle whereas a high pitch beep means you touched a wrong target.

Show the subject how to touch the screen during the first practice trial, including

- when you touch the first target it will be crossed out so you know you touched it
- when you touch the next target, a line – a path -- will be drawn between it and an immediately preceding target in the sequence so that you know you touched it
- when you miss the target computer beeps this way (low pitch, short beep as before)
- it is important that you touch the targets in a correct order (now, 1, 2, 3, etc.)
- when you touch the wrong target – a target out of order – the computer beeps this way (high pitch, longer beep)
- IT IS IMPORTANT THAT YOU TOUCH TARGETS AS QUICKLY AS YOU CAN and continue doing so until there are no more targets

Let the subject practice (1 trials) and explain any problems

Path finding/ 1 item load trials

What you have done was for practice – now it counts. Your task is exactly the same. The computer will show you a full page of targets all at the same time. Your task is to touch the targets with the mouse as fast and accurately as you can, in the order that is specified by the instructions for each test page.

To begin each test page, you will be shown a sequence, for example, 1, 2, 3, …, and this sequence defines the order in which you are to locate/touch the targets on the following test page. When you touch the correct target in each sentence, the computer will draw a line between it and the just preceding target. When you touch an incorrect target or if your touch misses the target, the computer will beep to remind you to be more accurate. A deep sounding beep means you missed the circle whereas a high pitch beep means you touched a wrong target.

Prior to each trial, while the sequence definition screen is showing, say the sequence definition for subject aloud and ask if they are ready prior to starting the trial.
1, 2, 3, …
Follow the sequence: 1, 2, ...
You first touch 1 then 2 then 3 and so on, until you touch all targets on the screen.
A, B, C, …
Follow the sequence: A, B, ...
You first touch A then B then C and so on, until you touch all targets on the screen.

Path finding/2 item load trials

For the next part of the test, the sequence of targets that you have to locate/touch is a bit more complex. You will be required to think more about the sequence. For example, instead of going from 1 to 2 to 3, etc., now the sequence of targets may go: 1, 14, 2, 15, 3, 16, or it may go: 1, A, 2, B, 3, C, ... The instructions preceding each page will specify the manner in which you have to locate/touch targets on the test. Please read the instructions carefully, figure out the sequence that you are required to follow, and then, locate and touch the targets as quickly and accurately as possible.

1, 14, 2, 15, ...
Follow the sequence: 1, 14, 2, 15, ...
You first touch 1 followed by 14 then 2 followed by 15 and so on, until you touch all targets.

A, N, B, O, ...
Follow the sequence: A, N, B, O, ...
You first touch A followed by N then B followed by O and so on, until you touch all targets.

1, A, 2, B, ...
Follow the sequence: 1, A, 2, B, ...
You first touch 1 followed by A then 2 followed by B and so on, until you touch all targets.

Please note the difference between the letter I and the number 1.

Point out the difference between the capital letter I and the number 1.

Path finding/3 item load trials

1, 9, 18, ...
Follow the sequence: 1, 9, 18, ...
You first touch 1 followed by 9 followed by 18
then 2 ...

A, I, R,...
Follow the sequence: A, I, R,...
You first touch A followed by I followed by R
then B ...

1, 7, 14, 20, ...
Follow the sequence: 1, 7, 14, 20, ...
You first touch 1 followed by 7 followed by 14 followed by 20
then 2 ...

A, G, N, T, ...
Follow the sequence: A, G, N, T, ...
You first touch A followed by G followed by N followed by T
then B ...

1, A, 7, G, ...
Follow the sequence: 1, A, 7, G, ...
You first touch 1 followed by A followed by 7 followed by G
then 2 ...

Computer Experience Questionnaire

The purpose of this questionnaire is to get information about your experience using computers.
Please answer each question as accurate as possible, and in the given order.

Decision Making Questionnaire
The purpose of this questionnaire is to get information about the strategies you use for decision-making.

Please answer each question as accurate as possible, and in the given order.

Appendix 10 – SPSS Data Analysis Syntax File

```
*************************************************
* This Program is property of Roberto J. Nicolalde and Bob Uttl*
*************************************************

* SPSS syntax file, scores psychological tests and computes statistics.

data list file='d:\data\javier\data\ppt.dat' fixed records=37
/subid 1-4
/testby 1-3 (a)
/testdate 1-6
/testtime 1-6 (a)
/age 1-2
/sex 1 (a)
/eduyrs 1-2
/edulev 1
/
/cuselen 1
/cusewhe1 to cusewhe5 1-5
/cusehrs 1-2
/cusefor1 to cusefor8 1-8
/cusecomf 1
/cusesats 1
/cmonsize 1
/cmontype 1
/gamesyes 1 gameshrs 9-12
/gamestx1 10-255 (a)
/gamestx2 10-255 (a)
/gamestx3 10-255 (a)
/driveyes 1 drivehrs 9-12
/driveyrs 1-2
/
/mdmq1 to mdmq10 1-10
/mdmq11 to mdmq22 1-12
/
/syna1 to syna25 1-25
/syna26 to syna55 1-30
/syna56 to syna84 1-29
/
/note1 9-255 (a)
/note2 9-255 (a)
/note3 9-255 (a)
/note4 9-255 (a)
/note5 9-255 (a)
/
```

```
.
execute.

*************************************************
*****COMPUTER EXPERIENCE****.
*************************************************.
frequency variables=cusewhe1 cusewhe2 cusewhe3 cusewhe4 cusewhe5
cusefor1 cusefor2 cusefor3 cusefor4 cusefor5 cusefor6 cusefor7 cusefor8.

compute xcusewhe=sum(cusewhe1, cusewhe2, cusewhe3, cusewhe4, cusewhe5).
compute xcusefor=sum(cusefor1, cusefor2, cusefor3, cusefor4, cusefor5, cusefor6,
cusefor7, cusefor8).
execute.

frequency variables=xcusewhe xcusefor cuselen cusehrs cusecomf cusesats
gamesyes driveyes.

examine /variables=xcusewhe xcusefor cuselen cusehrs cusecomf cusesats gamesyes
driveyes
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

*****************************************************************
***********
***** MELBOURNE DECISION MAKING QUESTIONNAIRE *****.
*****************************************************************
***********
*** Buck-passing ***.

reliability /variables=mdmq1 mdmq3 mdmq7 mdmq12 mdmq16 mdmq19
/scale(xmdmqbp)=mdmq1 mdmq3 mdmq7 mdmq12 mdmq16 mdmq19
/model=alpha
/summary=all.

compute xmdmqbp=mean(mdmq1,mdmq3,mdmq7,mdmq12,mdmq16,mdmq19).

frequency variables=xmdmqbp.

examine /variables=xmdmqbp
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.
```

```
*** Vigilance ***.

reliability /variables=mdmq2 mdmq5 mdmq8 mdmq11 mdmq13 mdmq17
/scale(xmdmqvi)=mdmq2 mdmq5 mdmq8 mdmq11 mdmq13 mdmq17
/model=alpha
/summary=all.

compute xmdmqvi=mean(mdmq2, mdmq5, mdmq8, mdmq11, mdmq13, mdmq17).

frequency variables=xmdmqvi.

examine /variables=xmdmqvi
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.


*** Procrastination ***.

reliability /variables=mdmq9 mdmq10 mdmq15 mdmq21 mdmq22
/scale(xmdmqpr)=mdmq9 mdmq10 mdmq15 mdmq21 mdmq22
/model=alpha
/summary=all.

compute xmdmqpr=mean(mdmq9, mdmq10, mdmq15, mdmq21, mdmq22).

frequency variables=xmdmqpr.

examine /variables=xmdmqpr
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.


*** Hypervigilance ***.

reliability /variables=mdmq4 mdmq6 mdmq14 mdmq18 mdmq20
/scale(xmdmqhv)=mdmq4 mdmq6 mdmq14 mdmq18 mdmq20
/model=alpha
/summary=all.

compute xmdmqhv=mean(mdmq4, mdmq6, mdmq14, mdmq18, mdmq20).
```

```
frequency variables=xmdmqhv.

examine /variables=xmdmqhv
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.


*************************************************************.
* SYNONYMS+ FORM A
*************************************************************.

recode syna1  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna1  .
recode syna2  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna2  .
recode syna3  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna3  .
recode syna4  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna4  .
recode syna5  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna5  .
recode syna6  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna6  .
recode syna7  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna7  .
recode syna8  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna8  .
recode syna9  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna9  .
recode syna10 (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna10 .
recode syna11 (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna11 .
recode syna12 (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna12 .
recode syna13 (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna13 .
recode syna14 (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna14 .
recode syna15 (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna15 .
recode syna16 (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna16 .
recode syna17 (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna17 .
recode syna18 (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna18 .
recode syna19 (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna19 .
recode syna20 (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna20 .
recode syna21 (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna21 .
recode syna22 (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna22 .
recode syna23 (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna23 .
recode syna24 (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna24 .
recode syna25 (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna25 .
recode syna26 (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna26 .
recode syna27 (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna27 .
recode syna28 (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna28 .
recode syna29 (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna29 .
recode syna30 (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna30 .
recode syna31 (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna31 .
recode syna32 (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna32 .
```

```
recode syna33  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna33 .
recode syna34  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna34 .
recode syna35  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna35 .
recode syna36  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna36 .
recode syna37  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna37 .
recode syna38  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna38 .
recode syna39  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna39 .
recode syna40  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna40 .
recode syna41  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna41 .
recode syna42  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna42 .
recode syna43  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna43 .
recode syna44  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna44 .
recode syna45  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna45 .
recode syna46  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna46 .
recode syna47  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna47 .
recode syna48  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna48 .
recode syna49  (3= 1)(0,9,sysmis=sysmis)(else=0) into xsyna49 .
recode syna50  (4= 1)(0,9,sysmis=sysmis)(else=0) into xsyna50 .
recode syna51  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna51 .
recode syna52  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna52 .
recode syna53  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna53 .
recode syna54  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna54 .
recode syna55  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna55 .
recode syna56  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna56 .
recode syna57  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna57 .
recode syna58  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna58 .
recode syna59  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna59 .
recode syna60  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna60 .
recode syna61  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna61 .
recode syna62  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna62 .
recode syna63  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna63 .
recode syna64  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna64 .
recode syna65  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna65 .
recode syna66  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna66 .
recode syna67  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna67 .
recode syna68  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna68 .
recode syna69  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna69 .
recode syna70  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna70 .
recode syna71  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna71 .
recode syna72  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna72 .
recode syna73  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna73 .
recode syna74  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna74 .
recode syna75  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna75 .
recode syna76  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna76 .
```

```
recode syna77  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna77  .
recode syna78  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna78  .
recode syna79  (2 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna79  .
recode syna80  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna80  .
recode syna81  (3 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna81  .
recode syna82  (1 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna82  .
recode syna83  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna83  .
recode syna84  (4 = 1)(0,9,sysmis=sysmis)(else=0) into xsyna84  .
execute.

compute synattl=mean(xsyna1 to xsyna84).
examine /variables=synattl /plot=stemleaf boxplot histogram npplot /id=subid
/statistics=descriptives extreme(10).

reliability /variables=xsyna1 to xsyna84
/scale(xsyna)=xsyna1 to xsyna84
/model=alpha
/summary=all.

sort cases by subid.

save outfile='d:\data\javier\stats\ppt.sav'.

*******************************************.
* PATH FINDING
*******************************************.

data list file='d:\data\javier\data\pfix.dat'
 /testid 1-10 (a) subid 11-20 date 21-29 (a) time 31-40 (time)
 block 41-45 step 46-50 path 51-55 pathlen 56-60
 touchno 61-65  xcoord 66-70 ycoord 71-75 clock 76-85 airtm 86-95 touchtm 96-105
 trgaim 106-110  trghit 111-115 ishit 116-120 conserrs 121-125 attempt 131-135
.
execute.

recode trghit (1 thru 24=0)(0=1) into miss.
compute falarm=0.
if((trgaim ne trghit)and(trghit ge 1)) falarm=1.
execute.

compute nxitemrt=airtm+touchtm.
```

```
recode step
(10=0)(0=11)(1=12)(2=21)(3=22)(4=23)(5=31)(6=32)(7=41)(8=42)(9=43) into
trialtp.

sort cases by subid trialtp attempt.

aggregate outfile='d:\data\javier\stats\pfixagg0.sav'
 /break   =subid trialtp attempt
 /pfidate =first(date)
 /pfitime =first(time)
 /pfietim =last(time)
 /ttltime =last(clock)
 /itemtm  =mean(nxitemrt)
 /touches =last(touchno)
 /misses  =sum(miss)
 /errors  =sum(falarm)
 /finitem =last(trghit)
.
get file='d:\data\javier\stats\pfixagg0.sav'.
execute.

descriptives /variables=all.


if((trialtp= 0)and(attempt=1)) pfi0m1=ttltime.
if((trialtp= 0)and(attempt=2)) pfi0m2=ttltime.
if((trialtp= 0)and(attempt=3)) pfi0m3=ttltime.
if((trialtp=11)and(attempt=1)) pfi1d1=ttltime.
if((trialtp=11)and(attempt=2)) pfi1d2=ttltime.
if((trialtp=11)and(attempt=3)) pfi1d3=ttltime.
if((trialtp=11)and(attempt=4)) pfi1d4=ttltime.
if((trialtp=12)and(attempt=1)) pfi1l1=ttltime.
if((trialtp=12)and(attempt=2)) pfi1l2=ttltime.
if((trialtp=12)and(attempt=3)) pfi1l3=ttltime.
if((trialtp=12)and(attempt=4)) pfi1l4=ttltime.
if((trialtp=21)and(attempt=1)) pfi2d1=ttltime.
if((trialtp=21)and(attempt=2)) pfi2d2=ttltime.
if((trialtp=21)and(attempt=3)) pfi2d3=ttltime.
if((trialtp=21)and(attempt=4)) pfi2d4=ttltime.
if((trialtp=22)and(attempt=1)) pfi2l1=ttltime.
if((trialtp=22)and(attempt=2)) pfi2l2=ttltime.
if((trialtp=22)and(attempt=3)) pfi2l3=ttltime.
if((trialtp=22)and(attempt=4)) pfi2l4=ttltime.
if((trialtp=23)and(attempt=1)) pfi2s1=ttltime.
```

```
if((trialtp=23)and(attempt=2)) pfi2s2=ttltime.
if((trialtp=23)and(attempt=3)) pfi2s3=ttltime.
if((trialtp=23)and(attempt=4)) pfi2s4=ttltime.
if((trialtp=31)and(attempt=1)) pfi3d1=ttltime.
if((trialtp=31)and(attempt=2)) pfi3d2=ttltime.
if((trialtp=31)and(attempt=3)) pfi3d3=ttltime.
if((trialtp=31)and(attempt=4)) pfi3d4=ttltime.
if((trialtp=32)and(attempt=1)) pfi3l1=ttltime.
if((trialtp=32)and(attempt=2)) pfi3l2=ttltime.
if((trialtp=32)and(attempt=3)) pfi3l3=ttltime.
if((trialtp=32)and(attempt=4)) pfi3l4=ttltime.
if((trialtp=41)and(attempt=1)) pfi4d1=ttltime.
if((trialtp=41)and(attempt=2)) pfi4d2=ttltime.
if((trialtp=41)and(attempt=3)) pfi4d3=ttltime.
if((trialtp=41)and(attempt=4)) pfi4d4=ttltime.
if((trialtp=42)and(attempt=1)) pfi4l1=ttltime.
if((trialtp=42)and(attempt=2)) pfi4l2=ttltime.
if((trialtp=42)and(attempt=3)) pfi4l3=ttltime.
if((trialtp=42)and(attempt=4)) pfi4l4=ttltime.
if((trialtp=43)and(attempt=1)) pfi4s1=ttltime.
if((trialtp=43)and(attempt=2)) pfi4s2=ttltime.
if((trialtp=43)and(attempt=3)) pfi4s3=ttltime.
if((trialtp=43)and(attempt=4)) pfi4s4=ttltime.
if((trialtp= 0)and(attempt=1)) pfie0m1=errors.
if((trialtp= 0)and(attempt=2)) pfie0m2=errors.
if((trialtp= 0)and(attempt=3)) pfie0m3=errors.
if((trialtp=11)and(attempt=1)) pfie1d1=errors.
if((trialtp=11)and(attempt=2)) pfie1d2=errors.
if((trialtp=11)and(attempt=3)) pfie1d3=errors.
if((trialtp=11)and(attempt=4)) pfie1d4=errors.
if((trialtp=12)and(attempt=1)) pfie1l1=errors.
if((trialtp=12)and(attempt=2)) pfie1l2=errors.
if((trialtp=12)and(attempt=3)) pfie1l3=errors.
if((trialtp=12)and(attempt=4)) pfie1l4=errors.
if((trialtp=21)and(attempt=1)) pfie2d1=errors.
if((trialtp=21)and(attempt=2)) pfie2d2=errors.
if((trialtp=21)and(attempt=3)) pfie2d3=errors.
if((trialtp=21)and(attempt=4)) pfie2d4=errors.
if((trialtp=22)and(attempt=1)) pfie2l1=errors.
if((trialtp=22)and(attempt=2)) pfie2l2=errors.
if((trialtp=22)and(attempt=3)) pfie2l3=errors.
if((trialtp=22)and(attempt=4)) pfie2l4=errors.
if((trialtp=23)and(attempt=1)) pfie2s1=errors.
if((trialtp=23)and(attempt=2)) pfie2s2=errors.
```

```
if((trialtp=23)and(attempt=3)) pfie2s3=errors.
if((trialtp=23)and(attempt=4)) pfie2s4=errors.
if((trialtp=31)and(attempt=1)) pfie3d1=errors.
if((trialtp=31)and(attempt=2)) pfie3d2=errors.
if((trialtp=31)and(attempt=3)) pfie3d3=errors.
if((trialtp=31)and(attempt=4)) pfie3d4=errors.
if((trialtp=32)and(attempt=1)) pfie3l1=errors.
if((trialtp=32)and(attempt=2)) pfie3l2=errors.
if((trialtp=32)and(attempt=3)) pfie3l3=errors.
if((trialtp=32)and(attempt=4)) pfie3l4=errors.
if((trialtp=41)and(attempt=1)) pfie4d1=errors.
if((trialtp=41)and(attempt=2)) pfie4d2=errors.
if((trialtp=41)and(attempt=3)) pfie4d3=errors.
if((trialtp=41)and(attempt=4)) pfie4d4=errors.
if((trialtp=42)and(attempt=1)) pfie4l1=errors.
if((trialtp=42)and(attempt=2)) pfie4l2=errors.
if((trialtp=42)and(attempt=3)) pfie4l3=errors.
if((trialtp=42)and(attempt=4)) pfie4l4=errors.
if((trialtp=43)and(attempt=1)) pfie4s1=errors.
if((trialtp=43)and(attempt=2)) pfie4s2=errors.
if((trialtp=43)and(attempt=3)) pfie4s3=errors.
if((trialtp=43)and(attempt=4)) pfie4s4=errors.
if((trialtp= 0)and(attempt=1)) pfim0m1=misses.
if((trialtp= 0)and(attempt=2)) pfim0m2=misses.
if((trialtp= 0)and(attempt=3)) pfim0m3=misses.
if((trialtp=11)and(attempt=1)) pfim1d1=misses.
if((trialtp=11)and(attempt=2)) pfim1d2=misses.
if((trialtp=11)and(attempt=3)) pfim1d3=misses.
if((trialtp=11)and(attempt=4)) pfim1d4=misses.
if((trialtp=12)and(attempt=1)) pfim1l1=misses.
if((trialtp=12)and(attempt=2)) pfim1l2=misses.
if((trialtp=12)and(attempt=3)) pfim1l3=misses.
if((trialtp=12)and(attempt=4)) pfim1l4=misses.
if((trialtp=21)and(attempt=1)) pfim2d1=misses.
if((trialtp=21)and(attempt=2)) pfim2d2=misses.
if((trialtp=21)and(attempt=3)) pfim2d3=misses.
if((trialtp=21)and(attempt=4)) pfim2d4=misses.
if((trialtp=22)and(attempt=1)) pfim2l1=misses.
if((trialtp=22)and(attempt=2)) pfim2l2=misses.
if((trialtp=22)and(attempt=3)) pfim2l3=misses.
if((trialtp=22)and(attempt=4)) pfim2l4=misses.
if((trialtp=23)and(attempt=1)) pfim2s1=misses.
if((trialtp=23)and(attempt=2)) pfim2s2=misses.
if((trialtp=23)and(attempt=3)) pfim2s3=misses.
```

```
if((trialtp=23)and(attempt=4)) pfim2s4=misses.
if((trialtp=31)and(attempt=1)) pfim3d1=misses.
if((trialtp=31)and(attempt=2)) pfim3d2=misses.
if((trialtp=31)and(attempt=3)) pfim3d3=misses.
if((trialtp=31)and(attempt=4)) pfim3d4=misses.
if((trialtp=32)and(attempt=1)) pfim3l1=misses.
if((trialtp=32)and(attempt=2)) pfim3l2=misses.
if((trialtp=32)and(attempt=3)) pfim3l3=misses.
if((trialtp=32)and(attempt=4)) pfim3l4=misses.
if((trialtp=41)and(attempt=1)) pfim4d1=misses.
if((trialtp=41)and(attempt=2)) pfim4d2=misses.
if((trialtp=41)and(attempt=3)) pfim4d3=misses.
if((trialtp=41)and(attempt=4)) pfim4d4=misses.
if((trialtp=42)and(attempt=1)) pfim4l1=misses.
if((trialtp=42)and(attempt=2)) pfim4l2=misses.
if((trialtp=42)and(attempt=3)) pfim4l3=misses.
if((trialtp=42)and(attempt=4)) pfim4l4=misses.
if((trialtp=43)and(attempt=1)) pfim4s1=misses.
if((trialtp=43)and(attempt=2)) pfim4s2=misses.
if((trialtp=43)and(attempt=3)) pfim4s3=misses.
if((trialtp=43)and(attempt=4)) pfim4s4=misses.
execute.

select if(finitem=24).
execute.

descriptives /variables=all.

aggregate outfile='d:\data\javier\stats\pfixagg1.sav'
 /break=subid
 /pfidate =first(pfidate)
 /pfitime =first(pfitime)
 /pfietime=last(pfietim)
 /pfi0m1  =mean(pfi0m1 )
 /pfi0m2  =mean(pfi0m2 )
 /pfi0m3  =mean(pfi0m3 )
 /pfi1d1  =mean(pfi1d1 )
 /pfi1d2  =mean(pfi1d2 )
 /pfi1d3  =mean(pfi1d3 )
 /pfi1d4  =mean(pfi1d4 )
 /pfi1l1  =mean(pfi1l1 )
 /pfi1l2  =mean(pfi1l2 )
 /pfi1l3  =mean(pfi1l3 )
 /pfi1l4  =mean(pfi1l4 )
```

```
/pfi2d1  =mean(pfi2d1 )
/pfi2d2  =mean(pfi2d2 )
/pfi2d3  =mean(pfi2d3 )
/pfi2d4  =mean(pfi2d4 )
/pfi2l1  =mean(pfi2l1 )
/pfi2l2  =mean(pfi2l2 )
/pfi2l3  =mean(pfi2l3 )
/pfi2l4  =mean(pfi2l4 )
/pfi2s1  =mean(pfi2s1 )
/pfi2s2  =mean(pfi2s2 )
/pfi2s3  =mean(pfi2s3 )
/pfi2s4  =mean(pfi2s4 )
/pfi3d1  =mean(pfi3d1 )
/pfi3d2  =mean(pfi3d2 )
/pfi3d3  =mean(pfi3d3 )
/pfi3d4  =mean(pfi3d4 )
/pfi3l1  =mean(pfi3l1 )
/pfi3l2  =mean(pfi3l2 )
/pfi3l3  =mean(pfi3l3 )
/pfi3l4  =mean(pfi3l4 )
/pfi4d1  =mean(pfi4d1 )
/pfi4d2  =mean(pfi4d2 )
/pfi4d3  =mean(pfi4d3 )
/pfi4d4  =mean(pfi4d4 )
/pfi4l1  =mean(pfi4l1 )
/pfi4l2  =mean(pfi4l2 )
/pfi4l3  =mean(pfi4l3 )
/pfi4l4  =mean(pfi4l4 )
/pfi4s1  =mean(pfi4s1 )
/pfi4s2  =mean(pfi4s2 )
/pfi4s3  =mean(pfi4s3 )
/pfi4s4  =mean(pfi4s4 )
/pfie0m1 =mean(pfie0m1)
/pfie0m2 =mean(pfie0m2)
/pfie0m3 =mean(pfie0m3)
/pfie1d1 =mean(pfie1d1)
/pfie1d2 =mean(pfie1d2)
/pfie1d3 =mean(pfie1d3)
/pfie1d4 =mean(pfie1d4)
/pfie1l1 =mean(pfie1l1)
/pfie1l2 =mean(pfie1l2)
/pfie1l3 =mean(pfie1l3)
/pfie1l4 =mean(pfie1l4)
/pfie2d1 =mean(pfie2d1)
```

```
/pfie2d2 =mean(pfie2d2)
/pfie2d3 =mean(pfie2d3)
/pfie2d4 =mean(pfie2d4)
/pfie2l1 =mean(pfie2l1)
/pfie2l2 =mean(pfie2l2)
/pfie2l3 =mean(pfie2l3)
/pfie2l4 =mean(pfie2l4)
/pfie2s1 =mean(pfie2s1)
/pfie2s2 =mean(pfie2s2)
/pfie2s3 =mean(pfie2s3)
/pfie2s4 =mean(pfie2s4)
/pfie3d1 =mean(pfie3d1)
/pfie3d2 =mean(pfie3d2)
/pfie3d3 =mean(pfie3d3)
/pfie3d4 =mean(pfie3d4)
/pfie3l1 =mean(pfie3l1)
/pfie3l2 =mean(pfie3l2)
/pfie3l3 =mean(pfie3l3)
/pfie3l4 =mean(pfie3l4)
/pfie4d1 =mean(pfie4d1)
/pfie4d2 =mean(pfie4d2)
/pfie4d3 =mean(pfie4d3)
/pfie4d4 =mean(pfie4d4)
/pfie4l1 =mean(pfie4l1)
/pfie4l2 =mean(pfie4l2)
/pfie4l3 =mean(pfie4l3)
/pfie4l4 =mean(pfie4l4)
/pfie4s1 =mean(pfie4s1)
/pfie4s2 =mean(pfie4s2)
/pfie4s3 =mean(pfie4s3)
/pfie4s4 =mean(pfie4s4)
/pfim0m1 =mean(pfim0m1)
/pfim0m2 =mean(pfim0m2)
/pfim0m3 =mean(pfim0m3)
/pfim1d1 =mean(pfim1d1)
/pfim1d2 =mean(pfim1d2)
/pfim1d3 =mean(pfim1d3)
/pfim1d4 =mean(pfim1d4)
/pfim1l1 =mean(pfim1l1)
/pfim1l2 =mean(pfim1l2)
/pfim1l3 =mean(pfim1l3)
/pfim1l4 =mean(pfim1l4)
/pfim2d1 =mean(pfim2d1)
/pfim2d2 =mean(pfim2d2)
```

```
/pfim2d3 =mean(pfim2d3)
/pfim2d4 =mean(pfim2d4)
/pfim2l1 =mean(pfim2l1)
/pfim2l2 =mean(pfim2l2)
/pfim2l3 =mean(pfim2l3)
/pfim2l4 =mean(pfim2l4)
/pfim2s1 =mean(pfim2s1)
/pfim2s2 =mean(pfim2s2)
/pfim2s3 =mean(pfim2s3)
/pfim2s4 =mean(pfim2s4)
/pfim3d1 =mean(pfim3d1)
/pfim3d2 =mean(pfim3d2)
/pfim3d3 =mean(pfim3d3)
/pfim3d4 =mean(pfim3d4)
/pfim3l1 =mean(pfim3l1)
/pfim3l2 =mean(pfim3l2)
/pfim3l3 =mean(pfim3l3)
/pfim3l4 =mean(pfim3l4)
/pfim4d1 =mean(pfim4d1)
/pfim4d2 =mean(pfim4d2)
/pfim4d3 =mean(pfim4d3)
/pfim4d4 =mean(pfim4d4)
/pfim4l1 =mean(pfim4l1)
/pfim4l2 =mean(pfim4l2)
/pfim4l3 =mean(pfim4l3)
/pfim4l4 =mean(pfim4l4)
/pfim4s1 =mean(pfim4s1)
/pfim4s2 =mean(pfim4s2)
/pfim4s3 =mean(pfim4s3)
/pfim4s4 =mean(pfim4s4)
.

get file='d:\data\javier\stats\pfixagg1.sav'.

descriptives /variables=all.

correlations /variables=
 PFI0M1
 PFI0M2
 PFI0M3
 PFI1D1
 PFI1D2
 PFI1D3
 PFI1D4
```

```
PFI1L1
PFI1L2
PFI1L3
PFI1L4
PFI2D1
PFI2D2
PFI2D3
PFI2D4
PFI2L1
PFI2L2
PFI2L3
PFI2L4
PFI2S1
PFI2S2
PFI2S3
PFI2S4
PFI3D1
PFI3D2
PFI3D3
PFI3D4
PFI3L1
PFI3L2
PFI3L3
PFI3L4
PFI4D1
PFI4D2
PFI4D3
PFI4D4
PFI4L1
PFI4L2
PFI4L3
PFI4L4
PFI4S1
PFI4S2
PFI4S3
PFI4S4
/print=nosig.

compute pfi0m = mean(pfi0m1 to pfi0m3).
compute pfi1d = mean(pfi1d1 to pfi1d4).
compute pfi1l = mean(pfi1l1 to pfi1l4).
compute pfi2d = mean(pfi2d1 to pfi2d4).
compute pfi2l = mean(pfi2l1 to pfi2l4).
compute pfi2s = mean(pfi2s1 to pfi2s4).
```

```
compute pfi3d = mean(pfi3d1 to pfi3d4).
compute pfi3l = mean(pfi3l1 to pfi3l4).
compute pfi4d = mean(pfi4d1 to pfi4d4).
compute pfi4l = mean(pfi4l1 to pfi4l4).
compute pfi4s = mean(pfi4s1 to pfi4s4).
execute.

correlations /variables=
 pfi0m
 pfi1d
 pfi1l
 pfi2d
 pfi2l
 pfi2s
 pfi3d
 pfi3l
 pfi4d
 pfi4l
 pfi4s
 /print=nosig.

sort cases by subid.
save outfile='d:\data\javier\stats\pfixagg2.sav'
 /keep=
 SUBID
 PFIDATE
 PFITIME
 PFIETIME
 pfi0m
 pfi1d
 pfi1l
 pfi2d
 pfi2l
 pfi2s
 pfi3d
 pfi3l
 pfi4d
 pfi4l
 pfi4s
 .

get file='d:\data\javier\stats\pfixagg2.sav'

descriptives /variables=all.
```

```
examine /variables=
pfi0m
 pfi1d
 pfi1l
 pfi2d
 pfi2l
 pfi2s
 pfi3d
 pfi3l
 pfi4d
 pfi4l
 pfi4s
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

*******************************************.
* SIMPLE RT PROCESSING
*******************************************.

data list file='d:\data\javier\data\srt.dat'
 /testid 1-10 (a) subid 11-20 date 21-29 (a) time 31-40 (time) block 41-45
 trial 46-50 trialx 51-55 delay 56-60 srt 61-70.
execute.

means tables=srt by subid.

compute xsrt10=trunc(srt/10).
frequencies xsrt10.

examine /variables=srt /plot=stemleaf.

recode srt (30 thru 790=copy)(else=sysmis).

examine /variables=srt /plot=stemleaf.

sort cases by subid block.
split file by subid block.
descriptives /variables=srt(zsrt).
split file off.

***** WHAT IS THE EFFECT? *****.
temporary.
select if((zsrt ge -3.00)and(zsrt le 3.00)).
```

```
means tables=srt by subid.

examine /variables=srt /plot=stemleaf boxplot histogram npplot.


***** EXCLUDE VALUES MORE THEN 3 SD FROM ANALYSIS *****.
if((zsrt lt -3.00)or(zsrt gt 3.00)) srt=-1.
recode srt (-1=sysmis)(1 thru hi=copy).
frequencies srt.

if((block=1)) srt1=srt.
if((block=2)) srt2=srt.
if((block=3)) srt3=srt.

sort cases by subid  block.
aggregate outfile='d:\data\javier\stats\srtagg0.sav'
 /break=subid
 /xsrtdate =first(date)
 /xsrttime =first(time)
 /xsrt1=mean(srt1)
 /xsrt2=mean(srt2)
 /xsrt3=mean(srt3)
.

get file='d:\data\javier\stats\srtagg0.sav'.
descriptives /variables=all.
compute xxsrt=mean(xsrt1,xsrt2,xsrt3).
examine /variables=xxsrt
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

correlations /variables=xsrt1 xsrt2 xsrt3 /print=nosig.

save outfile='d:\data\javier\stats\srtagg0.sav'.

********************************************.
* CARD SORTING
********************************************.

data list file='d:\data\javier\data\csr.dat'
 /testid 1-10 (a) subid 11-20 date 21-29 (a)
 time 31-40 (time) block 41-45 trial 46-50
 trialx 51-55 target 60 (a)  nodistr 61-65
```

```
csrrt 66-75 csracc 76-80.
execute.

compute xcsrrt10=trunc(csrrt/10).
frequencies xcsrrt10.

examine /variables=csrrt /plot=stemleaf.

recode csrrt (350 thru 1880=copy)(else=sysmis).

examine /variables=csrrt /plot=stemleaf.

sort cases by subid block nodistr.
split file by subid block nodistr.
descriptives /variables=csrrt(zcsrrt).
split file off.


***** WHAT IS THE EFFECT? *****.
temporary.
select if((zcsrrt ge -3.00)and(zcsrrt le 3.00)).
means tables=csrrt by subid.

***** EXCLUDE VALUES MORE THEN 3 SD FROM ANALYSIS *****.
if((zcsrrt lt -3.00)or(zcsrrt gt 3.00)) csrrt=-1.
if((zcsrrt lt -3.00)or(zcsrrt gt 3.00)) csracc=-1.
recode csrrt (-1=sysmis)(1 thru hi=copy).
recode csracc (-1=sysmis)(1 thru hi=copy).

examine /variables=csrrt /plot=stemleaf.

***** REMOVE RT FOR ERROR RESPONSES ******.
if(csracc=0) csrrt=-1.
recode csrrt (-1=sysmis)(0 thru hi=copy).

if((block=0)and(nodistr=0)) csrt01=csrrt.
if((block=1)and(nodistr=0)) csrt02=csrrt.
if((block=2)and(nodistr=0)) csrt03=csrrt.
if((block=0)and(nodistr=4)) csrt41=csrrt.
if((block=1)and(nodistr=4)) csrt42=csrrt.
if((block=2)and(nodistr=4)) csrt43=csrrt.
if((block=0)and(nodistr=8)) csrt81=csrrt.
if((block=1)and(nodistr=8)) csrt82=csrrt.
if((block=2)and(nodistr=8)) csrt83=csrrt.
```

```
if((block=0)and(nodistr=0)) csra01=csracc.
if((block=1)and(nodistr=0)) csra02=csracc.
if((block=2)and(nodistr=0)) csra03=csracc.
if((block=0)and(nodistr=4)) csra41=csracc.
if((block=1)and(nodistr=4)) csra42=csracc.
if((block=2)and(nodistr=4)) csra43=csracc.
if((block=0)and(nodistr=8)) csra81=csracc.
if((block=1)and(nodistr=8)) csra82=csracc.
if((block=2)and(nodistr=8)) csra83=csracc.

sort cases by subid block.
aggregate outfile='d:\data\javier\stats\csrxagg0.sav'
 /break=subid
 /xcsrdate =first(date)
 /xcsrtime =first(time)
 /csrt01=mean(csrt01)
 /csrt02=mean(csrt02)
 /csrt03=mean(csrt03)
 /csrt41=mean(csrt41)
 /csrt42=mean(csrt42)
 /csrt43=mean(csrt43)
 /csrt81=mean(csrt81)
 /csrt82=mean(csrt82)
 /csrt83=mean(csrt83)
 /csra01=mean(csra01)
 /csra02=mean(csra02)
 /csra03=mean(csra03)
 /csra41=mean(csra41)
 /csra42=mean(csra42)
 /csra43=mean(csra43)
 /csra81=mean(csra81)
 /csra82=mean(csra82)
 /csra83=mean(csra83)
.

get file='d:\data\javier\stats\csrxagg0.sav'.

descriptives /variables=all.

correlations /variables=
CSRT01
CSRT02
CSRT03
CSRT41
```

```
CSRT42
CSRT43
CSRT81
CSRT82
CSRT83
/print=nosig.

compute xcsr1=mean(csrt01,csrt41,csrt81).
compute xcsr2=mean(csrt02,csrt42,csrt82).
compute xcsr3=mean(csrt03,csrt43,csrt83).

compute xcsrx0=mean(csrt01,csrt02,csrt03).
compute xcsrx4=mean(csrt41,csrt42,csrt43).
compute xcsrx8=mean(csrt81,csrt82,csrt83).

compute xxcsr=mean(xcsr1,xcsr2,xcsr3).
execute.
examine /variables=xxcsr
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

graph /scatterplot(matrix)=xcsr1 xcsr2 xcsr3.

list subid xcsr1 xcsr2 xcsr3.

save outfile='d:\data\javier\stats\csrxagg0.sav'.


*******************************************.
* TME EZ PROCESSING
*******************************************.

data list file='d:\data\javier\data\tm2\averageez.dat' fixed records=1
/subid 1-4 sequence 5-6 (a) averaez 14-20.
execute.
frequency variables=averaez.

examine /variables=averaez
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\averageezx.sav'.
```

```
****************************************.
data list file='d:\data\javier\data\tm1\tm1EZ\tm1EZ.dat' fixed records=14
/subid 1-4 sequence 5-6 (a) printez 142-147
/
/
/
/
/
/
/
/
/
/
/
/
/.

execute.
compute printEZx=(printez/33)*100.

frequency variables=printEZx.
examine /variables=printEZx
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\Ezprintscore.sav'.
***********************************************.
data list file='d:\data\javier\data\tm2\ErrorTimeTME_EZ.dat' fixed records=1
/subid 1-4 sequence 5-6 (a) ETeasy 14-17.
execute.
compute ETeasyx=(ETeasy/6001)*100.

frequency variables=ETeasyx.

examine /variables=ETeasyx
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\ErrorTimeEzx.sav'.
```

```
*****************************************.
* TME DF PROCESSING
*****************************************.

data list file='d:\data\javier\data\tm2\averagediff.dat' fixed records=1
 /subid 1-4 sequence 5-6 (a) averadf 16-22.
execute.
frequency variables=averadf.

examine /variables=averadf
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\averageDfx.sav'.

***********************************.
data list file='d:\data\javier\data\tm1\tm1Diff\tm1Diff.dat' fixed records=14
/subid 1-4 sequence 5-6 (a) printdf 142-147
/
/
/
/
/
/
/
/
/
/
/
/
/.
execute.
compute printDFx=(printdf/37)*100.

frequency variables=printDFx.
examine /variables=printDFx
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\Dfprintscore.sav'.
*********************************************.
data list file='d:\data\javier\data\tm2\ErrorTimeTME_Diff.dat' fixed records=1
```

```
/subid 1-4 sequence 5-6 (a) ETDiff 16-19.
execute.
compute ETDiffx=(ETDiff/6001)*100.

frequency variables=ETDiffx.

examine /variables=ETDiffx
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\ErrorTimeDiffx.sav'.

*****************************************************************.
*****GLOBAL ANYLYSIS*************.
*****************************************************************.

match files file='d:\data\javier\stats\ppt.sav'
/file='d:\data\javier\stats\pfixagg2.sav'
/file='d:\data\javier\stats\srtagg0.sav'
/file='d:\data\javier\stats\csrxagg0.sav'
/file='d:\data\javier\stats\averageezx.sav'
/file='d:\data\javier\stats\Ezprintscore.sav'
/file='d:\data\javier\stats\averageDfx.sav'
/file='d:\data\javier\stats\Dfprintscore.sav'
/file='d:\data\javier\stats\ErrorTimeEZx.sav'
/file='d:\data\javier\stats\ErrorTimeDiffx.sav'
/by subid
/map.
execute.

descriptives /variables=
xmdmqbp
xmdmqvi
xmdmqpr
xmdmqhv
synattl
xxsrt
xxcsr
pfi0m
pfi1d
pfi1l
pfi2d
pfi2l
```

```
pfi2s
pfi3d
pfi3l
pfi4d
pfi4l
pfi4s
averaez
printEZx
eteasyx
averadf
printDFx
etdiffx
/statistics=mean stddev semean min max.

examine /variables=
xmdmqbp
xmdmqvi
xmdmqpr
xmdmqhv
synattl
xxsrt
xxcsr
pfi0m
pfi1d
pfi1l
pfi2d
pfi2l
pfi2s
pfi3d
pfi3l
pfi4d
pfi4l
pfi4s
averaez
printEZx
eteasyx
averadf
printDFx
etdiffx
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.
```

```
***********************************************************
*********
****** OUTLIER TREATMENT *******************.
*****************************************************************.

*******Path Finding Outlier Processing*********************.

if (pfi0m >=22603.66) pfi0m=22503.
examine /variables=pfi0m
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

if (pfi1d >43141) pfi1d=43141.
examine /variables=pfi1d
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

if (pfi1l >48645.5) pfi1l=48645.5.
examine /variables=pfi1l
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

if (pfi2d >67753.5) pfi2d=67753.5.
examine /variables=pfi2d
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

if (pfi2l >107216) pfi2l=107216.
examine /variables=pfi2l
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

if (pfi2s >73092.5) pfi2s=73092.5.
examine /variables=pfi2s
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

if (pfi3d >93659.5) pfi3d=93659.5.
```

```
examine /variables=pfi3d
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

if (pfi3l >189943.5) pfi3l=189943.5.
examine /variables=pfi3l
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

if (pfi4d >124676) pfi4d=124676.
examine /variables=pfi4d
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

if (pfi4l>186866) pfi4l=186866.
examine /variables=pfi4l
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

if (pfi4s >141239.5) pfi4s=141239.5.
examine /variables=pfi4s
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\OUTLpfixagg2.sav'

***** SIMPLE REACTION TIME OUTLIERS TREATMENT ***************.

if (xxsrt >301.2794) xxsrt=301.2794.
examine /variables=xxsrt
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\OUTLsrtagg0.sav'.

*********CARD SORTING OUTLIERS TREATMENT********************.

if (xxcsr >771.12) xxcsr=771.12.
```

```
examine /variables=xxcsr
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\OUTLcsrxagg0.sav'.

*********TME EASY OUTLIERS TREATMENT ************************.

get file='d:\data\javier\stats\averageezx.sav'.

if (averaez < 41.886) averaez=41.886.
examine /variables=averaez
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\OUTLaverageezx.sav'.

get file='d:\data\javier\stats\Ezprintscore.sav'.

if(printEZx <18.49) printEZx=18.49.
examine /variables=printEZx
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\OUTLEzprintscore.sav'.

get file='d:\data\javier\stats\ErrorTimeEzx.sav'.

if(ETeasyx > 85.036) ETeasyx=85.03582736211.
examine /variables=ETeasyx
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\OUTLErrorTimeEZx.sav'.


********* TME DIFFICULT OUTLIERS TREATMENT*****************.

get file='d:\data\javier\stats\averageDfx.sav'.
```

```
if (averadf <29.92) averadf=29.92.
examine /variables=averadf
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\OUTLaverageDfx.sav'.

*** GLOBAL ANALYSIS AFTER OUTLIERS TREATMENT**************.

match files file='d:\data\javier\stats\ppt.sav'
/file='d:\data\javier\stats\OUTLpfixagg2.sav'
/file='d:\data\javier\stats\OUTLsrtagg0.sav'
/file='d:\data\javier\stats\OUTLcsrxagg0.sav'
/file='d:\data\javier\stats\OUTLaverageezx.sav'
/file='d:\data\javier\stats\OUTLEzprintscore.sav'
/file='d:\data\javier\stats\OUTLaverageDfx.sav'
/file='d:\data\javier\stats\Dfprintscore.sav'
/file='d:\data\javier\stats\OUTLErrorTimeEZx.sav'
/file='d:\data\javier\stats\ErrorTimeDiffx.sav'
/by subid
/map.
execute.

descriptives /variables=
xmdmqbp
xmdmqvi
xmdmqpr
xmdmqhv
synattl
xxsrt
xxcsr
pfi0m
pfi1d
pfi1l
pfi2d
pfi2l
pfi2s
pfi3d
pfi3l
pfi4d
pfi4l
pfi4s
averaez
```

```
printEZx
eteasyx
averadf
printDFx
etdiffx
/statistics=mean stddev semean min max.

frequencies /variables=
xmdmqbp
xmdmqvi
xmdmqpr
xmdmqhv
synattl
xxsrt
xxcsr
pfi0m
pfi1d
pfi1l
pfi2d
pfi2l
pfi2s
pfi3d
pfi3l
pfi4d
pfi4l
pfi4s
averaez
printEZx
eteasyx
averadf
printDFx
etdiffx
/hist=normal
/percentiles=10 25 33.3 66.7 75.


*********Correlation for whole Population************.

correlations /variables=
age
eduyrs
xmdmqbp
xmdmqvi
xmdmqpr
```

```
xmdmqhv
synattl
xxsrt
xxcsr
pfi0m
pfi1d
pfi1l
pfi2d
pfi2l
pfi2s
pfi3d
pfi3l
pfi4d
pfi4l
pfi4s
averaez
printEZx
averadf
printDFx
eteasyx
etdiffx.

graph /scatterplot(matrix)=
age
eduyrs
xmdmqbp
xmdmqvi
xmdmqpr
xmdmqhv
averaez
printEZx
eteasyx
averadf
printDFx
etdiffx.

**********Regression****************************************.

REGRESSION /VARIABLES=
age
eduyrs
xmdmqbp
xmdmqvi
xmdmqpr
```

```
xmdmqhv
synattl
xxsrt
xxcsr
pfi0m
pfi1d
pfi1l
pfi2d
pfi2l
pfi2s
pfi3d
pfi3l
pfi4d
pfi4l
pfi4s
averaez
printEZx
eteasyx
averadf
printDFx
etdiffx
/DEPENDENT=
averaez
printEZx
eteasyx
averadf
printDFx
etdiffx
/METHOD=forward
/RESIDUALS
/CASEWISE=outliers(10)
/SCATTERPLOT (*ZRESID *ZPRED)
/PARTIALPLOT.

******************** GENDER ANALYSIS ***********************.

recode sex ('f'=1)('m'=0) into xfemale.
frequencies xfemale.

means tables=printEZx printDFx averaez averadf eteasyx etdiffx by xfemale.

t-test groups=xfemale(0,1) /variables=printEZx printDFx averaez averadf eteasyx
etdiffx.
```

```
graph /bar=xfemale by mean(printEZx).

sort cases by xfemale.
split file by xfemale.
correlations /variables=
xfemale age
eduyrs
xmdmqbp
xmdmqvi
xmdmqpr
xmdmqhv
synattl
xxsrt
xxcsr
pfi0m
pfi1d
pfi1l
pfi2d
pfi2l
pfi2s
pfi3d
pfi3l
pfi4d
pfi4l
pfi4s
averaez
printEZx
eteasyx
averadf
printDFx
etdiffx
.

examine /variables=age /plot=stemleaf.
examine /variables=eduyrs /plot=stemleaf.
frequency variables=edulev.
means tables=age eduyrs by xfemale.
list subid age sex eduyrs synattl xsrt1 xsrt2 xcsr1 xcsr2 pfi0m pfi1d averaez averadf
printEZx printDFx eteasyx etdiffx.

correlations /variables=
age xfemale
synattl
pfi4l
```

```
xxsrt
xxcsr
printEZx
printDFx.

graph /scatterplot(matrix)=
age xfemale
synattl
pfi4l
xxsrt
xxcsr
printEZx
printDFx.

graph /scatterplot(matrix)=
pfi4l
xxcsr
printEZx
printDFx.

examine /variables=
printEZx
printDFx.

*********** ANALYSIS BY SCENARIO ORDER***********************.

recode sequence ('S1'=1)('S2'=2) into xorder.

frequencies xorder.

means tables=printEZx printDFx averaez averadf eteasyx etdiffx by xorder.

t-test groups=xorder(1,2) /variables=printEZx printDFx averaez averadf eteasyx
etdiffx.

sort cases by xorder.
split file by xorder.
correlations /variables=
xfemale
age
eduyrs
xmdmqbp
xmdmqvi
xmdmqpr
```

```
xmdmqhv
synattl
xxsrt
xxcsr
pfi0m
pfi1d
pfi1l
pfi2d
pfi2l
pfi2s
pfi3d
pfi3l
pfi4d
pfi4l
pfi4s
averaez
printEZx
eteasyx
averadf
printDFx
etdiffx.
split file off.

sort cases by xorder.
split file by xorder.
graph /scatterplot(matrix)=
pfi4l
xxcsr
printEZx
printDFx
averaez
averadf
eteasyx
etdiffx.
split file off.


means tables=
synattl
xxsrt
xxcsr
 PFI0M
 PFI1D
 PFI1L
```

```
 PFI2D
 PFI2L
 PFI2S
averaez
averadf
printEZx
printDFx
by xorder.


*****************************************************************.
********* PRACTICE TRIALS ANALYSIS*****.
*****************************************************************.

********** TME P1 PROCESSING *****************************.

data list file='d:\data\javier\data\tm2\AverageP1.dat' fixed records=1
/subid 1-4 sequence 5-6 (a) averaP1 16-22.
execute.
save outfile='d:\data\javier\stats\averageP1x.sav'.

***********************************.
data list file='d:\data\javier\data\tm1\tm1P1\tm1P1.dat' fixed records=14
/subid 1-4 sequence 5-6 (a) printP1 142-147
/
/
/
/
/
/
/
/
/
/
/
/
/.
execute.
compute printP1x=(printP1/33)*100.
save outfile='d:\data\javier\stats\P1printscore.sav'.


********* TME P2 PROCESSING **************************.
```

```
data list file='d:\data\javier\data\tm2\AverageP2.dat' fixed records=1
/subid 1-4 sequence 5-6 (a) averaP2 16-22.
execute.
save outfile='d:\data\javier\stats\averageP2x.sav'.

***********************************.
data list file='d:\data\javier\data\tm1\tm1P2\tm1P2.dat' fixed records=14
/subid 1-4 sequence 5-6 (a) printP2 142-147
/
/
/
/
/
/
/
/
/
/
/
/
/.
execute.
compute printP2x=(printP2/33)*100.
save outfile='d:\data\javier\stats\P2printscore.sav'.


**************** TME P3 PROCESSING ****************************.

data list file='d:\data\javier\data\tm2\AverageP3.dat' fixed records=1
/subid 1-4 sequence 5-6 (a) averaP3 16-22.
execute.
save outfile='d:\data\javier\stats\averageP3x.sav'.

***********************************.
data list file='d:\data\javier\data\tm1\tm1P3\tm1P3.dat' fixed records=14
/subid 1-4 sequence 5-6 (a) printP3 142-147
/
/
/
/
/
/
/
```

```
/
/
/
/
/
/.
execute.
compute printP3x=(printP3/33)*100.
save outfile='d:\data\javier\stats\P3printscore.sav'.

***************** TME P4 PROCESSING ***************************.

data list file='d:\data\javier\data\tm2\AverageP4.dat' fixed records=1
/subid 1-4 sequence 5-6 (a) averaP4 16-22.
execute.
save outfile='d:\data\javier\stats\averageP4x.sav'.

***********************************.
data list file='d:\data\javier\data\tm1\tm1P4\tm1P4.dat' fixed records=14
/subid 1-4 sequence 5-6 (a) printP4 142-147
/
/
/
/
/
/
/
/
/
/
/
/
/.
execute.
compute printP4x=(printP4/33)*100.
save outfile='d:\data\javier\stats\P4printscore.sav'.

***************** TME P5 PROCESSING **********************.

data list file='d:\data\javier\data\tm2\AverageP5.dat' fixed records=1
/subid 1-4 sequence 5-6 (a) averaP5 16-22.
execute.
save outfile='d:\data\javier\stats\averageP5x.sav'.
```

```
***********************************.
data list file='d:\data\javier\data\tm1\tm1P5\tm1P5.dat' fixed records=14
/subid 1-4 sequence 5-6 (a) printP5 142-147
/
/
/
/
/
/
/
/
/
/
/
/
/.
execute.
compute printP5x=(printP5/33)*100.
save outfile='d:\data\javier\stats\P5printscore.sav'.

*****************examine practice************.

match files file='d:\data\javier\stats\averageP1x.sav'
/file='d:\data\javier\stats\averageP2x.sav'
/file='d:\data\javier\stats\averageP3x.sav'
/file='d:\data\javier\stats\averageP4x.sav'
/file='d:\data\javier\stats\averageP5x.sav'
/file='d:\data\javier\stats\P1printscore.sav'
/file='d:\data\javier\stats\P2printscore.sav'
/file='d:\data\javier\stats\P3printscore.sav'
/file='d:\data\javier\stats\P4printscore.sav'
/file='d:\data\javier\stats\P5printscore.sav'
/file='d:\data\javier\stats\OUTLaverageezx.sav'
/file='d:\data\javier\stats\OUTLEzprintscore.sav'
/file='d:\data\javier\stats\OUTLaverageDfx.sav'
/file='d:\data\javier\stats\Dfprintscore.sav'
/by subid
/map.
execute.

descriptives /variables=
averaP1
averaP2
averaP3
```

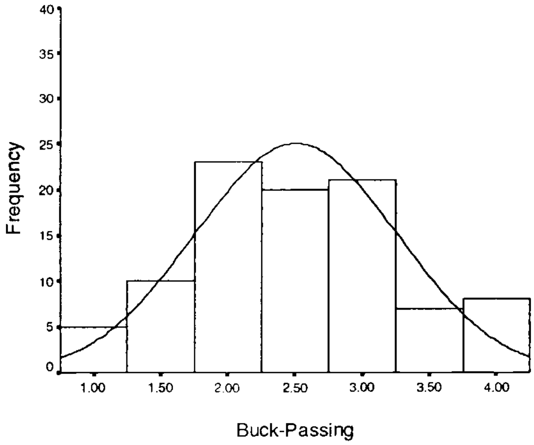
```
averaP4
averaP5
printP1x
printP2x
printP3x
printP4x
printP5x
/statistics=mean stddev semean min max.

examine /variables=
averaP1
averaP2
averaP3
averaP4
averaP5
printP1x
printP2x
printP3x
printP4x
printP5x
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

correlations /variables=
printP1x
printP2x
printP3x
printP4x
printP5x
.

graph /line=mean(
printP1x
printP2x
printP3x
printP4x
printP5x
printEZx
printDFx).
graph /errorbar(stddev)=printP1x
printP2x
printP3x
printP4x
```

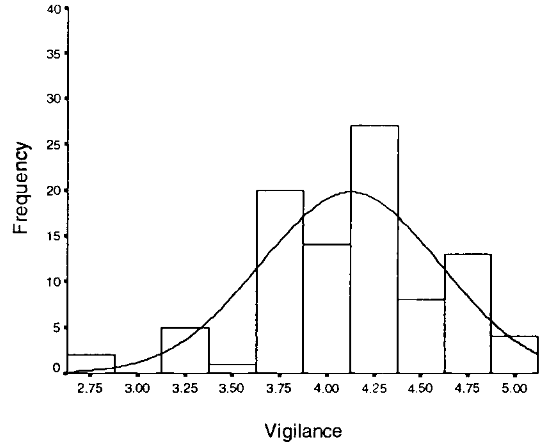
```
printP5x
printEZx
printDFx.

t-test pairs=printP5x printP4x.
t-test pairs=printEZx printDFx.

recode sequence ('S1'=1)('S2'=2) into xorder.

frequencies xorder.

means tables=printEZx printDFx averaez averadf  by xorder.

t-test groups=xorder(1,2) /variables=printEZx printDFx averaez averadf.

sort cases by xorder.
split file by xorder.
correlations /variables=
xfemale
age
eduyrs
xmdmqbp
xmdmqvi
xmdmqpr
xmdmqhv
synattl
xxsrt
xxcsr
pfi0m
pfi1d
pfi1l
pfi2d
pfi2l
pfi2s
pfi3d
pfi3l
pfi4d
pfi4l
pfi4s
averaez
printEZx
eteasyx
averadf
printDFx
```

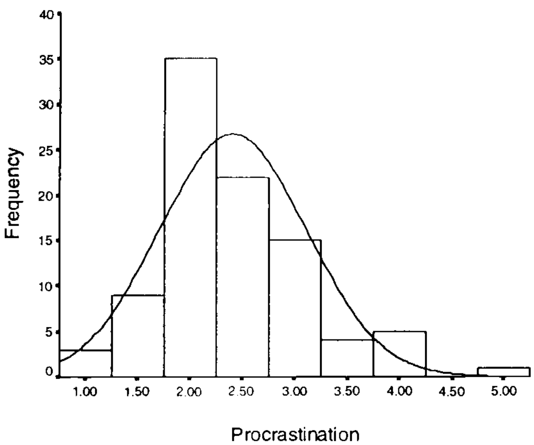
```
etdiffx.
split file off.


sort cases by xorder.
split file by xorder.
graph /scatterplot(matrix)=
pfi4l
xxcsr
printEZx
printDFx
averaez
averadf
eteasyx
etdiffx.
split file off.


******Process outliers TMEP1*************.

get file='d:\data\javier\stats\P1printscore.sav'.

if (printP1x <= 34.36) printP1x=34.36.
examine /variables=printP1x
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\P1printscore.sav'.

*********Process outliers TMEP2*************.

get file='d:\data\javier\stats\P2printscore.sav'.

if (printP2x <= 56.74) printP2x=57.74.
examine /variables=printP2x
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\P2printscore.sav'.

*********Process outliers TMEP3*************.
```

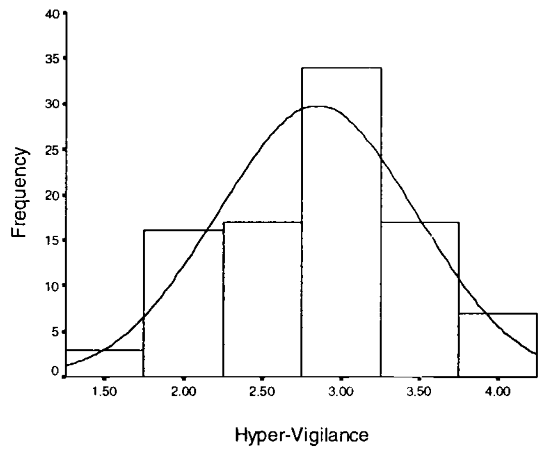
```
get file='d:\data\javier\stats\P3printscore.sav'.

if (printP3x <= 65.46) printP3x=65.
examine /variables=printP3x
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\P3printscore.sav'.

*********Process outliers TMEP4*************.

get file='d:\data\javier\stats\P4printscore.sav'.

if (printP4x <= 64.29) printP4x=65.29.
examine /variables=printP4x
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\P4printscore.sav'.

*********Process outliers TMEP5*************.

get file='d:\data\javier\stats\P5printscore.sav'.

if (printP5x <= 67.52) printP5x=68.
examine /variables=printP5x
/id=subid
/statistics=descriptives extremes(10)
/plot=stemleaf boxplot histogram npplot.

save outfile='d:\data\javier\stats\P5printscore.sav'.
```

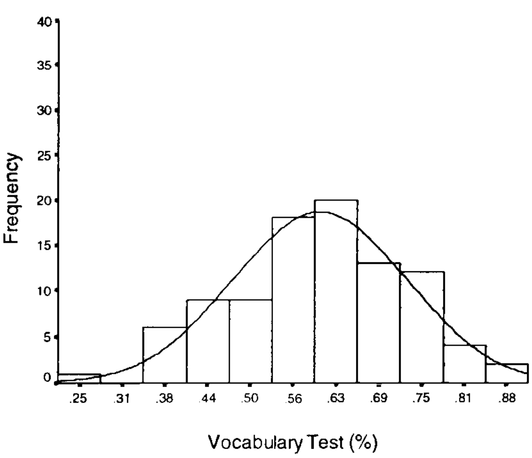
Appendix 11 – Histograms

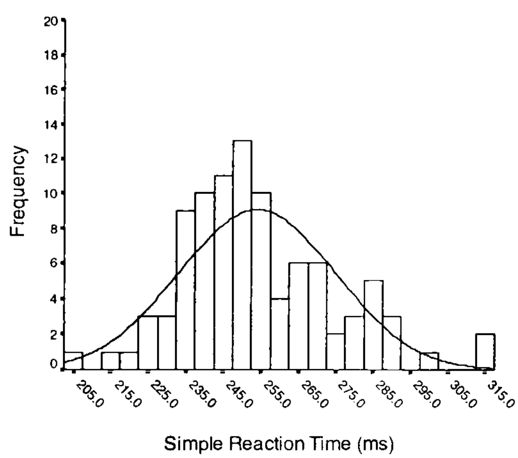

Frequency
0
5
10
15
20
25
30
35
40
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Buck-Passing

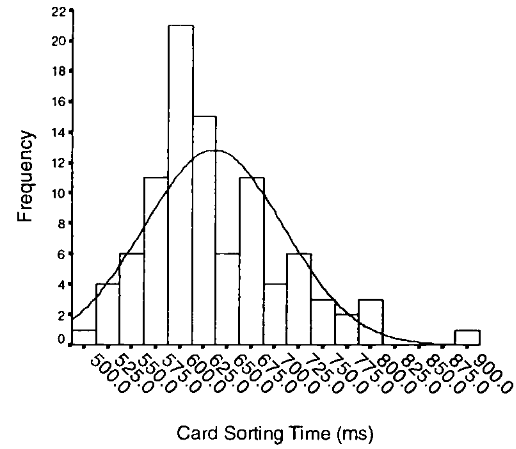

Frequency
0
5
10
15
20
25
30
35
40
2.75
3.00
3.25
3.50
3.75
4.00
4.25
4.50
4.75
5.00
Vigilance

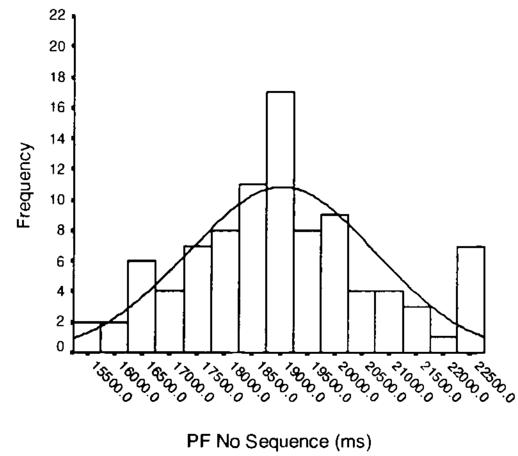

Frequency
0
5
10
15
20
25
30
35
40
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Procrastination

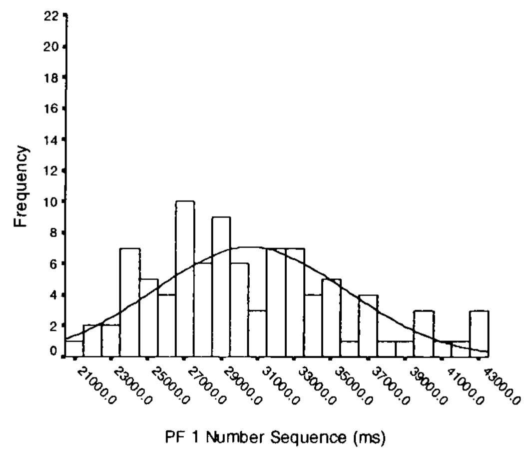

Frequency
0
5
10
15
20
25
30
35
40
1.50
2.00
2.50
3.00
3.50
4.00
Hyper-Vigilance

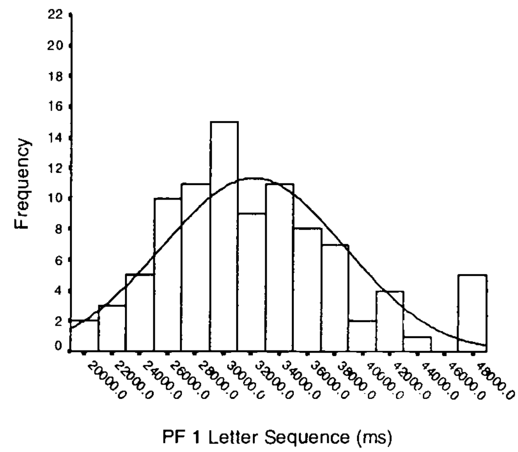

Frequency
0
5
10
15
20
25
30
35
40
.25
.31
.38
.44
.50
.56
.63
.69
.75
.81
.88
Vocabulary Test (%)

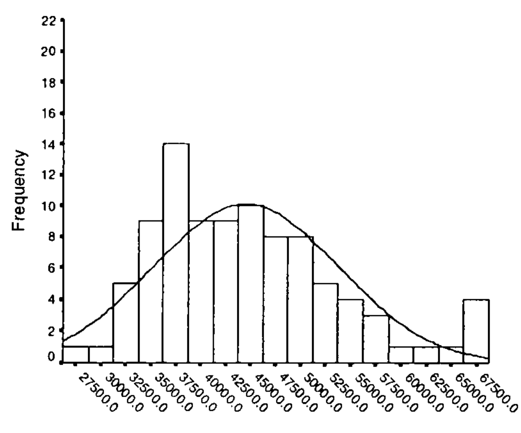

Frequency
0
2
4
6
8
10
12
14
16
18
20
205.0
215.0
225.0
235.0
245.0
255.0
265.0
275.0
285.0
295.0
305.0
315.0
Simple Reaction Time (ms)

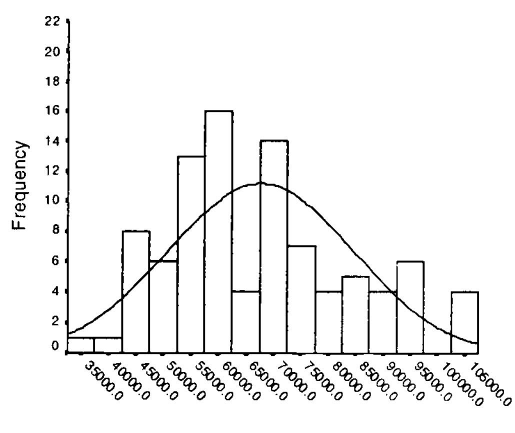

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
500.0 525.0 550.0 575.0 600.0 625.0 650.0 675.0 700.0 725.0 750.0 775.0 800.0 825.0 850.0 875.0 900.0
Card Sorting Time (ms)

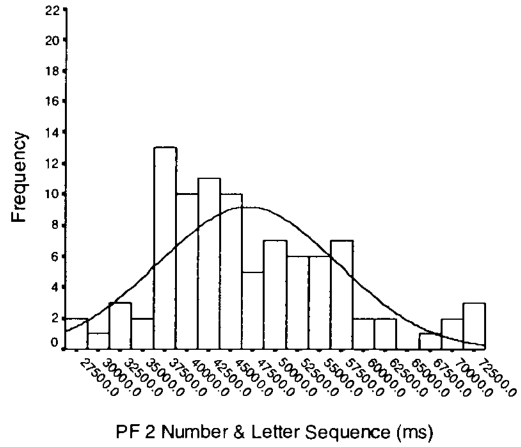

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
15500.0 16000.0 16500.0 17000.0 17500.0 18000.0 18500.0 19000.0 19500.0 20000.0 20500.0 21000.0 21500.0 22000.0 22500.0
PF No Sequence (ms)

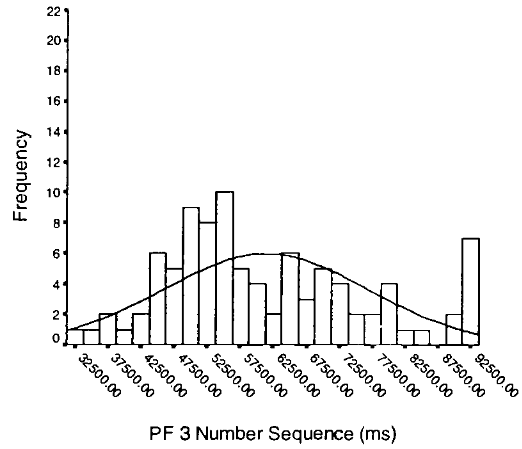

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
21000.0 23000.0 25000.0 27000.0 29000.0 31000.0 33000.0 35000.0 37000.0 39000.0 41000.0 43000.0
PF 1 Number Sequence (ms)

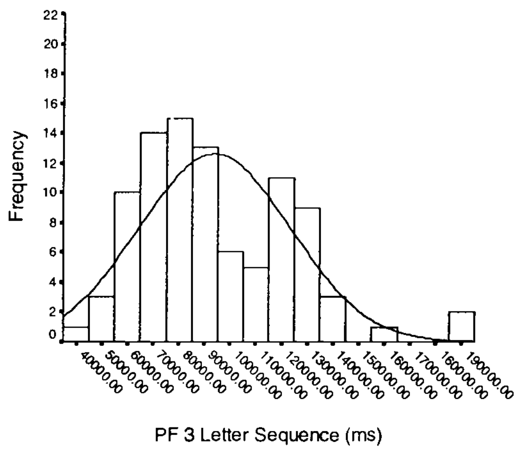

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
20000.0 22000.0 24000.0 26000.0 28000.0 30000.0 32000.0 34000.0 36000.0 38000.0 40000.0 42000.0 44000.0 46000.0 48000.0
PF 1 Letter Sequence (ms)

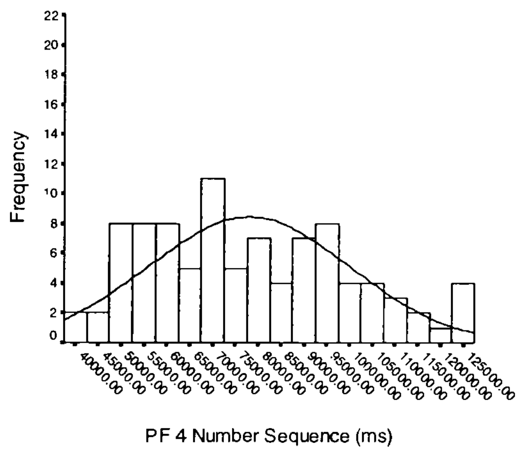

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
27500.0 30000.0 32500.0 35000.0 37500.0 40000.0 42500.0 45000.0 47500.0 50000.0 52500.0 55000.0 57500.0 60000.0 62500.0 65000.0 67500.0
PF 2 Number Sequence (ms)

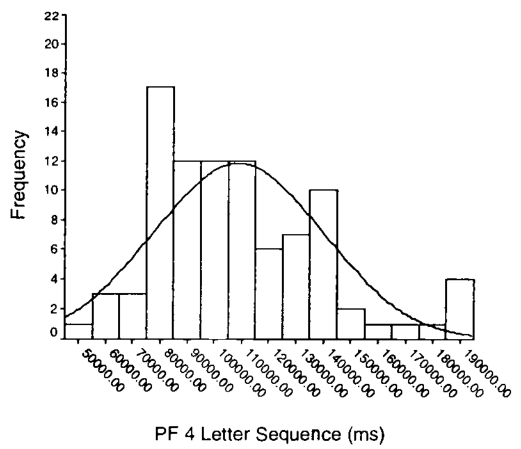

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
35000.0 40000.0 45000.0 50000.0 55000.0 60000.0 65000.0 70000.0 75000.0 80000.0 85000.0 90000.0 95000.0 100000.0 105000.0
PF 2 Letter Sequence (ms)

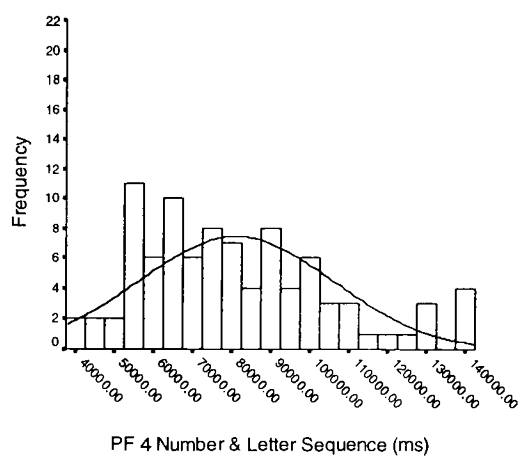

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
27500.0 30000.0 32500.0 35000.0 37500.0 40000.0 42500.0 45000.0 47500.0 50000.0 52500.0 55000.0 57500.0 60000.0 62500.0 65000.0 67500.0 70000.0 72500.0
PF 2 Number & Letter Sequence (ms)

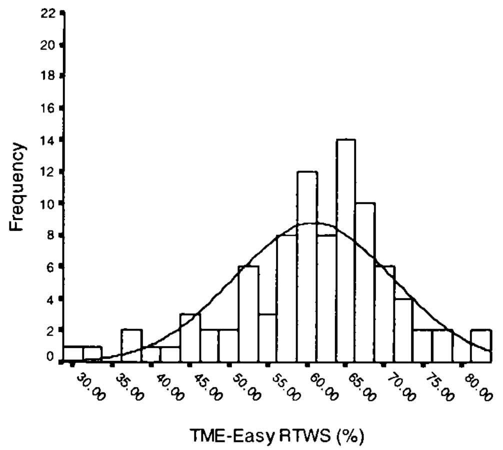

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
32500.00 37500.00 42500.00 47500.00 52500.00 57500.00 62500.00 67500.00 72500.00 77500.00 82500.00 87500.00 92500.00
PF 3 Number Sequence (ms)

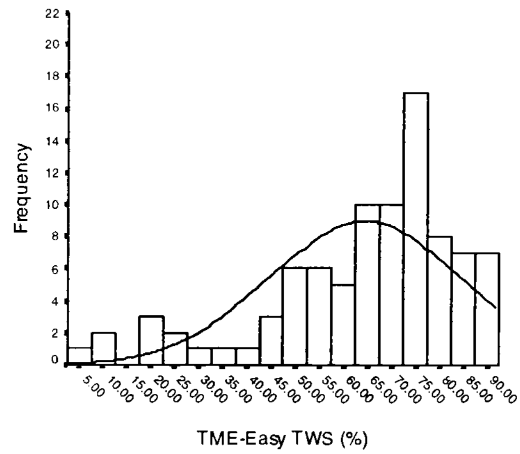

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
40000.00 50000.00 60000.00 70000.00 80000.00 90000.00 100000.00 110000.00 120000.00 130000.00 140000.00 150000.00 160000.00 170000.00 180000.00 190000.00
PF 3 Letter Sequence (ms)

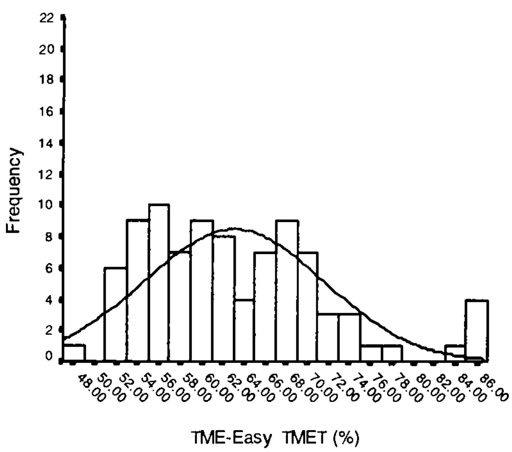

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
40000.00 45000.00 50000.00 55000.00 60000.00 65000.00 70000.00 75000.00 80000.00 85000.00 90000.00 95000.00 100000.00 105000.00 110000.00 115000.00 120000.00 125000.00
PF 4 Number Sequence (ms)

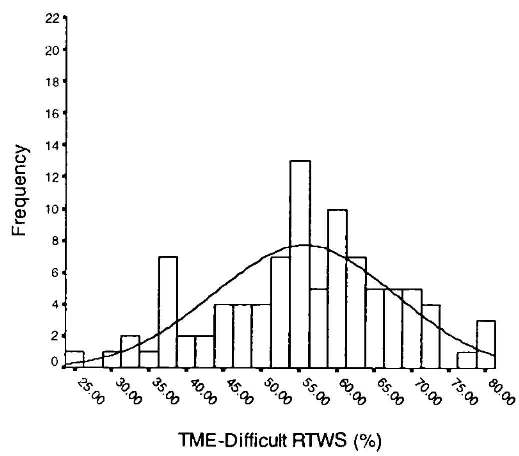

Frequency
0 2 4 6 8 10 12 14 16 18 20 22
50000.00 60000.00 70000.00 80000.00 90000.00 100000.00 110000.00 120000.00 130000.00 140000.00 150000.00 160000.00 170000.00 180000.00 190000.00
PF 4 Letter Sequence (ms)


Frequency
0 2 4 6 8 10 12 14 16 18 20 22
40000.00 50000.00 60000.00 70000.00 80000.00 90000.00 100000.00 110000.00 120000.00 130000.00 140000.00
PF 4 Number & Letter Sequence (ms)


Frequency
0
2
4
6
8
10
12
14
16
18
20
22
30.00 35.00 40.00 45.00 50.00 55.00 60.00 65.00 70.00 75.00 80.00
TME-Easy RTWS (%)


Frequency
0
2
4
6
8
10
12
14
16
18
20
22
5.00 10.00 15.00 20.00 25.00 30.00 35.00 40.00 45.00 50.00 55.00 60.00 65.00 70.00 75.00 80.00 85.00 90.00
TME-Easy TWS (%)


Frequency
0
2
4
6
8
10
12
14
16
18
20
22
48.00 50.00 52.00 54.00 56.00 58.00 60.00 62.00 64.00 66.00 68.00 70.00 72.00 74.00 76.00 78.00 80.00 82.00 84.00 86.00
TME-Easy TMET (%)


Frequency
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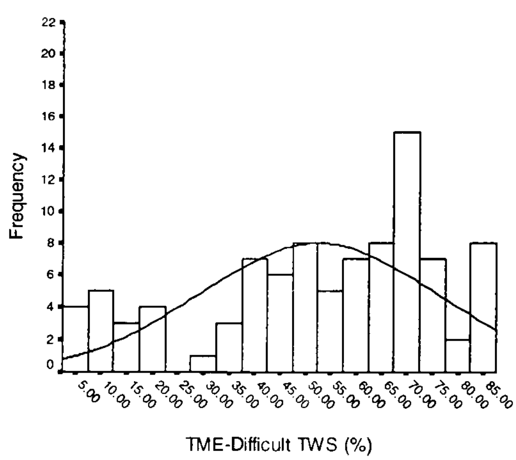
4
6
8
10
12
14
16
18
20
22
25.00 30.00 35.00 40.00 45.00 50.00 55.00 60.00 65.00 70.00 75.00 80.00
TME-Difficult RTWS (%)


Frequency
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6
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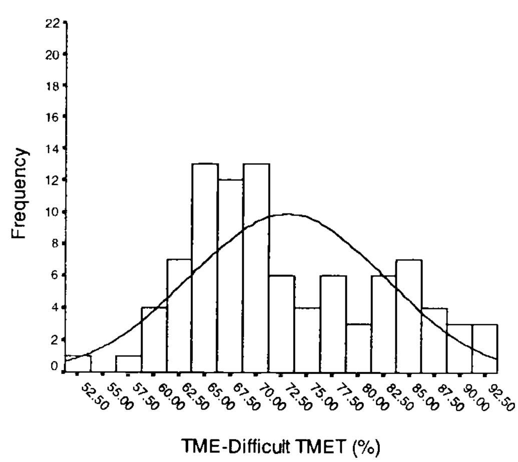
10
12
14
16
18
20
22
5.00 10.00 15.00 20.00 25.00 30.00 35.00 40.00 45.00 50.00 55.00 60.00 65.00 70.00 75.00 80.00 85.00
TME-Difficult TWS (%)


Frequency
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2
4
6
8
10
12
14
16
18
20
22
52.50 55.00 57.50 60.00 62.50 65.00 67.50 70.00 72.50 75.00 77.50 80.00 82.50 85.00 87.50 90.00 92.50
TME-Difficult TMET (%)