FRIEND/FOE IDENTIFICATION ACCURACY AND SHOOTING PERFORMANCE: EFFECTS OF PRIOR TASK LOADING AND TIME PRESSURE

by

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A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the Department of Psychology
in the College of Sciences
at the University of Central Florida
Orlando, Florida

Spring Term
2007

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ABSTRACT

The current dismounted soldier and the soldier of the future will be “loaded” with more information processing tasks while they perform shooting tasks. It is conceivable that some increased level of cognitive tasking may be performed simultaneously with required shooting tasks. The effect of cognitive load on shooting performance has been previously examined (Scribner and Harper, 2001). This study concentrated on the effect of various cognitive workload demands on a friend-foe discrimination shooting task in a single- and dual-task scenario. In light of this, it is imperative that the soldier not be overburdened mentally, which may result in decreased survivability and lethality. Specifically, this study was designed to examine the ability of the soldier to perform friend-foe target discrimination and shooting accuracy, with varying target exposure times, friendly target signatures, and varying cognitive load demands (working memory recall task). Using the Small Arms Simulator Testbed (SAST) we examined the effects of manipulations of working memory load and sustained information transfer, on shooting performance (as measured by target acquisition and friend/foe discrimination indices). Additionally, we investigated subjective measures of workload and stress. A secondary task, administered aurally, was given to subjects to attend to while they performed shooting (friend/foe discrimination task) scenarios: working memory recall task. Each type of task consisted of three levels of difficulty. Analysis of variance revealed significant differences for the memory recall task during shooting and non-shooting conditions. Furthermore, results showed that workload increased as a function of task demand, with associated decreases in shooting performance.

I dedicate this dissertation to my constant support group: my parents and my Grandmother, who through their love, encouragement, and support over the years have made this achievement possible.

ACKNOWLEDGMENTS

There are numerous individuals whose cooperation and inspiration have helped to make this research project a successful one. I would like to extend my appreciation to my chair and advisor, Dr. Peter Hancock, who encouraged me and provided me with the freedom to conduct research in the areas of human factors that I find the most captivating. I would also like to thank my other intra-department committee members, Dr. Szalma, Dr. Mouloua, and Dr. Rinalducci, who have been my most influential professors for a number of years. I would especially like to thank my outside committee member, Drs. Tal Oron-Gilad and Gareth Conway, whose constant support, guidance, encouragement, and patience throughout my dissertation process surpassed all responsibilities of a committee member. I am fortunate and grateful to have had the experience of working with them.

Additionally, I would like to thank my family and friends whom without, I would not have accomplished so much; especially my mom and dad, for the years of encouragement and support; you have both been an inspiration to me in so many ways.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
GAS	General Adaptation Syndrome
GLM	General Linear Model
LSD	Fisher's Least Significant Difference
NASA-TLX	NASA-Task Load Index
RSME	Rating Scale Mental Effort
SAST	Small Arms Simulator Testbed

CHAPTER ONE: INTRODUCTION

> *Best policy in war--thwart the enemy's strategy, second best--disrupt his alliances through diplomacy, third best--attack his army in the field, worst strategy--attack walled cities. Attack cities only when there is no alternative. (Griffith 1963, 77-78)*
>
> Sun Tzu, *The Art of War*

Sun Tzu's words, recorded over two thousand years ago, represent twentieth century United States Army doctrine for fighting on urban terrain and in built up areas. The Army Field Manual (FM) 100-5, *Operations*, the Army's doctrinal foundation during the Cold War, stated, "*Commanders should avoid committing forces to the attack of urban areas unless the mission absolutely requires doing so*" (United States Army 1976, 81). Adherence to this principle, though sound, is becoming increasingly difficult as world urbanization increases. The current version of FM 100-5 (1993) limits its discussion of urban operations to the following passage:

> "Urban operations present unique and complex challenges to the Army forces. Urban operations can occur in any of the geographical environments. They can constrain technological advantages; they impact on battle tempo; they force units to fight as small, decentralized elements; they also create difficult moral dilemmas due to the proximity of large numbers of civilians. Commanders must enforce discipline in their operations to minimize unnecessary collateral damage and civilian casualties" (US Army 1993, 14-4).

Throughout history, military planners have viewed urban cities as centers of gravity. As such, in war, cities are something to be either protected or taken away, depending upon one's perspective (Marine Corps Warfighting Publication, 1998). Cities house the population centers, transportation hubs, seats of government, sources of wealth, centers for industry, information networks, and key nodes of communication within a nation. Recent forecasts based on population statistics and the worldwide migration trend from agrarian to industrialized societies predict "*that 85% of the world's population will reside in urbanized areas by the year 2025*" (United States Marine Corps 1998, 1-1).

As the world trend toward urbanization increases, the military significance of cities is therefore likely to increase proportionally. Thus, urban areas are expected to be the future battlefield and combat in urban locations cannot be avoided.

Consequently, the past decade has seen a rise in Military Operations in Urban Terrain (MOUT) where units must function in cities and villages rather than on traditional battlefields which take place in relatively open, uninhabited terrain. The streets and buildings comprising the terrain possess unique characteristics and the nature of inter-city warfare, where civilians are intermixed with hostile units, is quite different from traditional battlefields (Grau & Kipp, 1999). Furthermore, the intensity level of operations conducted in MOUT varies tremendously, and different levels of conflict call for drastically different responses and tactics. While current training addresses MOUT tactics and procedures, the extent of that training pales in comparison to traditional combat training (Grau & Kipp, 1999; Klug, 2000).

Additionally, the MOUT environment presents a distinct set of tactical, procedural, and cognitive challenges to soldiers and their leaders. These unique challenges are exacerbated by the fact that most Army personnel, with the exception of specialized units such as the Rangers and Special Operations Forces, have relatively little MOUT-related experience. Although the unique nature of the cognitive challenges of decision-making within the MOUT environment has been acknowledged as a problem in need of research, experimental studies investigating the subject remain sparse.

The cognitive demands of operating in a MOUT environment vary considerably from traditional battlefields. Fighting typically takes place in close quarters, against a poorly-defined enemy and amongst a mix of hostile and non-hostile civilians. Such environments require that the small unit leaders attend to multiple data sources, prioritize among competing and sometimes conflicting goals, and make rapid decisions, all under highly stressful conditions (Strater, Endsley, Pleban, & Matthews, 2001). MOUT operations place demands on military personnel for new types of technical skills and include unusual and specific cognitive requirements related to decisions necessary in an urban setting. For example, a platoon leader who has learned to estimate the time needed to set up a hasty defense or a movement to contact will have to judge the time/distance relationships for tasks such as the clearing of buildings.

Consequently, even if soldiers are extremely well prepared to carry out difficult tactical procedures and operations, the danger is that they may not be protected from the consequences of poor decisions made by their immediate leaders. In most cases, MOUT judgments and decisions are difficult to make. For example, these decisions often must be made under extreme time pressure, with high degrees of uncertainty, and in a setting of high vulnerability. One reason soldiers are more vulnerable in a MOUT environment as compared to a traditional battlefield is the city itself: a city's complex set of systems and high population densities poses the most daunting problems in urban combat. Additionally, the presence of civilian populations often conflict with "war convention," which are the accepted rules that guide military conduct, tactics, and decision making during combat (Grau & Kipp, 1999). As urban combat can assume many different forms, including siege, guerilla warfare and terrorism suppression with the uncertainty of changing from one location to the next, soldiers are acutely more vulnerable to stress, injury, errors, and death.

MOUT places relatively junior officers in highly demanding situations, facing high risks and acute stress where they must operate with a high degree of independence. With current training, these leaders may have very little preparation for handling the decisions they must make during a MOUT mission (Grau & Kipp, 1999; Littleton & Freeman, 2003; Klug, 2000). In past conflicts, such as in Kuwait, Chechnya, Mogadishu, Berlin in WWII, and Hue City, inaccurate or poor decisions in a MOUT mission resulted in considerable loss of life. As in these examples, and as in many other urban battlefields, the casualty rates can be staggering compared to the warfare conducted in open terrain such as Desert Storm (Grau & Kipp).

One must assume potential adversaries have studied the lessons of past conflicts and have realized that the urban environment and its tendency for increased casualties, resource expenditure, and collateral damage, can be a technologically advanced enemy's "Achilles heel." A key lesson learned by us adversaries in the battles of Hue and Mogadishu is that urban combat denies the better-equipped military many of its advantages.

At present, the United States Army's Manual, FM 90-10, Military Operations on Urbanized Terrain, published in 1979, is being rewritten. As the doctrinal review process begins, it remains imperative for the Army to analyze all aspects of its operational and tactical warfighting on urban terrain. The planning, preparation and decision-making processes for conducting MOUT merit analysis and scrutiny as part of the review.

Since 1932, the army has published ten versions of FM 101-5, staff organization and operations. With each revision, the principal analytical tool, which commanders and staffs use to analyze problems and formulate solutions, the decision-making process, gets revised. The military decision-making process (MDMP) continues to evolve as changes to the art and science of war occur. As depicted in Figure 1, MDMP is a seven-step analytical process, which guides commanders, staffs, and junior leaders from receipt of mission to the production of an order. The MDMP is the foundation on which deliberate and time-constrained planning and decision-making is based. The MDMP helps the commander and his staff examine battlefield situations and reach logical decisions. The MDMP is a detailed, deliberate, sequential, and time-consuming process used when adequate planning time and sufficient staff support are available to thoroughly examine numerous friendly and enemy courses of action (United States Army 1997, 5-1).

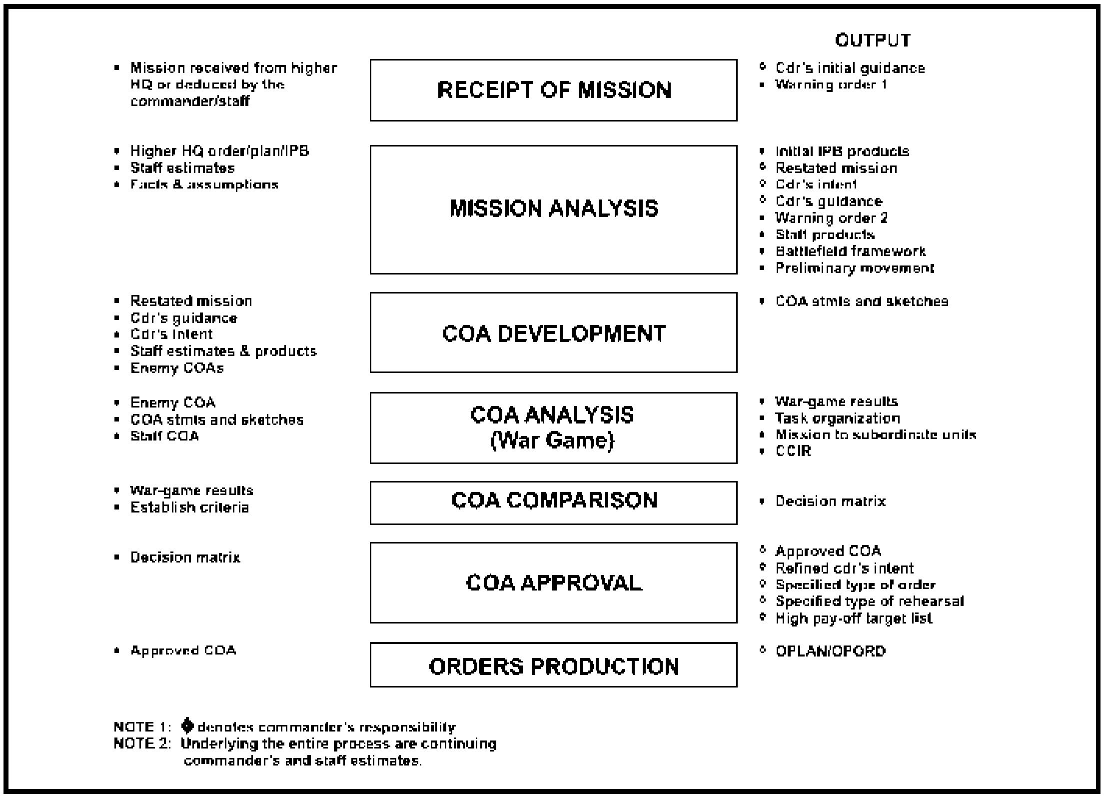


Figure 1 Military decision-making process

The emerging threats and conditions of future MOUT will require commanders and staffs to examine their traditional methods of decision making for urban combat and look for new, more-thorough methods of decision-making and how best to train junior leaders on the ground to make effective and accurate decisions. The MDMP remains critical to the success or failure of all Army operations, but particularly in the urban environment.

The increased population and accelerated growth of cities, the unique cognitive challenges associated with operating in a MOUT environment, and the current lack of training, especially decision making skills, have made the problems of combat in a MOUT environment an urgent requirement for the US Army (Military Operations on Urbanized Terrain (MOUT) Center for Army Lessons Learned, 2003).

In combat soldiers experience both physical and mental fatigue, prolonged periods of heightened vigilance, and extreme danger (Harris, Hancock, & Harris, 2005). As Mareth and Brooker (1982) found, battlefield conditions can completely incapacitate some soldiers, but not affect the performance of other soldiers. In combat, failure to fire the weapon has been highlighted as just one type of a performance decrement produced by stress (Marshall, 1947). This finding has also been demonstrated in simulated battlefield conditions (Villoldo & Tarno, 1984). It has been found that the perception of danger (Berkum, 1964) and the presence of real stress (Belland & Bissell, 1994) can cause disruptive effects in performance of military personnel. Additionally, Wickens and Flach (1988) predicted performance decrements in combat produced by stress because military decisions involve a wide spectrum of information-processing components, and stress impairs each of these different information-processing stages (see Hancock, 1986; Wickens, 1996). However, a review of the literature has shown that these stress-related cognitive changes are difficult to identify as the basis of reduced operational performance (Callister, Percival, & Retzlaff, 1999; Elsmore, Naitoh, & Linnville, 1992; Slaven & Windle, 1999).

In light of these and other findings, it can be seen that the concept of performance decrements produced by stress in a combat environment is not a new concern for both the military and researchers. However, the need to better understand the effects of stress in a combat environment has become increasingly more important with recent development of new technologies designed to enhance the soldier’s capability (Harris, Hancock and Harris, 2005). Obviously, in a combat environment, maintaining a high level of performance, both of cognitive skills (i.e., decision making tasks) and motor skills (i.e., shooting accurately) is critical and may ultimately mean the difference between life and death. Consequently, it is of utmost importance that we identify information-processing tasks or task components that may prove to be the most vulnerable to combat stress (Orasanu & Becker, 1996), and to evaluate changes in the soldiers capacity under the effects of realistic, operational stress (Harris et al., 2005).

The dismounted soldier of the future will be “loaded” with more information processing tasks while he is still expected to perform shooting tasks. It is conceivable that in the future, soldiers will experience prior task loading before implementing a mission in which an increased level of cognitive tasking must be performed simultaneously with shooting tasks, often under acute time pressure. Therefore, the current program of study was designed to address these typical combat stressors that may affect the shooting performance of a soldier. These studies will examine the ability of the soldier to perform friend-or-foe target discrimination, with varying target exposure times, prior task loading, and varying cognitive load in a dual-task paradigm.

The current program of study is conducted to examine the ability of the soldier to perform a cognitive task while shooting. Additionally, it will examine the ability of participants to maintain the primary task of shooting pop-up friend-or-foe scenarios while performing a secondary task of monitoring incoming information from a unmanned aerial vehicle (UAV). Finally, the program of study will examine the effect of cognitive workload levels and prior task loading on the ability of soldiers to correctly make “shoot-no-shoot” decisions in a MOUT friend-or-foe target environment.

The current program of study is relevant to the interests of the Army to enable future dismounted system designers to design for minimum cognitive disruption. The cognitively loaded and potentially mentally fatigued (prior task loading) dismounted soldier must be able to respond efficiently and effectively to single and multiple hostile scenarios in a MOUT environment. The results from these studies may provide researchers in the Department of Defense, academia, and industry with information about the efficacy of information systems for small arms shooters.

CHAPTER TWO: LITERATURE REVIEW

Friend-Or-Foe Identification as a Decision Making Task

On the battlefield, it is imperative that soldiers be able to continually and rapidly detect targets, correctly discriminate friend from foe, make a “shoot-no-shoot” decision and then shoot only the foe with accuracy. Research from the Persian Gulf War has shown that of the 219 U.S. causalities, 154 were killed in battle. Thirty-five soldiers, or 22.7% of these battle deaths were the result of friendly fire (Helmkamp, 1994). Data from all 20th Century conflicts demonstrate a consistent fratricide rate of at least 10-15%, and it has been argued that correct target identification is impaired by combat stress including time on task, and time pressure (Steinweg, 1994).

Two Theoretical Approaches to Decision Making

Decision theory, the study of how decisions are made and the situations that surround such decisions, has evolved from the classical, or “behavioral” model of decision making (e.g., static and dynamic decision theories; Edwards, 1962; consequential choice, matching, and reassessment; Lipshitz, 1994; The Contingent Operator Stress Model; Kontogiannis, 1996) to the relatively young field of Naturalistic Decision Making (NDM); Klein, 1998). Traditionally, research in the former areas focused on only one part of the decision making process, the “decision event,” and adopted the perspective that the crucial part of decision making occurs when the decision maker identifies the problem and chooses a course of action from a variety of well-specified alternatives on the basis of determining well-known goals, purposes, and values which remain stable over time (Orasanu & Connolly, 1993). In this context, research on decision events focuses on the ability of the decision maker to use all available information in selecting the best course of action.

Sternberg (1986a) addressed principles of dynamic decision theory in a manner similar to Edwards (1962), however, he addressed them in terms of real-world decisions. He argued that real-world decisions are separate from decisions made in traditional research, conducted primarily in the laboratory with naïve participants. Sternberg was one of the first researchers to address the issue that the models of traditional decision-making did not correspond with the problems encountered in the real world. He asserted that to be able to make effective decisions in the real world, the decision maker must use critical thinking skills, but these skills are not included in the earlier models of decision making. He outlined ten areas where the requirements of making real world decisions do not correspond with the methods in which decision skills are taught through the traditional models (see Sternberg, 1985a).

Shortly after Sternberg (1986a) presented his perspective on the differences between traditional decision making models and the problems arising outside of the artificial confines of the laboratory in everyday real world problems, a series of researchers (Beach & Lipshitz, 1993; Brehmer, 1990, Klein, 1993; Orasanu & Connelly, 1993) followed his lead and continued to move the field of decision making in a new direction. They studied how experienced people make decisions in their natural environments or in simulations that preserved the key elements of their environments. This marked the beginning of a shift in how decision making research was conducted. This shift towards the new paradigm, NDM has come about for several reasons: decision environments have become increasingly more sophisticated and complex, people in the work environment are facing more cognitively demanding tasks, and with this increase in complexity and high technology fields, the consequences of poor or ineffective decisions is becoming more costly (e.g., Cannon-Bowers, Salas, & Pruitt, 1996). Aviation accidents (Stokes, Kemper, & Kite, 1997), military training accidents (Klein, 1998), and industrial accidents (Kontogiannis, 1996; Roth, 1997) are often caused by humans making poor decisions, and these events can have expensive and catastrophic consequences resulting in serious injury or loss of life. Hence, decision making literature has become increasingly more focused on how it occurs in the real world, under naturalistic conditions. Over the last decade, therefore, the study of NDM has moved the field of decision making away from the laboratory and into real-world environments such as the fire station (Klein, 1993b), the medical emergency room (Bogner, 1997; Klein, 1998), to naval warships (Klein, 1998; Schraagen, 1997), and airplane cockpits (Kaemf & Orasanu, 1997; Stokes et al., 1997).

Orasanu and Connelly (1993) modified Sternberg's (1986a) dynamic decision theory in terms of real-world decisions and identified eight factors that characterize decision making in these naturalistic environments:

1) Decisions pertaining to ill-structured problems;

2) Decisions involving uncertain and dynamic environments;

3) The decision maker often has shifting, ill-defined, or competing goals;

4) Action/feedback loops: involves multiple decisions rather than a single decision;

5) Time pressure: many NDM environments require decisions to be made under significant, even acute time pressure.

6) High stakes: the consequences for a poor decision can be grave (e.g., loss of life);

7) Multiple decision makers; and

8) Decisions are often made in organizational settings, where the goals are general rather than specific to an individual.

According to Orasanu and Connolly (1993), all of these factors need not be present or at their extreme for a decision to be considered naturalistic. Some or all of them may be present in order for a decision to be considered naturalistic. NDM researchers attempt to describe how people are actually making decisions in real world environments, not to prescribe the correct way to make a decision (Klein, 1997b). The study of NDM has clearly made some important contributions to the field of decision making through its focus on how decisions are made by knowledgeable, experienced people in complex, real-world environments. In addition to examining the characteristics of the naturalistic environment, it is important to understand the factors that affect decision making strategies within those environments, especially factors that may lead to poor decisions (Kelly & Karau, 1999), such as various stressors.

Decision Making Under Stress

Stressful, threatening, uncertain, or demanding situations can lead to a number of undesirable consequences, including heightened anxiety (see Driskell & Salas, 1991, 1996; Keinan, 1987). Stress can also be debilitating and lead to errors, poor performance, and bad decisions (Orasanu, 1997). Before considering decision making under stress, a brief overview of stress theories and the effects of stress as reported in the literature is presented as a foundation. Although there seems to be no single universally agreed definition of stress and consequently no single measure that tells us when a person is stressed or operating under stressful conditions (Hancock & Desmond, 2001), theories of stress can be classified as stimulus-based, response-based, or transactionally founded. (see Hancock & Desmond, 2001; Hockey, 1986; Driskell & Salas, 1996 for reviews of the stress literature). According to Janis and Mann (1977), stimulus based theories identify stressors and then determine their effects on participants. Stressors may influence the availability of information processing and include environmental stressors (e.g., heat, cold, noise, vibration) and task-related stressors (e.g., time pressure, workload, information load, or fatigue) which may interfere with the participant's ability to function effectively (Orasanu, 1997). Stressors are therefore not only environmental, but may also be biological, and/or cognitive events that challenge or threaten the well-being of an organism, increase its arousal or activation level, and deplete its resources (e.g., Hobfoll, 1991). They can be extraneous, (non-work stress) or indigenous (stress created by the task).

Response-based theories originated with Selye's "Generalized Adaptation Syndrome" (GAS;1936; 1980) and define stress based on the responses of the participants which may be physiological, behavioral, or subjective. According to this theory, the participant responds to a stressor by a general pattern of arousal to meet the demands of the situation, followed by exhaustion of resources, and eventually possibly even death. Some theories of stress emphasize physiological indicators of stress such as general arousal of the central nervous system, including heart rate variability (HRV) or Galvanic Skin Response (GSR) (Hockey, 1986), or activation of the endocrine system (Levine, 1988). Decrements in performance in the presence of stressors relative to their absence may also reflect stress. However, decrements in performance may also reflect non-stress related factors such as lack of motivation or interest.

Transactional theories of stress (Lazarus, 1996; Lazarus & Folkman, 1984) consider the interaction between potential stressors and a person's cognitive appraisal of the situation. Specifically, stimuli are considered to be stressors only if the participant perceives them as a threat or as creating a demand that exceeds his or her capabilities. Hockey (1986) observed that a participant's perception of a stressor as a threat largely determined the degree of physiological response, though subjective measures of stress do not always correlate well with physiological or behavioral measures.

The concept of stress can be easily understood in the context of Figure 1. Stressors, depicted on the left of the figure, are typically (but not always) degrading, influencing information processing and cognition that are not inherent in the content of that information itself, nor in the skills of the human (Wickens & Hollands, 2001). These stressors usually have three effects: 1) Produce an emotional or "affective" experience, such as frustration or arousal. 2) Physiological arousal which is observable such as in changes in heart rate. 3) Stressors affect characteristics of information processing, although this effect does not always degrade performance. As depicted in the Figure 2, these effects may have either internal or external influences on human performance.

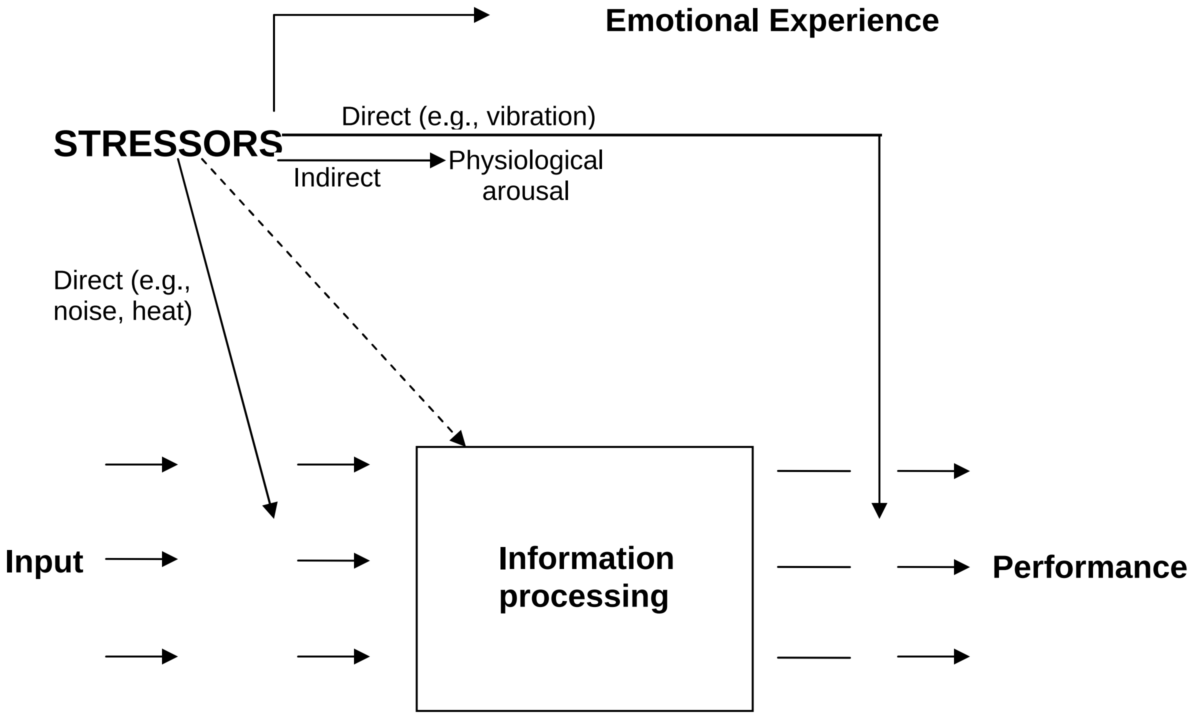


Figure 2 Representation of stress effects

Stress and Performance

Research in cognitive psychology has made many contributions to an understanding of acute and chronic stress effects on performance by identifying the factors that contribute to operator stress under emergency or other abnormal circumstances and by suggesting how operators might be trained to respond more effectively in these circumstances (Hancock & Desmond, 2001). Although the Yerkes-Dodson Law (1908) has been used to explain the effects of stress on performance, evidence suggested that this theory is too simplistic and fundamentally flawed (Hancock & Ganey, 2002; Hancock, Ganey, & Szalma, 2002; Hockey & Hamilton, 1983). Others have developed frameworks of stress, but none have been successful at explaining the inconsistent effects of stress on performance (Hockey & Hamilton, 1983). In an attempt to supercede the limitations of the inverted-U, Hancock and Warm (1989) combined existing psychological and physiological theories of the effects of stress and developed a unified theory that enables the prediction of these effects on performance both psychologically and physiologically. This model can be used to explain the effects of stress in the current program of study because soldiers operating and making decisions in a MOUT environment will undoubtedly be exposed to both physical and mental stressors.

Additionally, Hancock and Warm's (1989) model establishes ranges of adaptability; as the ranges of adaptability are breached, performance fails progressively. This model can handle issues of combined physical and mental demand because it uses an index for both physiological and psychological performance. "Input level stress increases through change and intensity, prolongation of exposure time, or both in combination; output is eventually affected" (Hancock & Warm, 1989, p.526). As depicted in the model, failure in psychological performance will be apparent before failure in physiological performance.

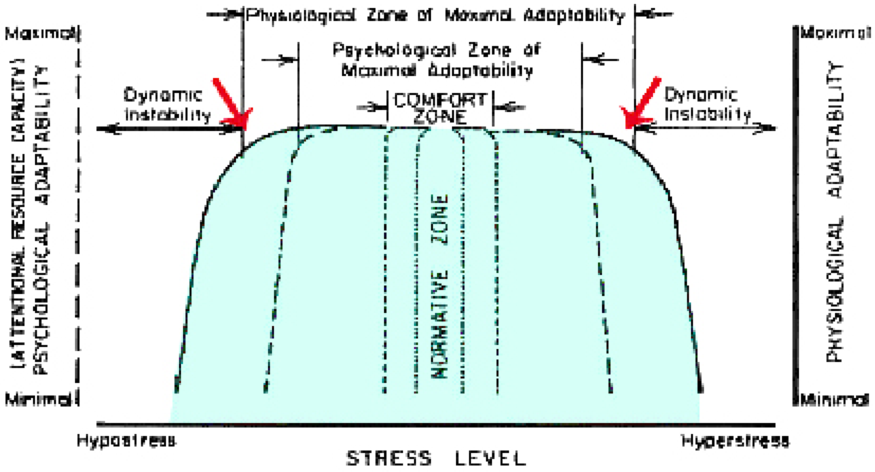


Figure 3 The Hancock and Warm (1989) Model for Maximal Adaptability

Hancock and Warm (1989) pointed out an important constraint that a general theory of stress and cognition has to accommodate is that various sources of stress from the environment do not all impact performance in the same way. Conversely, different individuals might react to the same stressor in different ways. Hancock and Warm examined the differing effects of performing sustained attention tasks under noise in contrast to performance patterns that emerge from the influence of heat stress. They also note that the task itself serves as its own source of stress, and that an integrated view of stress and performance must consider the task as a primary influence in the generation of stress. Any theory of stress would benefit by accommodating these multiple sources of stress and their potentially non-additive effects on performance. Ultimately, Hancock and Warm assert that stress is a dynamic phenomenon through the operator’s active, effortful attempts at adaptation.

There are a plethora of theories regarding stress effects on performance, though it is outside the scope of this paper to review them all. In general, a range of mechanisms have been proposed that attempt to account for performance failures. These mechanisms include (but are not limited to) arousal levels (some theories propose that under- and over-arousal result in nonoptimal attentional focus) and resource usage (prolonged or difficult tasks can reduce the attentional resources available for a task). Theories differ in their assumptions about these processes. Some attribute little or no role to consciousness or awareness, asserting that stress effects are direct, automatic, and intuitive. Others assign major performance control functions to plans, appraisals, analyses, and other cognitive phenomena. No theory seems to completely offer a comprehensive and accepted account of stress processes.

Decision-Making in a MOUT Environment under Stress

Combat typically involves several stressors such as task demand, time pressure, fatigue, and acute noise stress, as well as general deployment issues (separation from family, different culture, language barriers). MOUT-related decision-making has not yet been investigated under these stressors. Although the increasing amount of real-time battlefield information available to soldiers is intended to facilitate decision-making processes for achieving tactical, operational, and strategic objectives, the capacity of human information processing systems is limited and may be further compromised under the stress of combat (Johnson & Merullo, 1999). During the chaos and confusion of combat the soldier is often faced with multiple sources of information and must make difficult split-second decisions under tremendous stress, which may ultimately determine life or death of the individual, as well as the welfare of the fighting unit. Infantry experts have estimated that less than 20% of combatants maintain peak performance levels while engaged in a firefight (Drozd, 2003). Two types of errors that could potentially compromise the outcome of a battle are (1) failure to engage the enemy (Kerrick & Allender, 2005; Marshall, 1947; as cited in Harris, et al., 2005) and (2) failure to refrain from engaging friendly combatants or civilians (Kerrick & Allender, 2005). Statistics are available on the percentage of friendly combatants engaged in recent wars. For example, Helmkamp (1994) reported that 22.7% of the 219 U.S. casualties during the Persian Gulf War were the result of friendly fire incidents. These statistics provide a rationale for the need to further investigate the effects of task demand and high cognitive workload (i.e., multi-tasking) on decision-making accuracy and soldier performance during combat. Such research has significant implications with respect to the design of military technology and whether such technology enhances soldier lethality and survivability or inadvertently interferes with optimal utilization of attentional resources.

Previous researchers have manipulated the following variables in an effort to simulate (both in laboratory and field environments) some of the stressors likely to be encountered during combat: time pressure, (Landers, Qi, & Courtet, 1985), fatigue (Johnson, Merullo, Montain, & Castellani, 2001), and task difficulty (Sterman & Mann, 1995). It could be argued that a common denominator of the stressors cited above is that they all impose mental demands, or increased workload, on the soldier.

Johnson and Merullo (1999) employed a friend-foe discrimination paradigm to study target detection speed and decision accuracy over a 3-hr period of simulated sentry duty with and without the administration of 200 mg caffeine immediately prior to beginning sentry duty. They observed decrements in target detection speed and shooting accuracy over the 3-hr period and the decrements were less with caffeine. Target detection error rates did not change over time (4.3%) but were lower with caffeine versus without (2.5% vs. 5.8%). The results of this study suggest that sustained vigilance in a military context imposes significant mental demands associated with performance decrements, though the ingestion of 200 mg caffeine attenuates such decrements.
Scribner and Harper (2001) imposed secondary task demands on soldiers during a shooting primary task. Soldiers were instructed to maintain performance of a friend-or-foe discrimination

shooting task while simultaneously performing a secondary mental arithmetic task in one condition and memory task in another. They observed stable target discrimination accuracy and shooting performance of the soldiers across single- and dual-task conditions but performance decreased for both mental arithmetic and memory tasks when performed during shooting versus independently. These findings indicate the high attentional demands involved in identifying and firing upon enemy targets and provide evidence of limited information-processing capacity. The lack of effect for target discrimination accuracy and shooting performance suggests that the soldiers were able to prioritize the shooting task but at the expense of any spare resource capacity to processes additional information while engaged in shooting and therefore, performance in tasks perceived to be less salient is allowed to reduce in order to focus on the primary task – engaging the enemy targets. The implications of this study are that attentional resources of soldiers may be at or near full capacity during battle and provides insight as to how friendly-fire incidents might occur (Scribner & Harper, 2001). During the chaos and confusion of combat communication on the battlefield may be compromised.

A follow-up study Scribner (2002) showed that manipulating visual stimuli to obscure the distinction between enemy and friendly targets, thereby increasing mental demands, resulted in a significantly higher rate of target detection errors during dual- versus single-task shooting. The number of friendly targets engaged during dual-task shooting (7.0%) was more than four times higher than was engaged during single-task shooting (1.6 %) when visual discrimination of targets was made more difficult. Thus, it appears that the interaction of cognitive (i.e., mental arithmetic) and sensory-perceptual (i.e., visual discrimination) demands exceeded the soldiers' capacity to perform the primary shooting task at optimal levels. Clearly, it is crucial that we investigate the effects of these stressors on decision-making in MOUT environments.

Decision Making under Time Stress

Time stress has been previously established as a valid source of stress that may affect human performance (Doob, 1971; Hancock & Desmond, 2001). It is frequently an integral component of decision making, and is especially inherent during combat. Time pressure in decision making is created when the individual has insufficient time to deliberate about choosing the correct course of action to solve a problem. Research has indicated that time pressure has an effect on decision making processes and strategies (Ahituv, Igbaria, & Sella 1998; Dror et al., 1998; Dror et al., 1999; Kelly & Karau, 1999; Klein, 1993; Ordonez & Benson, 1997). These studies indicate that decision makers under time pressure, as compared with decision makers not under time pressure, may switch from a complex decision strategy to a simpler decision strategy (Dror et al., 1998), will demonstrate a decrease in the quality of their decisions and overall performance (Ahituv et al., 1998), and will report feeling more stressed and have less confidence in their decisions (Kelly & Karau, 1999).

Additionally, high levels of time pressure and stress can lead to perceptual narrowing and thus a reduced utilization of available cues, decreased vigilance, and reduction in working memory capacity (Stokes, Barnett, & Wickens, 1987; Klein, 1997; Orasanu & Fischer, 1997; Orasanu, 1997). In high-tempo event-driven environments, decision makers may not have the time or the attentional resources that are required to examine and evaluate multiple possible hypotheses (Wickens & Flach, 1988; Maule, 1997; Orasanu & Fischer, 1997). Both the hypothesis and action generation stages require retrieval of information from long-term memory, such as prior experience with similar conditions, may not be available. Also, requiring individuals to make decisions within a limited time frame may create pressure and stress for them personally, increasing the level of arousal and physiological stress (Ahituv, Igbaria, & Sella 1998).

For example, in a study of how commanders in the Israeli Air Force use defensive resources in the face of an aerial attack by enemy combat aircraft, Ahituv et al. (1998) found that time pressure impaired performance. The subjects with unlimited time performed better in all three types of scenarios (progressing from relatively simple decisions to more difficult decisions) with fewer ground attacks and more enemy aircraft hits. These results indicate that the effects of time pressure had a negative effect on the performance of decision makers, affecting the accuracy and effectiveness of decision making (Ahituv et al., 1998). During combat, and especially once a MOUT mission has started, the speed at which decisions will be required will continue to accelerate, making time-sensitive decisions the norm, rather than the exception.

Stress Theories

There are many theories of how stress affects performance, yet there are very few unified theories that encompass the effects of various forms of stressors on performance. Early unitary theories on stress and human performance attributed emotional arousal as the source of performance decrements (Cannon, 1915; Selye, 1956). The arousal theory was supported by many studies using the narrow band approach, testing the effects of various stressors on a single task (Hockey & Hamilton, 1983). The effects that different stressors had on performance varied, yet they fit into a recognizable pattern. Incentives improved performance and stressors such as noise, thermal stress, and fatigue degraded performance. Later, combining two stressors resulted in the canceling of the decremented effects of a single stressor (Broadbent, 1963; Wilkinson, 1963). The results of these studies, and many others, patterned the inverted-U function and supported the arousal theory (Yerkes & Dodson, 1908).

Although the Yerkes-Dodson Law has been used to explain the effects of stress on performance, evidence suggested that this theory was too simplistic and flawed (Hancock & Ganey, 2003; Hancock, Ganey, & Szalma, 2002; Hockey & Hamilton, 1983). Others have developed frameworks of stress, but none have been successful in explaining the inconsistent effects of stress on performance (Hockey & Hamilton, 1983). Hancock, Ward, Szalma, Stafford, and Ganey (2002), recognized that creating a descriptive framework that entailed the effects of stress on performance as having been difficult for two reasons. The effects depended upon features of the environment and the individual operator, and second, the effects of various sources of stress were not uniform across all forms of information processing. In an attempt to circumvent the limitations of the inverted-U, Hancock and Warm (1989) developed a unified theory that enabled the prediction of the effects of stress both psychologically and physiologically, which they termed a dynamic model of stress and performance. Hancock and Warm's (1989) model was based upon three approaches which were known as the "trinity of stress." The three approaches consist of input features (environmental stressors), adaptation features (coping mechanisms), and output features (changes in bodily functions and performance efficiency). This model provided a general architecture that explained the effects that various stressors had on individual capabilities at each level of the aforementioned approaches. In accordance with the model of stress and attention, performance was affected by stress when it increased to the point that it was outside of the comfort zone (see Figure 2). "Input level stress increases through change and intensity, prolongation of exposure time, or both in combination; output is eventually affected (Hancock & Warm, 1989, p.526)."

This model was also a bipolar representation of the effects of stress, taking into account the underload and overload of stress on the individual. If individuals were in a state of “hypostress” then he or she was not receiving enough stress to perform at an optimal level and were out side of the comfort zone. Subsequently, when stress became overwhelming, individuals reached the point of discontinuity, and were again outside of the comfort zone, in “hyperstress.”

Although there are many theoretical models of stress that could have been used to predict warning compliance behavior under stress, this study applied the Hancock and Warm Model (1989) because it was an overarching theory that was useful in predicting the effects of varying levels of stress on shooting performance, friend-foe identification decision making task, HRV, and UAV monitoring.

Task Demand as a Source of Stress

Traditionally, researchers have attempted to understand stress by focusing on a specific source of stress, (for example, time pressure), and then understand how variations in the stressor levels affect performance. This view places the external sources of stress as most the important source. However, as emphasized by the Hancock and Warm (1989) model, the performance of the task itself should also be considered as a major source of stress. This is especially critical to consider when understanding stress influences on the soldier operating and making critical decisions in a MOUT combat environment. Because these operations place large cognitive demands on the soldier (such as diagnosing and predicting, situation awareness, cognitive demands associated with new technologies, multi-tasking, vigilance, perceptual skills, improvising, and recognizing anomalies), mission requirements must be considered as the primary source of stress, and other sources of stress, such as heat, time pressure, fatigue, noise, etc., considered as secondary sources of stress that interact with the demands of the task itself. New tasks required of the soldiers on the ground in a combat MOUT environment and initiated by new technologies, such as operating and monitoring Unmanned Aerial or Ground Vehicles while simultaneously completing a MOUT mission, are very demanding for the soldier (both cognitively and physically), and can therefore be viewed as potential sources of stress.

Although the Hancock and Warm (1989) model indicates that the performance of the task itself should be considered as a major source of stress, there is some discrepancy in the literature in reference to the difference between the constructs of task demand and workload. For purposes of the current program of research, the following distinction between the two constructs is made: Hiburn and Jorna (2001) suggest that task load is the demand imposed by the task itself and workload is the subjective experience of task demand. Similarly, Parasuraman and Hancock (2001) also suggest that there is a distinction between the two constructs. "Workload may be driven by the task load imposed on the human operators from external environment sources but not deterministically so, because workload is also mediated by the individual response of the human operators to the load and their skill levels, task management strategies, and other personal characteristics" (p.306). Consequently, task load is the demand placed on the individual while performing a task, while workload is the experience that the individual has while attempting to adapt to the demand.

Cognitive Workload

Cognitive load is an important aspect of the concept of mental workload which Kantowitz (1988) defined as "an intervening variable similar to attention that modulates or indexes the tuning between the demands of the environment and the capacity of the operator." Two main aspects of mental workload exist within the human factors research; task demands and the capacity of the operator, are incorporated in this definition. When task demands are high, mental workload is high and/or the capacity of operator is low. There are individual differences in the capacity of the operator and it can be moderated by environmental factors.

Neerincx van Doorne, and Ruijsendaal (2000), describe three task related factors that contribute to the demands on cognition: time pressure, task set switches, and level of information processing. Time pressure is simply the time required to perform a task in relation to the time available. Cognitive load increases when an operator must switch their mental resources from one task to another. This occurs because the operator must switch between mental models every time they must switch from one task to another.

The level of information processing also affects cognitive load. The level of processing has been categorized at three levels as skills, rules, and knowledge (Rasmussen, 1986). Skills are automatic tasks that require little mental effort. Skill based tasks are usually well-trained tasks, such as riding a bicycle (once you have already mastered the task). Rules are standard procedures that are carried out when once information is presented. Finally, knowledge based tasks are the most complex cognitive task. Knowledge based tasks incorporate the skills and rules that have been previously learned and applied them in novel situations.

Subsequently, task demand is one of many workload drivers. In a review of the literature on workload five factors that contribute to workload include, but are not limited to (a) goals and performance criteria for that task, (b) task structure, (c) the quality, format, and modality of information presentation, (d) the cognitive processes involved, (e) the characteristics of the response device (Messick & Wickens, 1993). Cognitive load is thus difficult to define and measure. Though it cannot be directly assessed, various measures are currently used to assess cognitive load indirectly, and thus provide separate but significant contributions to the understanding of cognitive load.

The Relationship between Cognitive Workload and Task Demand

Previous research indicates that task demand can vary within and between laboratory and real world settings. For instance, many tasks have a steady demand on the individual, while other tasks fluctuate in demand ranging from low, to medium, to high task demand. There is a vast amount of literature on vigilance tasks performed in the laboratory which were typically of low task demand (see Davies & Parasuraman, 1982; Warm, 1984). Results from vigilance studies have shown a consistent association between task demand and workload such that as task demand increases, performance decreases and subjective workload increases (Warm, Dember, Gluckman, & Hancock, 1991; Warm, Dember, & Hancock, 1996, Szalma, et al., 2004). However, very little empirical data considered task demand transitions, such that the demand shifted from low to moderate or high demand. Such cases of demand transition are common in real world tasks, especially in multi-task environments. For instance, soldiers in combat typically wait in a low demand environment until the demand becomes suddenly extremely high (bombing, weapon firing, etc.). Therefore, evidence from existing data from research on vigilance and multi-tasking suggests that the relationship between task demand and workload is not always directly associated and is often dissociated, warranting further research.

Furthermore, O’Donnell and Eggemeir (1986) suggested that performance and workload were not associated when the task demand exceeded the resources available. Yeh and Wickens (1988) used the attentional resource theory as an explanatory framework (see Kahneman, 1973; Navon & Gopher, 1979; Wickens, 1980), and they identified three circumstances in which dissociation could occur:

a) When more resources are invested into the task to improve resource limited tasks (Norman & Bobrow, 1975),

b) If working memory demands are increased due to multi-tasking and,

c) When performance is sensitive to a subtask element and subjective workload measures reflect a more global demand.

This phenomenon could also be explained in the context of the Hancock and Warm (1989) model; when task demand is at a low or moderate level, the operator could adapt to the task demand, and thus, performance and workload will be true associations. Furthermore, when task demand increases and goes beyond the resources available, performance would increase, or no change would occur (dissociations and insensitivities).

Working Memory

Working memory is a familiar term used in psychology, specifically in the area of cognitive psychology. Although the term working memory is common, trying to figure out what the term actually means is a little more difficult. There are three main reasons why it is difficult to define what working memory is, a) short-term memory and working memory are often used interchangeably, b) there are various metaphors used to describe working memory, c) numerous structural representations of working memory exist.

The first reason that defining working memory is so difficult is due to the fuzziness in distinction between working memory and short-term memory (Brainerd & Kingma, 1985). These terms are often used interchangeably in the literature, hence, making it difficult to understand if the constructs of working memory and short-term memory are one in the same or separate memory systems. Secondly, many metaphors are used to describe working memory. For instance, the “resource metaphor”, the “box” or “mental energies” are often used to describe certain aspects of the working memory system. Each metaphor highlighted a different aspect of working memory, and, depending on the theorists, different functions of the memory systems. Thirdly, unitary and non-unitary models of working memory exist. One of the most controversial topics in working memory is the notion that working memory is comprised of either a single or a unitary pool of resources.

Although there are many definitions of working memory (Cowan 1988, 1995; Engle, Kane, & Tuholski, 1999; Kieras, Meyer, Mueller, & Seymour, 1999), Baddeley's (1993) definition is one of the most widely accepted, "a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks such as language comprehension, learning, and reasoning" (p. 556). The commonality that all of these definitions have, regardless of the model that represents the construct, is that working memory is responsible for the storage and processing of information.

Working Memory and Attention

Many models of working memory and attention have made the distinction between the two concepts, but parsing them apart can be difficult, if not impossible. For instance, resource theories of attention were later incorporated into working memory models of attention (Kahnemman, 1973; Navon & Gopher, 1979). Attention and working memory share many commonalities and separating the two are difficult, and perhaps impossible. It is hard to parse apart where attention begins and working memory ends because they are closely related. Many theorists consider them one in the same. Baddeley (1993) suggested that working memory and attention were so tightly knit that "working attention" better suited the integration of the two. The processing resources that are involved in both constructs have blurred the lines between them. As aforementioned, the unitary, non-unitary resource theories of attention were later integrated into working memory models. Furthermore, the introduction of the central executive (Baddeley, 1986) and the functions that it controlled were very similar to attention functions.

A consensus about the relationship between attention and working memory did not exist. Not all working memory theorists supported the notion that attention was an integrated part of the working memory system (O'Reilly, Braver, & Cohen, 1999). Subsequently, the more accepted models of working memory included attention as a key component. For instance, Baddeley had made changes to the original multiple component model of working memory (Baddeley & Hitch, 1974). Baddeley (1996) then hypothesized that the central executive controlled and regulated the two slave systems, as well as, focused and switched attention. In addition, Cowan (1988) had also taken attention into account as a function of working memory and had advocated that the allocation of attention was controlled jointly by (a) the automatic recruitment of attention to especially noticeable events and (b) voluntary, effort that demanded processes directed by the central executive. Similarly, Engle, Kane, and Tuholski (1999) supported the notion that working memory consisted of limited capacity controlled attention. They suggested that controlled attention capabilities were central to individual differences in working memory capacity. What these researchers considered controlled attention, was the same construct that Baddeley and Hitch (1974) had coined the central executive.

Although there is a need for further investigation into attention and the role it plays in working memory, the majority of the research supports the notion that attention is a component of working memory, and that these two processes are not separate. It is imperative to this research endeavor to decide which working memory contention is supported. Working memory was the focus of the current research endeavor, not attention. However, many of the stress models specifically looked at attention without mention of working memory capacity or limitations. Specifically, Hancock and Warm's (1989) model of stress and attention and Wickens' (1984) processing resources in attention model, all focus on attention; again with no mention of working memory. One explanation of why working memory was not considered in these models (and no clarification was provided) is that the stress models were developed before the link between attention and working memory was established. Thus, in this line of research the stress models were used to define stress and the effects that it had on working memory.

The many theories that encompassed the literature on working memory all have had unique perspectives on the architecture and functions of the system. Controversy still exists in the recent literature on working memory as a single or general construct of working memory and attention as component of working memory. For the purpose of this line of research, the separate pool of resources was adopted (Daneman & Tardiff, 1987; Engle, Cantor, & Carullo, 1992; Turner & Engle, 1989), as well as, attention as a component of working memory (Baddeley & Hitch, 1974; Engle, Kane, & Tuholski, 1999). Specifically, in support of the work by Shah and Miyake (1996), the notion that separate pools of resources fuel the cognitive activities of spatial and verbal working memory was assumed. Furthermore, the separate pools of resources were not in the periphery, but played a more central role in the processing and storage components of working memory.

CHAPTER THREE: PURPOSE OF THE CURRENT RESEARCH

This chapter indicates the purpose of the current program of research and the experimental hypotheses. Processing efficiency theory (PET) (Eysenck & Calvo, 1992) relates to the relationship between performance effectiveness and effort/processing resources invested. According to the PET, there are two predicted effects of stress and anxiety on performance: 1) attentional interference effect, and 2) a motivational function. PET was specifically developed to account for how anxiety influences performance. Traditionally, anxiety has been considered detrimental to performance in test anxiety conditions, yet, current literature, mostly within the domain of sport performance, suggests that anxiety has both facilitative and debilitative functions (e.g., Eubank, Collins, & Smith, 2000; Jones, Hanton, & Swain, 1994; Jones & Swain, 1992: Jones, Swain, & Hardy, 1993).

Previous research (Calvo, 1985; Calvo & Aalmo, 1987; Eysenck, 1982, 1985; and Weinberg, 1990) has indicated mixed effects of anxiety and performance. Therefore, another aim of the current program of study was to investigate the effects of stress and anxiety on performance. Additionally, using the Small Arms Simulator Testbed II (SAST II) as a testbed, the performance effectiveness in a target acquisition and friend/foe discrimination task as individuals transition from edge of the comfort zone to region of maximal adaptability was examined. An additional objective of the current study was to identify changes in processing efficiency under varying degrees of working memory demand and sustained information transfer. And consequently, determine whether one has debilitative or facilitative effects on performance in a virtual MOUT combat environment. Therefore, the hypotheses of the first experiment were in the current program of research:

Hypothesis 1. That performance on the primary task (friend/foe discrimination task) would be maintained as working memory task demand (secondary task) and anxiety increased, only at the cost of increased effort.

Hypothesis 2: Consistent with PET predictions, it was hypothesized that performance would remain effective, but less efficient. Changes would occur in processing efficiency under varying degrees of working memory demand. Specifically, that as working memory demands increased, processing efficiency would decrease.

Hypothesis 3: That perceived workload and mental effort would increase as working memory task demand increased, indicating a performance-workload association.

Hypothesis 4: Consistent with the Hancock and Warm (1989) model, it was hypothesized that a performance decrement would be found on the secondary task as workload increased, indicating that the operator is no longer in their comfort zone, and therefore unable to maintain optimal performance on both tasks.

An additional aim of the current program of study was to investigate soldier performance under combat related stressors using the SAST II as a testbed. Specifically, it was of interest to investigate the effects of time pressure, task demand, and prior task loading on shooting accuracy, and maintaining an optimal level of performance in a dual-task MOUT environment. This research effort had several objectives:

1) To empirically assess the role of time pressure on shooting performance mental workload and performance on the UAV monitoring task in a virtual MOUT environment;

2) To empirically assess the affects of prior task loading on shooting performance, mental workload and performance on the UAV monitoring task in a virtual MOUT environment;

3) To empirically assess decision making, combat-related stress, and performance in a virtual MOUT multi-task environment.

Finally, the ultimate goal is to implement the knowledge gained in the development of training aids for decision-making in MOUT environments that increase resilience to the negative effects of stress on a low-cost, portable, yet high fidelity platform.

O'Donnell and Eggemeir (1986) suggested that performance and workload were not associated when the task demand exceeded the resources available, otherwise workload and performance would be associated. This phenomenon could also be explained in the context of the Hancock and Warm (1989) model; when task demand is at low or moderate levels, the individual performing the task could adapt to the task demand and thus performance and workload would be true associations. Yet, when task demand is at a high level, the individual performing the task can no longer adapt to the task demand. Therefore, the hypotheses of the both experiments in the current program of research were:

Hypothesis 5 (a): Experiment 1; that subjective workload and subjective mental effort would be correlated with task demand; in, when the working memory demand is two or four. Specifically, that as task demand increases, both subjective measures will increase.

Hypothesis 5 (b): Experiment 2; that subjective workload and subjective mental effort would be correlated with task demand; when the time pressure conditions on the primary task are one, three, five and seven seconds, when the soldier is exposed to prior task loading, and when the secondary task (the UAV monitoring task) is present.

Hypothesis 6 (a): Experiment 1; subjective workload and subjective mental effort measures, would be significantly lower when there was no working memory demand compared to conditions when the working memory demand was two or four.

Hypothesis 6 (b):Experiment 2, these measures would be significantly lower when the time pressure condition was seven and five seconds compared to conditions of one and three seconds. Additionally, in Experiment 2, these measures would be significantly lower when the soldier is not exposed to prior task loading compared to when he is exposed to prior task loading.

Hypothesis 7: In Experiment 2 it was hypothesized that when the time pressure condition is one second on the primary task, it will exceed the resources available and task load will not be associated with workload measures.

CHAPTER FOUR: EXPERIMENT ONE

Method

Experimental Participants

Participants were recruited from the undergraduate population at the University of Central Florida via the Experimetrix website and fliers. Students who chose to participate in this research effort were compensated via financial reimbursement, at a rate of $7.50 per hour of participation. If the student opted to terminate their participation, the student was paid for the time that he or she participated. Participation time was rounded up to the nearest half.

Experimental Tasks

Primary Task: Friend/Foe Discrimination Task

This task consisted of two different types of stimuli/targets based on the images of assault rifles (Figure 4). The non-target was be an M-16 and the target was be an AK-47. Both stimuli/targets were superimposed over the silhouette stimulus and the friend/foe discrimination was based upon the weapon. A cross-hair red target was located approximately on the center of mass on the silhouette to provide an aim point. Three stimuli were presented simultaneously, one of which was a target and the remaining two were non-targets on 50% of the trials. On the other 50% of the trials only non-targets were presented. The spatial location of each stimulus (targets/non-targets) was randomly generated across the screen to prevent the predictability of the appearance of a target. Each stimulus was presented for three seconds and then disappeared from view, even if the participant did not shoot the target.

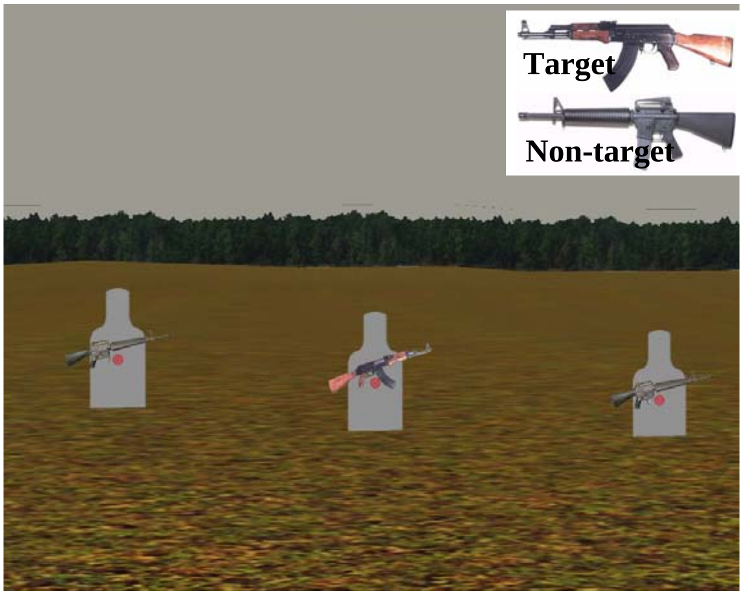


Figure 4 Screenshot from the SAST II displaying the two types of stimuli/targets superimposed on the silhouette stimuli

Secondary Task: Memory Recall Task

The memory task consisted of the auditory presentation of cue words and association words. The combinations simulated unit battalion numbers and locations (e.g., north, south, east, and west). This task was designed to provide varying demands on working memory. There were three levels of the secondary task using a working memory task demand of zero, two, or four. During the pre-block routine in each condition, the participant learned two or four combinations of the cue and association words and practiced responding correctly to each stimulus. During execution of the primary task the participant was presented with the secondary task auditorilly via headphones. The participants responded to the secondary task stimuli via three triggers mounted to the weapon. One trigger was pressed in response to the presentation of a valid cue word and true association word, the second trigger was pressed in response to the presentation of a valid cue word and false association word, and the third trigger was pressed in response to an invalid cue word.

Experimental Apparatus

Small Arms Simulator Testbed II (SAST II)

The SAST II (Naval Air Warfare Center Training Systems Division, 2000) is a research testbed used as a tool for the evaluation and study of both current and new weapon concepts. The SAST II testbed provides a validated synthetic environment that is easily modified by the user, the developer, or industry for the purpose of the evaluation of new weapon concepts and can be used for data collection and ongoing research regarding small arms weapons systems. The system is a single user testbed designed to precisely measure and record the performance parameters of both user and weapon in a controlled environment (see Figure 4). Additionally, the SAST II system applies physics based models, empirically based models, and physical models to represent real world ballistics, weapons dispersions, fire control systems, animated targets, recoil, weapon functionality, sensors, and atmospheric effects. The visual display is presented to the user on a 120-inch diagonal projection screen using a high resolution LCD graphics projector. The user views simulated testing and training scenarios, representing typical small arms firing situations, from a fixed viewing distance of approximately 180 inches. Targets displayed to the user are displayed as graphical objects located within a high fidelity 3-D graphical database.

Figure 5: The SAST II facility including the weapon and the visual display.

Complex firing range scenarios (see Figure 6) can be specified to include target type, target range, target location, target action, target exposure, and target speed.

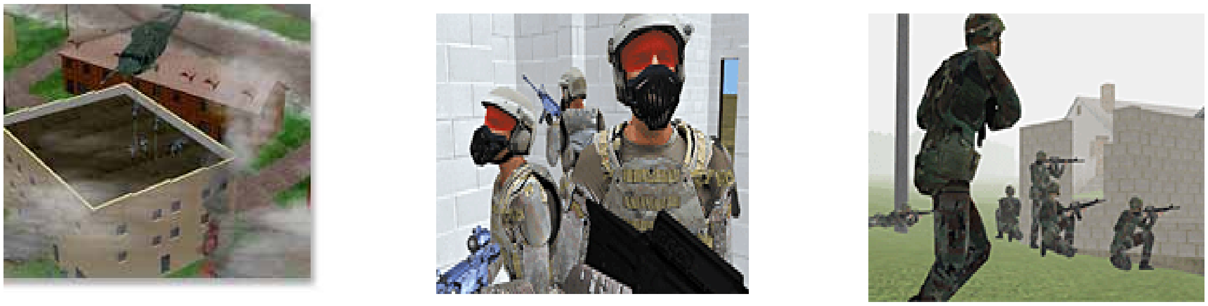


Figure 6 Examples of the SAST II complex firing range scenarios

Simulated weapons, fully instrumented for realism, are provided to the user to engage targets (see Figure 7). A precision high-speed tracking system (IRD) provides two-dimensional continuous weapon aim point data to the system computer. Recoil is simulated using pneumatic recoil devices. Polyphonic sound effects, including weapon noise are simulated with a PC sound card and a speaker system. Weapon aim-point and trigger pull are continuously monitored and stored during scenario runs. Weapon aim-point data are used for playback analysis and statistical calculation of weapon and user performance parameters.

Figure 7 The SAST weapon configuration including the high-speed tracking system

BIOPAC MP150A System

The MP System is a computer-based physiological data acquisition system that performs many of the same functions as a chart recorder or other data viewing device, but is superior to such devices in that it transcends the physical limits commonly encountered (such as paper width or speed). Data collection generally involves taking incoming signals (usually analog) and sending them to the computer, where they are (a) displayed on the screen and (b) stored in the computer's memory (or on the hard disk). These signals can then be stored for future examination, much as a word processor stores a document or a statistics program saves a data file. Graphical and numerical representations of the data can also be produced for use with other programs. For this program of study, we will be measuring heart rate variability (HRV). This technique is non-invasive and poses no risk to the participants. HRV is measured via prepared electrodes that are attached to the participants' skin with medical tape.

LabVIEW, Version 7.0. LabVIEW

(National Instruments, 2004) is a graphical development environment for creating flexible and scalable test, measurement, and control applications rapidly and at minimal cost. LabVIEW is an open environment designed to make interfacing with any measurement hardware simple. For the current program of study, LabVIEW was used to integrate and synchronize the SAST II system, the presentation of the secondary task, and the Biopac system.

Design Overview

The dependent measures were:

1) Response time (RT) for the primary task (mean response, time participants required to pull the trigger on the weapon after the appearance of the targets); 2) response time for the secondary task (mean response time, participants required to press a trigger in response to the secondary task stimuli); 3) shooting accuracy; 4) accuracy on the secondary task; 5) heart rate variability; and 6) subjective measures of workload, anxiety, and transient states associated with mood, arousal and fatigue.

The first experiment included the following within-participant factors: 1) presentation of secondary task (half of the trials included the presentation of a secondary task, half of the trials did not have a secondary task; 2) increasing levels of working memory demand (recognition task; three levels); and 3) friend/foe discrimination task (half of the trials included a target (foe), half of the trials did not include a target. The presentation of trials (no secondary task, secondary task, target, no target) within each working memory demand condition was randomized so that each condition was presented to each participant an equal number of times. Additionally, the order of presentation of each working memory demand condition (0, 2, and 4) was also randomized (see Figure 8).

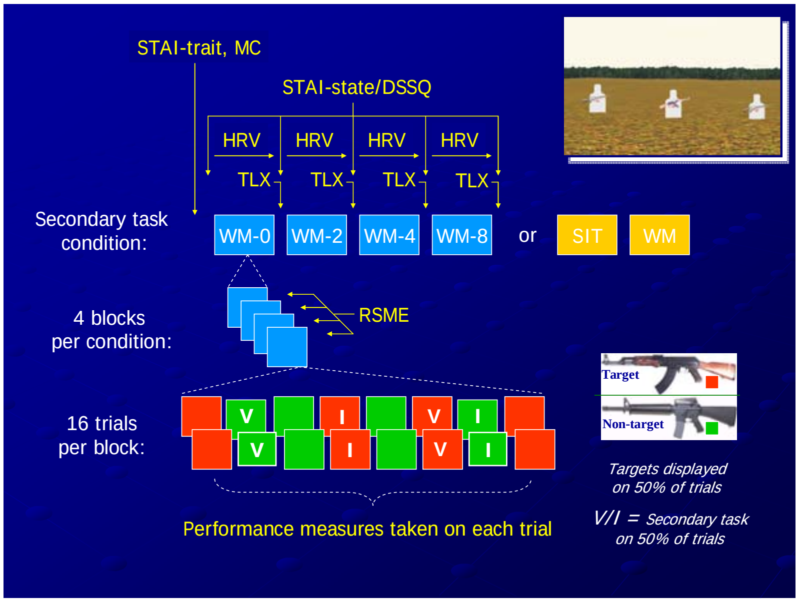


Figure 8 Design overview and task administration of psychophysiological measures and primary/secondary tasks

Experimental Procedure

Each participant was randomly assigned to one of the three working memory presentation orders, with an equal number of participants tested in each order. For each participant, the sand bags (enabling a seated, supported firing position) were adjusted for differences in height, the weapon was calibrated for accurate tracking and aiming vectors, and the triggers attached to the weapon (to allow the participant to respond to the secondary task stimuli) were adjusted for handedness and finger position. The participants received training and practice so that they became familiar with firing the weapon, identifying the targets, and the secondary task.

Each session (approximately three hours) consisted of administration of the subjective measures, training and practice on both the primary and secondary tasks, and of the presentation of the three conditions of the secondary task. Each participant completed shooting scenarios for each condition of the secondary task (each working memory demand condition) which consisted of four blocks of 16 trials totaling 64 trials per working memory condition. Each trial consisted of the simultaneous presentation of one of two types of target stimuli (target, or non-target) and in half of the trials, the presentation of the secondary task. The trials were organized such that each participant was presented with an equal number of trials which included: the secondary task with an enemy target, secondary task without an enemy target, no secondary task with an enemy target, and no secondary task without an enemy target.

The presentation of trials within each working memory demand condition was randomized so that each condition was presented to each participant an equal number of times. Additionally, the order of presentation of each working memory demand condition (0, 2, and 4 items) was counterbalanced. Following each block, participants completed the RSME and between conditions, participants received a five-minute break. Finally, participants were debriefed via a verbal and written statement.

Results

All data were analyzed with repeated measures analyses of variance (ANOVAs). Means and standard deviations were computed for all dependent measures of shooting performance (shots, hits, and reaction times), subjective workload assessment (NASA-TLX), and subjective mental workload assessment (RSME). Because of the number of ANOVAs performed, a Bonferroni family-wise alpha correction was used to determine new alpha levels of statistical significance. None of the significant data were affected by these new alpha levels.

Primary Task Performance

A two-way 2(secondary task present/absent) X 3(working memory (0, 2, and 4 items)) within-participants, repeated measures analysis of variance (ANOVA) was conducted on performance in the friend/foe discrimination primary shooting task. The independent variables consisted of presentation of the secondary task in which the battalion number and location combinations were presented to the participant and varying levels of working memory demand. The dependent variable was the percent correct (number of times the participant correctly identified and hit the target) at each level of working memory demand. The main effect of presence of the secondary task and working memory demand on shooting performance were not statistically significant, Wilk's $\Lambda = .98$, $F(1, 36) = .38$, $p = .69$, partial $\eta 2 = .11$, and Wilk's $\Lambda = .99$, $F(1, 36) = .03$, $p = .87$, partial $\eta 2 = .001$, respectively. However, as depicted in Figure 9, in working memory conditions 0 and 2, participants were more accurate in the shooting task when there was no secondary task than when the secondary task was present. This was not the case in working memory condition 4; possibly due to the combination of practice and fatigue effects.

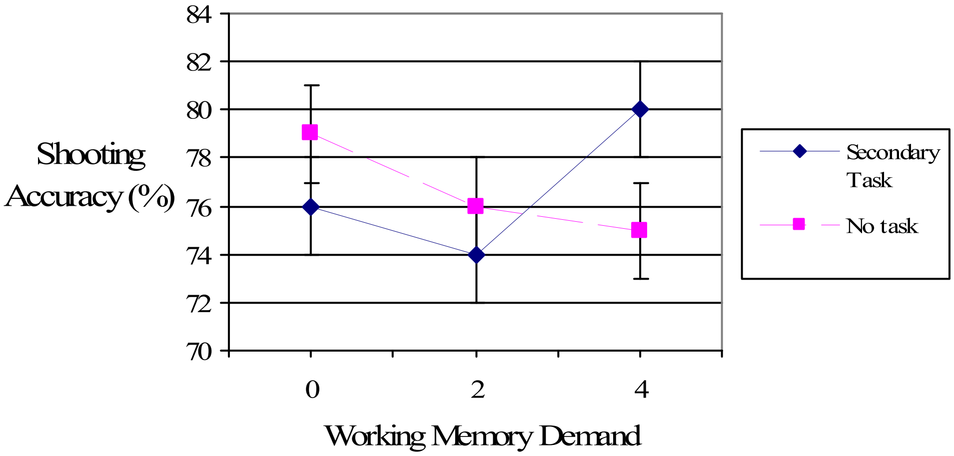


Figure 9 Relationship between presence of the secondary task and working memory demand

Secondary Task Performance

A two-way 2(primary task target present/absent) X 2(working memory demand (2, 4 items)) within-participants repeated measures ANOVA was conducted on secondary task performance (percent correct: number of times the participant correctly recognized and responded to the presentation of the battalion number and azimuth location). There was a significant main effect of presence of a target and working memory demand, Wilk's Λ = .61, F (1, 18) = 11.47, p = .003, partial η2 = .39, and Wilk's Λ = .76, F(1, 18) = 5.61, p = .03, partial $\eta 2$ = .61, respectively. These results show that participants were significantly more accurate on the recognition task when there was not a target present than when a target was present and when the working memory demand level was two (see Figure 10).

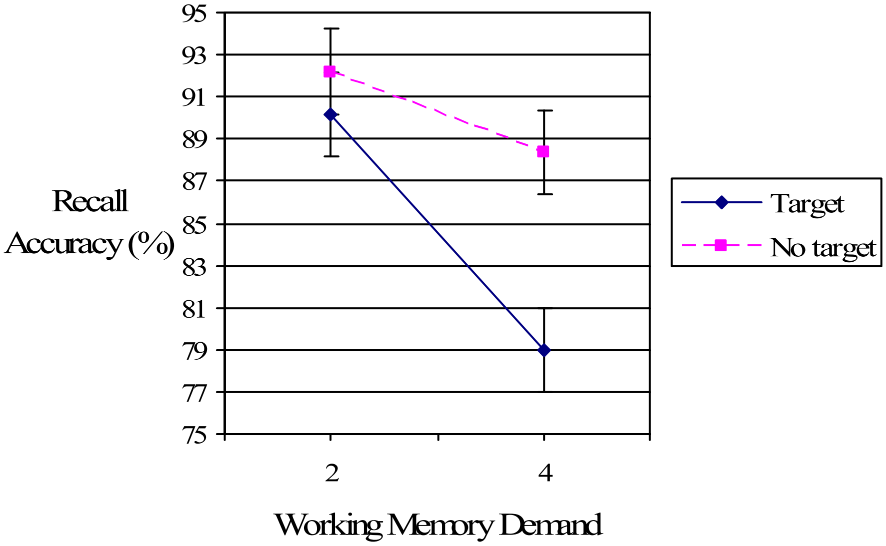


Figure 10 Relationship between the presence of a target and working memory demand

Perceived Mental Workload (RSME)

A 3(working memory demand) X 4(block) within-participants repeated measures ANOVA was conducted on the subjective ratings of perceived mental workload (RSME). There was a significant main effect of working memory demand and block, Wilk's $\Lambda = .35$, $F(2, 31) = 29.32$, $p = .001$, and Wilk's $\Lambda = .55$, $F(3, 31) = 8.08$, $p = .001$, respectively. Specifically, participants reported that a higher level of mental effort was required as a function of working memory demand; as the working memory demand increased, the ratings of mental effort increased (see Figure 11). Additionally, and consistent with our hypotheses, participants reported that a lower level of mental effort was required as a function of time in each working memory demand condition.

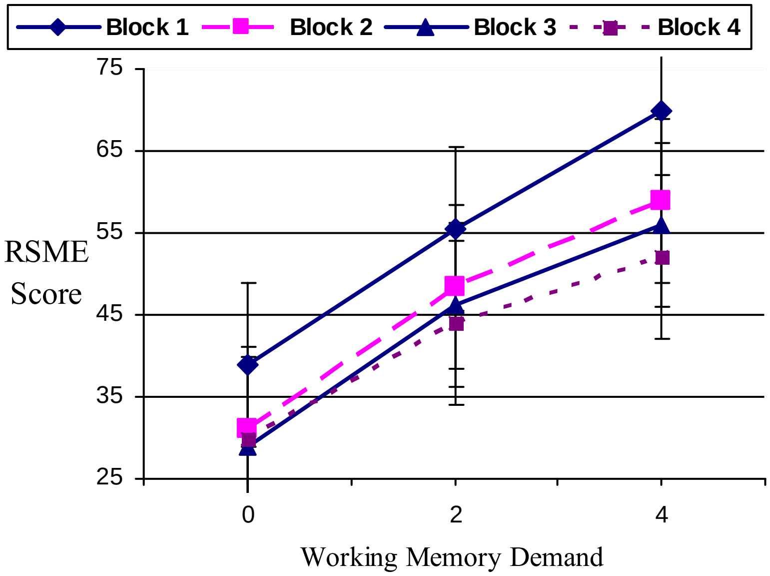


Figure 11 Relationship between subjective mental effort and working memory demand

Subjective Workload - NASA-TLX

In order to determine if time pressure demand affected subjective workload a one-way ANOVA was conducted. The independent variable, time pressure demand, included four levels: not time pressure, two, and four. The results yielded a significant main effect of time pressure demand and perceived workload, Wilk's $\Lambda = .44$, $F(1, 9) = 22.06$, $p = .001$ as depicted in Figure 12. These results indicate that as predicted, as time pressure demand increased, the subjective ratings of workload also increased.

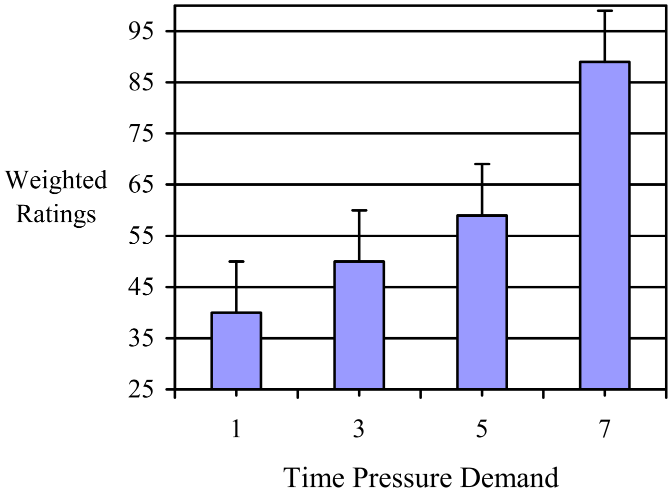


Figure 12 Relationship between subjective workload (NASA-TLX) and time pressure demand

Discussion

This study is the first to investigate processing efficiency in a military context and in a high fidelity simulator. The use of a high fidelity simulator is important in this case because the target aiming and target acquisition task are performed using a real weapon which adds to the physical and the hand-eye coordination demands of the task. As can be seen from the results there are changes in performance for both the primary and the secondary task as the global demands change, clearly indicating that it is not the case of one task dominating the other. However, contrary to our hypothesis, when the task was most demanding (both primary and secondary tasks were present in the highest working memory demand condition), participants' were more accurate on the shooting task when the secondary was present than when there was no secondary task. One possible explanation for these results is that there were combined practice and fatigue effects. Hence, the variability among participants increased, and possibly the analysis of the anxiety data could contribute to the understanding of these changes. Additionally, because participants were significantly less accurate on the recognition task in the same high demand condition, it is possible that participants stopped attending to the secondary task and focused all of their attention on the primary, more salient shooting task. This would be consistent with the Hancock and Warm (1989) model indicating that participants were no longer in their comfort zone and were unable to maintain an optimal level of performance on both tasks. Furthermore, such pattern could also be explained using Hockey's (1997) compensatory control model. Specifically, it may be that as attentional demand increased participants regulated their effort downward on the secondary task to free resources required to successfully engage the primary task.

Furthermore, the mental workload measures correlate with this global demand, indicating a performance-workload association (Hancock, 1996; Yeh & Wickens, 1988). Thus additional investigations of this relationship are necessary. Current efforts are underway to examine the hypothesized effects of trait anxiety on performance and perceived workload. In addition, the other form of workload assessment, physiological measurement, will be examined to test whether there is physiological evidence that participants reduced their effort in the face of high working memory demand. These analyses will provide a more coherent understanding of the results. Future studies will be able to refine these findings and better explain the tradeoff in performance as task demand increases.

CHAPTER FIVE: EXPERIMENT TWO

Experimental Method

Experimental Participants

Participants were recruited from the Reserve Officer Training Corp at the University of Central Florida; all participants were first through fourth year cadets currently enrolled in the program and the university. Cadets who chose to participate in this research effort were compensated via financial reimbursement at a rate of $7.50 per hour of participation. If a cadet opted to terminate their participation, they were paid for the time that he participated. Participation time will be rounded up to the nearest half hour or hour of participation.

Experimental Tasks

Primary Task: Friend/Foe Discrimination Task (Decision Making Task)

The primary task consisted of two different types of stimuli/targets (Figure 13): the non-target were a green esil pop-up target, the enemy target was a black esil pop-up target. Both types of targets “popped-up” in various (randomized) places in a MOUT environment and the friend/foe discrimination was based upon the color of the esil pop-up target. Three stimuli were presented simultaneously, one of which was an enemy target and the remaining two non-targets on 50% of the trials. On the other 50% of the trials only non-targets were presented. The spatial location of each stimulus (targets/non-targets) was randomly generated in the environment to prevent the predictability of the appearance of a target while maintaining the difficulty level of engaging each target (the targets were placed approximately the same along the Y and Z axis’).

Additionally, the inter-trial-interval was randomized between 1 and 5 seconds to prevent predictability of when the targets would appear. In an effort to manipulate time pressure, the amount of time the pop-up targets were presented in four different time conditions (1, 3, 5, and 7 seconds). In the event that the target was "shot" by the participant, it dropped, providing feedback.

Figure 13 Screen shot of the virtual MOUT environment with one enemy target (black esil pop-up target) and two friendly targets (green esil pop-up targets)

Secondary Task: UAV Monitoring Task

The secondary task consisted of a simulated Unmanned Aerial Vehicle (UAV) monitoring and target detection task. Various static UAV potential targets (tanks, soldiers, Hummvee's (HMMWV), etc.; screen shots from the SAST II Rocktown environment) were superimposed on the SAST screen in the participant's Useful Field of View (UFOV) via a second projector (See Figure 14). The UFOV is the area from which one can extract visual information in a brief glance without head or eye movement. The limits of this area are reduced by poor vision, difficulty dividing attention and/or ignoring distraction, and slower processing ability. The presentation of the UAV stimuli was synchronized with the presentation of the SAST stimuli via LabVIEW. This task was designed to simulate information coming in from the UAV to the soldier monitoring the UAV via a Head Mounted Display (HMD). In half the trials a single potential target was present, half the trials did not contain any potential targets.

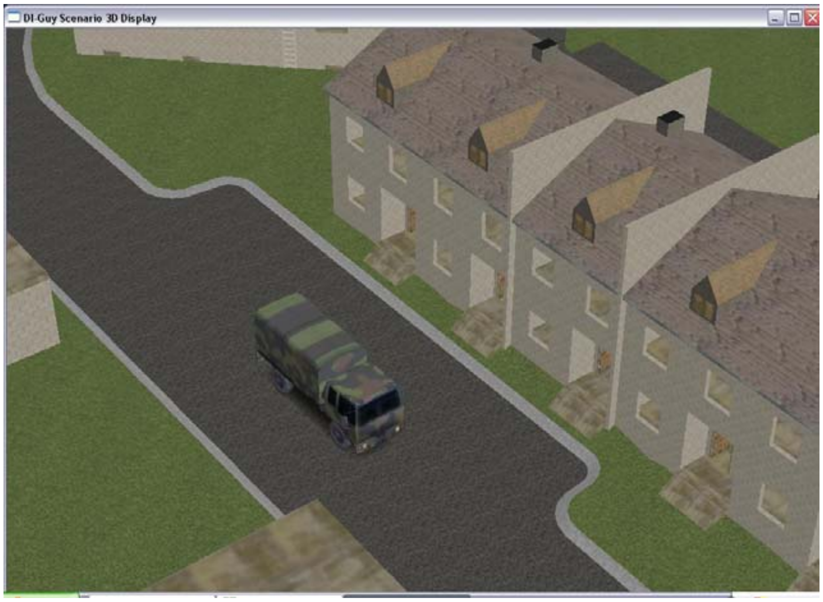


Figure 14 Screen shot of a simulated potential target as viewed from a UAV

Participant's were presented with the primary and secondary tasks simultaneously and responded to the stimuli via two secondary triggers mounted to the weapon. One trigger was pressed in response to the presentation and recognition of a potential UAV target; the second trigger was pressed to indicate that the participant monitored the UAV information and recognized that no potential target was present.

Experimental Apparatus

All experimental apparatus used was the same as used in Experiment 1.

Design Overview

The dependent measures for the primary (friend/foe discrimination shooting task; decision making task) were:

1) Shooting Accuracy: the percent of enemy targets shot (enemy targets in the MOUT environment divided by enemy targets shot).

1.1) Shooting Quality (miss): measured by the number of times the participant fired a shot but failed to hit the target

2) Response Time: mean response time participants required to pull the weapon trigger after the appearance of the enemy targets, measured in seconds

The dependent measures for the secondary task (UAV monitoring/detection task) were:

1) UAV Target Detection Accuracy: monitor, recognize, and respond to potential targets; monitor, recognize, and respond to the absence of a potential target, failure to respond, measured as a percent);

2) Response Time: mean response time participants required to press the secondary triggers when simulated UAV information was presented; measured in seconds)

Subjective measures were:

1) Measures of workload (NASA-TLX);

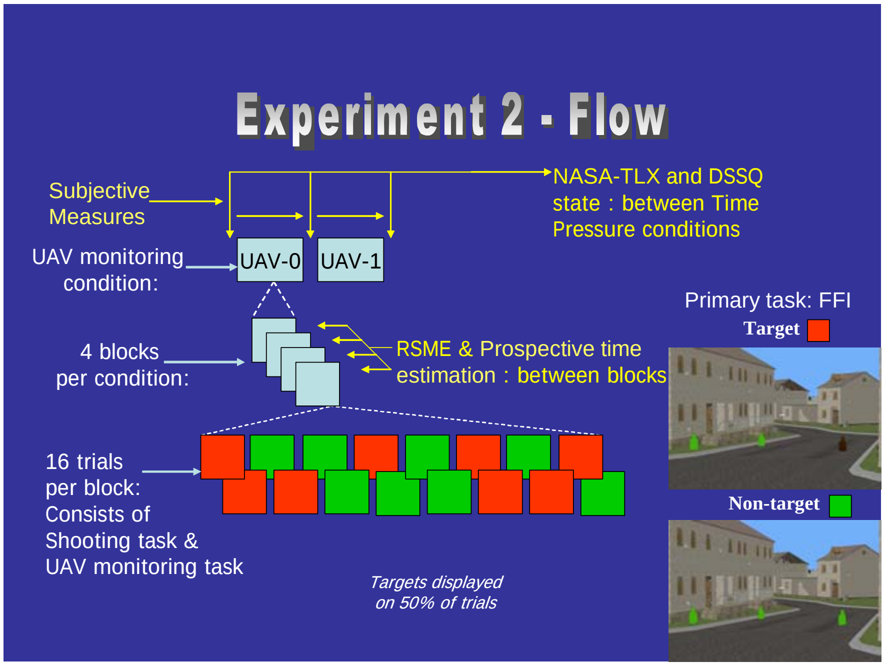
2) Measures of mental effort (RSME) across blocks (time)

The second experiment included the following within-participant factors:

1) Time Pressure: there were four levels of time pressure manipulated via the duration which the targets on the primary task were visible (1, 3, 5, and 7 seconds);

2) Prior Demand: Participants completed two sessions of identical trials; in one session the participant was exposed to prior task demand, in a second session the participant did not experience prior task demand.

In an effort to prevent order effects, the presentation of trials (UAV target present vs. absent), enemy target present, vs. absent) within each time pressure condition and the order of presentation of each time pressure condition (1, 3, 5, and 7 seconds) were partially counterbalanced so that each condition was presented to each participant an equal number of times. Additionally, the order of prior task demand exposure (administered on either on the first or second session) was also partially counterbalanced so that each participant experienced each condition once (See Figure 15).



Experiment 2 - Flow

Subjective Measures

NASA-TLX and DSSQ state : between Time Pressure conditions

UAV monitoring condition:

UAV-0

UAV-1

Primary task: FFI

Target 🟥

4 blocks per condition:

RSME & Prospective time estimation : between blocks

16 trials per block: Consists of Shooting task & UAV monitoring task

Non-target 🟩

Targets displayed on 50% of trials

Figure 15 Design overview and task administration of subjective measures and primary/secondary tasks

Experimental Procedure

Participants were randomly assigned to one of the four time pressure presentation orders, with an equal number of participants tested in each order. For each participant, the sand bags (enabling a seated, supported firing position) was adjusted for differences in height, the weapon was calibrated for accurate tracking and aiming vectors, and the secondary triggers attached to the weapon (to allow the participant to respond to the secondary task stimuli) were adjusted for handedness and finger position. Finally, the participants received practice to provide familiarity with firing the weapon, identifying the enemy and non-enemy targets, and the UAV potential targets.

Each session (approximately four hours) consisted of the administration of the subjective measures; practice on both the primary and secondary tasks, and of the presentation of the four time pressure conditions of the shooting task. Each participant completed shooting scenarios for each time pressure condition which consisted of four blocks of 16 trials totaling 64 trials per time pressure condition. Each trial consisted of the simultaneous presentation of one of two types of target stimuli (target, or non-target) and in half of the trials, the presentation of a potential UAV target. The participants responded to the UAV task by pressing one of two secondary triggers attached to the weapon. One trigger was pressed in response to no UAV targets present and a second trigger was pressed in response to detecting one potential UAV target.

The trials were organized such that each participant was presented with an equal number of trials which included: the UAV monitoring/detection task with an enemy target present, the UAV monitoring/detection task without an enemy target present, no UAV target present with an enemy target present, and no UAV target present without an enemy target present.

Following each block, participants completed the RSME and following each time pressure condition, participants completed the RSME, the NASA-TLX and the DSSQ-post (state), and then received a five-minute break. Additionally, participants were assigned randomly to complete the experimental trials with either prior task demand in the first or second session. The participants completed identical experimental trials with and without prior task demand on separate days within the same week. The prior task demand consisted of participants completing an extremely cognitively demanding navigating/mission task using Ghost Recon for 30 minutes prior to beginning the experimental trials. When there was no prior task demand, the participants watched a replay of a navigating/mission in Ghost Recon 30 minutes.

Results

All data were analyzed with repeated measures analyses of variance (ANOVAs). Means and standard deviations were computed for all dependent measures of shooting performance (shots, hits, and reaction times), subjective workload assessment (NASA-TLX), and subjective mental workload assessment (RSME). Because of the number of ANOVAs performed, a Bonferroni family-wise alpha correction was used to determine new alpha levels of statistical significance. None of the significant data were affected by these new alpha levels.

Friend/foe shooting Task Performance

In order to determine if the presence of the secondary task and time pressure affected friend/foe shooting performance when prior task demand was present or absent, a three-way 2 (secondary task present vs. absent) X 4 (time pressure (1, 3, 5, and 7 seconds) X 2 (prior task demand present or absent) within-participants repeated measures analysis of variance (ANOVA) was conducted on percent correct (number of times the participant correctly identified and hit the target when there was an enemy target present). The independent variables included the secondary task: present or absent, time pressure: enemy targets present for one, three, five or seven seconds, and prior task demand: present or absent. The dependent variable was the percent of enemy targets shot (enemy targets in the MOUT environment divided by enemy targets shot). As predicted, a significant main effect for time pressure was found, Wilk's Λ = .010, $F(3, 7)$ = 240.97, $p \geq .001$. There were no significant main effects of secondary task, Wilk's Λ = .987, $F(1, 9)$ = .120, p = .737 (Figure 16) or prior task demand, Wilk's Λ = .734, $F(1, 9)$ = 3.26, p = .104 (Figure 17). There were no significant interactions.

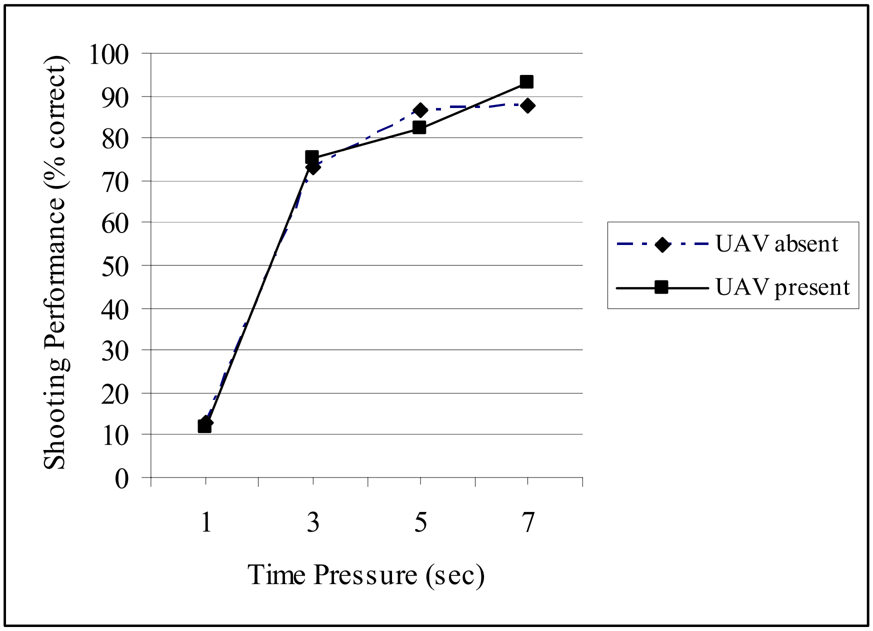


Figure 16 Relationship between shooting accuracy and the secondary task

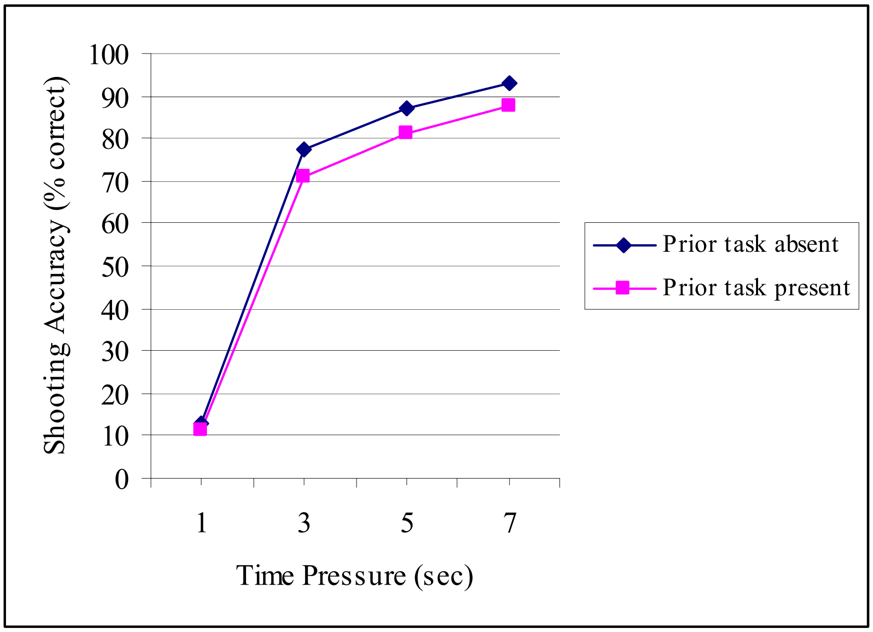


Figure 17 Relationship between shooting accuracy and prior task demand

Table 1

The ANOVA Table for the Friend/foe Shooting Task

Source	df	Mean Square	F	Sig.	Observed Power(a)
Prior Task	1	904.40	3.26	.104	.365
Error(Prior Task)	9	277.37			
UAV	1	10.61	.120	.737	.061
Error(UAV)	9	88.34			
Time Pressure	3	51679.79	252.44	.000	1.00
Error(Time Pressure)	27	204.74			
Pre Task * UAV	1	15.13	.183	.679	.067
Error(Pre Task * UAV)	9	82.51			
Pre Task * Time Pressure	3	41.31	.430	.733	.124
Error(Pre Task * Time Pressure)	27	96.18			
UAV * Time Pressure	3	174.92	1.94	.147	.444
Error(UAV * Time Pressure)	27	90.08			
Pre Task * UAV * Time Pressure	3	125.32	2.21	.110	.499
Error(Pre Task * UAV * Time Pressure)	27	56.64			

Computed using alpha = .05

An additional analysis was conducted on the friend/foe shooting task in order to examine if there were differences between prior task demand and time pressure for reaction time when the secondary task was either absent or present. A three-way 2 (secondary task present or absent) X 4 (time pressure (1, 3, 5, and 7 seconds) X 2 (prior task demand present or absent) ANOVA was conducted on shooting task response time. The independent variables were the secondary task, prior task demand and time pressure. A significant main effect was found only for time pressure, Wilk's $\Lambda = .222$, $F(1, 9) = 8.19$, $p = .011$, and there were no significant interactions.

UAV Identification Task

Due to unforeseen technological difficulties, four participants were not included in the analyses. In order to determine if the presence of the primary task and time pressure affected performance on the UAV identification task when the enemy target was present or absent, a three-way 2 (enemy target present or absent) X 2 (prior task demand present or absent) X 4 (time pressure (1, 3, 5, and 7 seconds) within-participants repeated measures ANOVA was conducted on percent correct (number of times the participant correctly identified the UAV target). The independent variables included the enemy target (in the friend/foe shooting task): present or absent, time pressure: enemy targets present for one, three, five or seven seconds and prior task demand: present or absent. The dependent variable was the percent of UAV targets identified (UAV targets present divided by UAV targets identified). Contrary to the hypotheses, there were no significant main effects found for time pressure, Wilk's $\Lambda = .536$, $F(1, 5) = .867$, $p = .545$, enemy target, Wilk's $\Lambda = .674$, $F(1, 5) = 2.41$, $p = .181$ and prior task demand, Wilk's $\Lambda = 1.0$, $F(1, 5) = .978$, $p = .001$. However, as depicted in Figures 18 and 19, the data suggests that as time pressure demand decreased, participants were more accurate identifying the UAV targets in the absence of both the enemy target and prior task demand. There were no significant interactions.

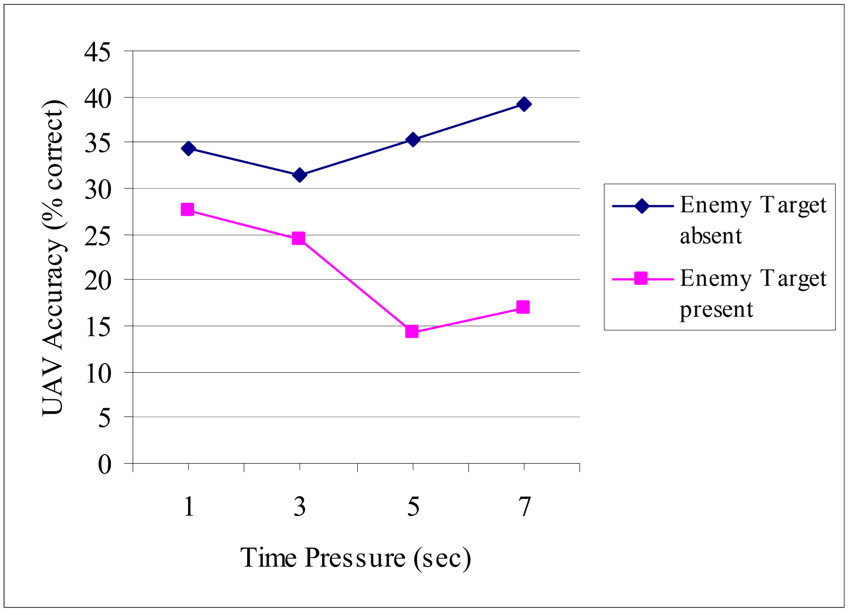


Figure 18 Relationship between UAV identification performance and presence of an enemy target

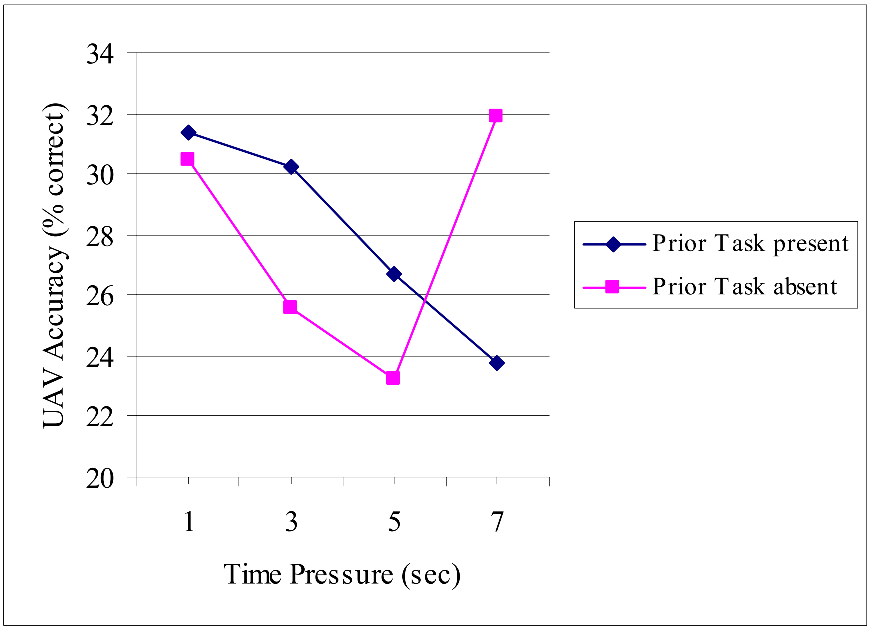


Figure 19 Relationship between UAV shooting accuracy and prior task

Table 2

The ANOVA Table for the UAV Identification Task

Source	df	Mean Square	F	Sig.	Observed Power(a)
Prior Task	1	.146	3.26	.001	.050
Error(Prior Task)	5	169.05			
Target	1	4910.48	2.41	.181	.245
Error(Target)	5	2034.44			
Time Pressure	3	154.24	1.25	.327	.267
Error(Time Pressure)	15	123.53			
Target * PT	1	27.56	.249	.639	.070
Error(Target * PT)	5	110.52			
Target * Time Pressure	3	456.95	1.62	.227	.339
Error(Target * Time Pressure)	15	282.65			
PT * Time Pressure	3	193.04	.780	.523	.178
Error(PT * Time Pressure)	15	247.54			
Target * Prior Task * Time Pressure	3	98.76	.855	.485	.192
Error(Target * Prior Task * Time Pressure)	15	115.48			

Computed using alpha =.05

An additional analysis was conducted on the UAV identification task in order to examine the differences between prior task demand and time pressure for reaction time when the enemy target was either present or absent. A three-way 2 (prior task demand present or absent) X 2 (primary task present or absent) X 4 (time pressure (1, 3, 5, and 7 seconds) within-participants repeated measures ANOVA was conducted on response time. The independent variables were primary task demand, prior task demand and time pressure. Significant main effects were found for prior task demand, Wilk's *Λ* = .436, *F*(1, 5) = 6.46, *p* = .05 and time pressure, Wilk's *Λ* = .222, *F*(3, 15) = 4.90, *p* = .04, but not for primary task demand, Wilk's *Λ* = .830, *F*(1, 5) = 1.02, *p* = .358. Additionally, there was a significant interaction between prior task demand and time pressure, Wilk's *Λ* = .222, *F*(3, 15) = 7.37, *p* = .003.

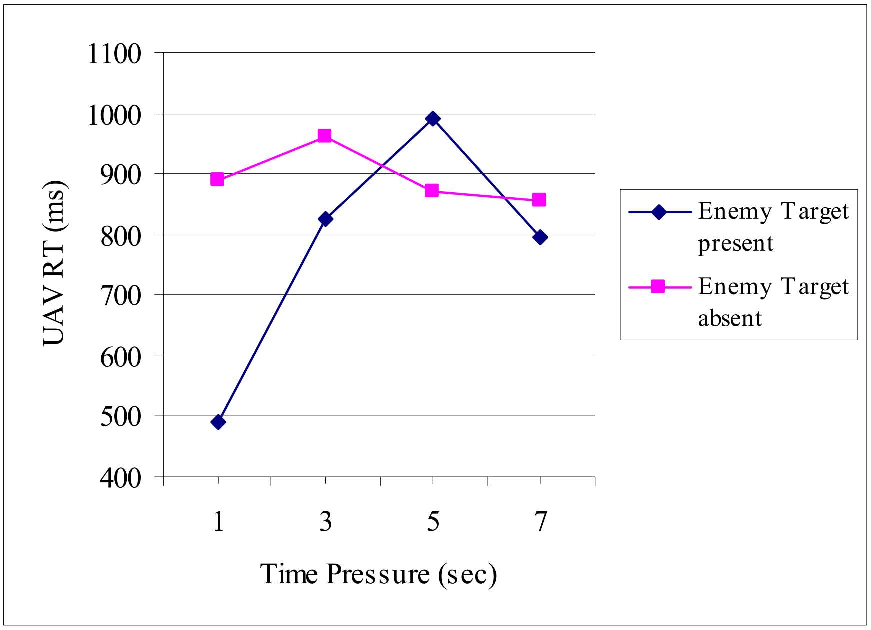


Figure 20 Relationship between UAV response time and enemy target when prior task demand was absent

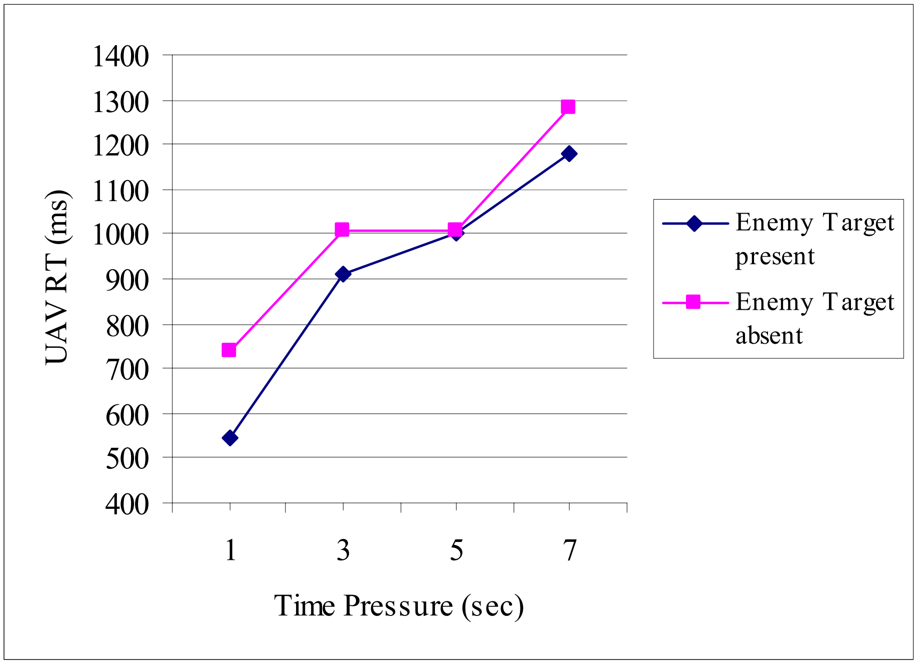


Figure 21 Relationship between UAV response time and enemy target when prior task demand was present

Table 3

The ANOVA Table for the UAV Identification Task Response Time

Source	df	Mean Square	F	Sig.	Observed Power(a)
Prior Task	1	364468	6.46	.05	.536
Error(Prior Task)	5	56397			
Target	1	289749	1.02	.358	.132
Error(Target)	5	282982			
Time Pressure	3	609996	4.90	.014	.815
Error(Time Pressure)	15	124622			
Target * PT	1	1801.93	.065	.809	.055
Error(Target * PT)	5	27767			
Target * Time Pressure	3	126287	1.86	.180	.385
Error(Target * Time Pressure)	15	68050			
PT * Time Pressure	3	228207	7.37	.003	.947
Error(PT * Time Pressure)	15	30964			
Target * Prior Task * Time Pressure	3	29757	.569	.644	.140
Error(Target * Prior Task * Time Pressure)	15	52284			

Computed using alpha level = .05

Perceived Mental Workload (RSME)

In order to determine the effects of time pressure and block a three-way 2 (prior task demand present or absent) 4 (time pressure demand (1, 3, 5, and 7 seconds) X 4 (block) within-participants repeated measures ANOVA was conducted on the subjective ratings of mental workload (RSME) when prior task demand was present or absent. The independent variables included prior task demand: present or absent, time pressure: enemy targets present for one, three, five or seven seconds, and block. The dependent variable was the raw score on the RSME. Significant main effects were found for prior task demand, Wilk's Λ = .653, $F(1, 9) = 4.78$, p = .05, time pressure, Wilk's Λ = .113, $F(3, 7) = 18.26$, $p = .001$, and block, Wilk's Λ = .232, $F(3, 7)$ = 7.73, p = .013. Specifically, participants reported that a higher level of mental effort was required as a function of time pressure demand; as the time pressure demand increased, the ratings of mental effort increased. Additionally, participants reported that a lower level of mental effort was required as a function of block: as participants progressed through each block, mental effort decreased over time.

Although there was not a statistically significant interaction between prior task demand and block, Wilk's Λ = .654, $F(3, 7) = 1.23$, $p = .367$, Figures 22 and 23 suggest that participants required less mental effort when they were not subjected to prior task demand.

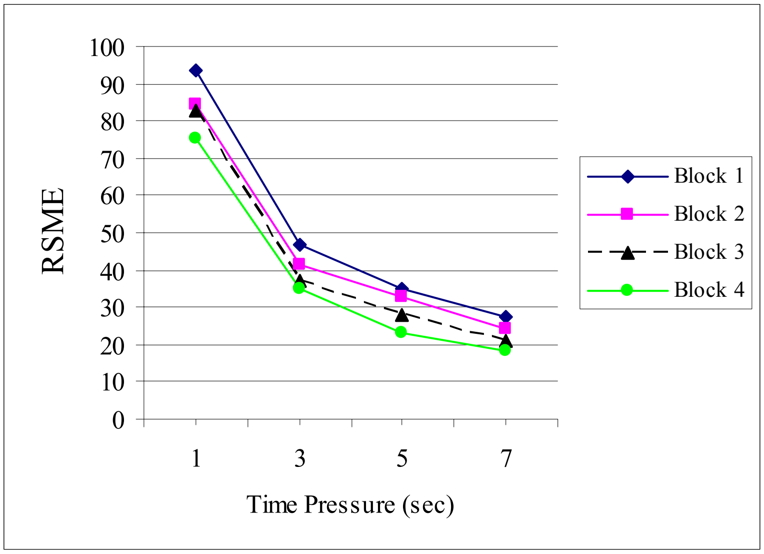


Figure 22 Relationship between subjective mental effort (RSME) and time pressure demand when the prior task was *present*

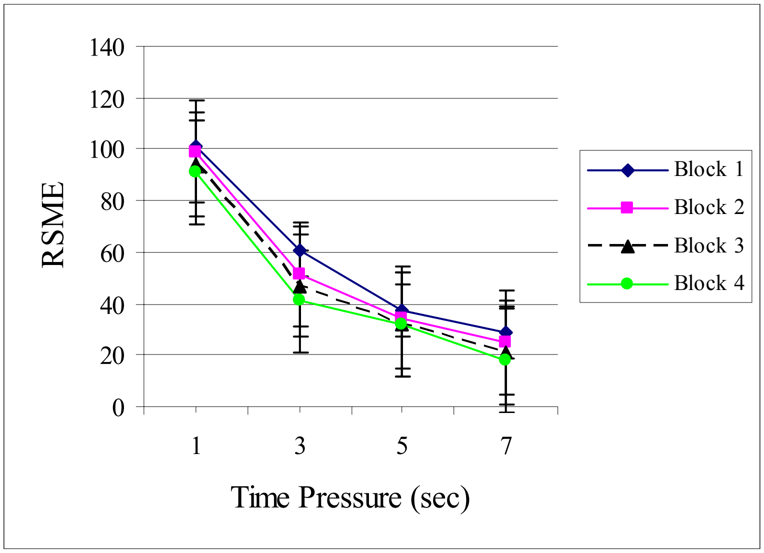


Figure 23 Relationship between subjective mental effort (RSME) and time pressure demand when prior task demand was *absent*

Clearly, level one (1 second) was significantly different from all other levels of time pressure ($p \leq .001$); because it was very improbable that either the primary or secondary tasks could be achieved successfully under such extreme time stress, participants reported considerably higher levels of mental effort than at any other condition. However, consistent with the hypothesis regarding time pressure, all other levels were significantly different from each other (see Table 4).

Table 4

The ANOVA Table for the Rating Scale Mental Effort Pairwise Comparisons

(I) Time Pressure	(J) Time Pressure	Std. Error	Sig.[a]
1	2	6.2	.000
	3	7.0	.000
	4	8.3	.000
2	1	6.2	.000
	3	3.9	.008
	4	4.9	.001
3	1	7.0	.000
	2	3.9	.008
	4	3.3	.023
4	1	8.3	.000
	2	4.9	.001
	3	3.3	.023

Subjective Workload - NASA-TLX

In order to determine if time pressure demand affected subjective workload a one-way ANOVA was conducted. The independent variable, time pressure demand, included four levels: one, three, five and seven seconds. The results yielded a significant main effect of time pressure demand and perceived workload, Wilk's $\Lambda = .44$, $F(1, 9) = 22.06$, $p = .001$ as depicted in Figure 24. These results indicate that as predicted, as time pressure demand increased, the subjective ratings of workload also increased.

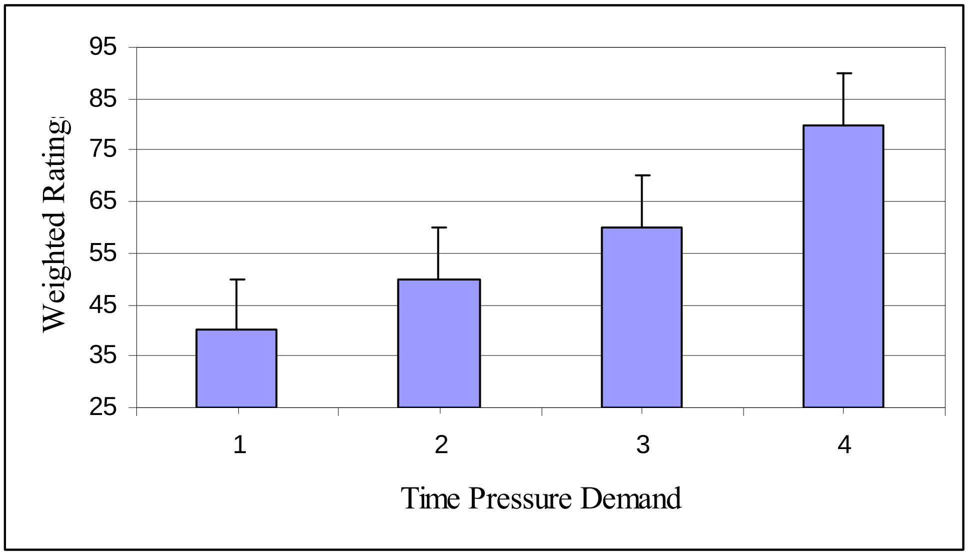


Figure 24 Relationship between subjective workload (NASA-TLX) and time pressure demand

Discussion

Experiment 2 was conducted to empirically assess:

1) The role of time pressure in decision-making accuracy, shooting performance and performance on the UAV monitoring task in a virtual MOUT environment;

2) The affects of prior task loading on decision-making accuracy, shooting performance, mental workload and performance on the UAV monitoring task in a virtual MOUT environment;

3) Decision making, combat-related stress, and performance in a virtual MOUT multi-task environment.

These assertions were examined via several hypotheses. Hypothesis 5 (b) predicted that there would be a positive correlation between subjective workload, subjective mental effort and task demand; when the time pressure conditions on the primary task were one, three, five and seven seconds, when the soldier was exposed to prior task loading, and when the secondary task (the UAV monitoring task) was present. Consistent with these hypothesis, as the levels of task demand increased within the time pressure and primary task conditions, subjective measures of both workload and mental effort demand increased. However, contrary to this hypothesis, participants did not report higher levels of workload and mental effort when the secondary task was present. One possible explanation for this inconsistency is that the secondary task was not difficult enough and did not elicit a high enough level of stress to adversely affect performance on the primary task. Additionally, and consistent with hypothesis 6 (b), both subjective measures were significantly lower when the time pressure condition was seven and five seconds compared to conditions of one and three seconds and when the soldiers were not exposed to prior task loading compared to when exposed to prior task loading.

For the hypothesis on task demand, it was predicted that task load would not be associated with workload measures when the time pressure condition was one second on the primary task. Consistent with this hypothesis, primary task performance was affected by the extreme time pressure condition, exceeding the participants' resources available, and was therefore not associated with workload rating measures.

As can be seen from the results, there are changes in performance for both the primary and secondary tasks as the global demands change, clearly indicating that it is not the case of one task dominating the other.

CHAPTER SIX: OVERALL DISCUSSION

The sequential association and dissociation between objective performance and the individual's perception of the demands visited upon them by the task is a crucial transition since it informs us as to stress effects on capability and renders insight into ways in which psychological understanding varies systematically from reality.

In the present work, two different phases of the association-dissociation relationship were expressed in two experimental results. In the second experiment, the driving demand of the primary task pushed the participant close to the levels of their capacity. The secondary UAV task sought to measure the degree to which this primary load challenged their absolute capacity, however, as a simple target detection task it failed in sensitivity with respect to assessment capacity. Fortunately, the subjective evaluations were able to reflect this demand level and showed at the extremes of time pressure, participants were unable to accomplish the task in any meaningful fashion and thus lie in the region of failed performance in the Hancock and Warm (1989) model. Given these maximal conditions, it follows the predictions of this latter model that there is a high degree of association between performance and subjective workload since performance is minimal and workload approaches a maximal state.

In contrast, results from the first experiment do provide evidence of dissociation with performance of the primary task improving while secondary task performance was decreasing. The subjective measures failed to track primary task performance (which is presumably is the protected task), being evidence of a dissociation. This is not a pure dissociation since the environment required more than one task and to a reasonable degree we can see that much of the objective performance change is represented by a trade-off strategy between primary and secondary performance. What is unique here is the suggestion that the trade-off strategy or task priority selection may be a drive of cognitive workload perception as much as the absolute demands of the two components (primary and secondary) of the overall task itself.

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