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Fatigue's Influence on Workload, Situation Awareness, and Performance in a Military Simulation of Combat

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FATIGUE'S INFLUENCE ON WORKLOAD, SITUATION AWARENESS, AND PERFORMANCE IN A MILITARY SIMULATION OF COMBAT

by

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ABSTRACT

FATIGUE'S INFLUENCE ON WORKLOAD, SITUATION AWARENESS, AND PERFORMANCE IN A MILITARY SIMULATION OF COMBAT

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Military operations routinely require military personnel to consistently perform their duties over several hours or days. Tasks that require prolonged work can lead to mental fatigue and decreased performance. The transactional model proposes that individuals cope with changes in the environment and maintain performance. This ability to cope is determined by factors of the environment and the individual's personality. One environmental factor that can influence coping is extended task performance. This study examined the effect of extended task performance and its interaction with task difficulty. Participants interacted with the military simulation game Command and Conquer: Generals ™ for three hours. They were assigned to either the easy or difficult level of the game. Extended task performance led to an increase in feelings of fatigue. However, it also led to a decrease in mental workload. Contradictory findings were found for situation awareness. Performance on the item measuring perception decreased while performance on items measuring prediction increased. Participants' game performance increased in that they killed more opposers and lost less of their own troops over time. Participants in the difficult group experienced more fatigue than those in the easy group. Task difficulty had no significant interaction with time spent on the task. This study extends current knowledge by providing evidence for the effect of time-on-task fatigue in relation to mental workload, situation awareness, and performance. The use of a computer

simulation game, Command and Conquer: Generals ™ provides an opportunity to examine the effect of extended task performance in an interactive environment. Providing quantifiable data about when and to what extent time-on-task fatigue influences performance can provide a framework for additional training measures. Additionally, the data collected implicate that performance can improve over time; particularly if the task is continuous, participants have past experience with it, and are motivated to continue performing the task.

This dissertation is dedicated to my parents for their support and encouragement.

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INTRODUCTION

Military officers encounter stressful and intense conditions in battle. They are often required to work 24 to 72 hr missions without rest (Gal & Mangelsdorff, 1997). Also, they are required to be aware of their surroundings, the locations of their compatriots, and the presence of enemy forces. Furthermore, they must use this information to make quick decisions in critical situations where they may oppose varying numbers of opponents (Zsambok & Klein, 1997). These circumstances can lead to an increase in fatigue and perceived workload and a decrease in performance and situation awareness.

Several theories have been proposed to explain the relationship between fatigue and performance decrements. According to Kahneman's (1973) resource theory, performance decreases as task demands deplete cognitive resources. The adaptation model indicates individuals adapt to the needs of the tasks. However, stressors such as changes in task load and performing a task over prolonged periods of time can exceed the threshold for adaptability and performance decrements may occur. Unlike the resource theory, the adaptation model proposes that decrements occur when task demand is low. Performance is maintained when task demand is high. The transactional model expands upon this view by indicating that individuals develop perceptions of the task and strategies for coping with the task based on their interaction with environmental stressors such as task load. If individuals are unable to successfully cope, task performance declines. One stressor that has not been explicitly explored is extended task performance. In this study, time-on-task fatigue was investigated as an environmental stressor. Its

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effect on performance and its interaction with task difficulty were examined. First, specific ramifications of fatigue on performance and the theories underlying it were considered. Next, the relationship between fatigue and mental workload and fatigue's effect on situation awareness were discussed. Then the use of computer simulation was discussed.

Fatigue

Fatigue can be both physiological and cognitive. Both types can cause performance decrements. Physical fatigue occurs when muscular functioning decreases after activity. It results in a decreased ability to control or move muscles. This inability to control muscles leads to increased errors and lower dexterity. Researchers have shown that mental fatigue results in cognitive processing and performance detriments. For the purpose of this dissertation, mental fatigue will be the primary topic of discussion. Mental fatigue can be caused by several factors including lack of sleep and circadian disruption. Other factors can affect mental fatigue including nutrition, physical health, and task demands (Lal & Craig, 2001). Extended performance of tasks has also led to fatigue. Tasks lasting over thirty minutes have often resulted in performance decrements including an increase in errors (Sanders, 1998).

Mental fatigue can be classified as either active or passive fatigue. Active fatigue involves performing motor tasks for an extended period of time. Passive fatigue involves continuous observations of a system with few motor responses implemented to make adjustments to the system. Each can lead to performance decrements. Continually performing tasks is believed to lead to a depletion of cognitive resources that can be used to meet the task's demands. Passive fatigue is believed to understimulate operators leading them to be less attentive to implementing actions that maintain the system's status (Desmond & Hancock, 2001).

Fatigue is associated with the occurrence of emotional changes such as increases in depression, anger, and confusion (Lieberman et al., 2005). Mental fatigue is also associated with increases in reaction times and errors and decreases in problem-solving abilities (Van der Linden, Frese, & Meijman, 2003). Tasks that are low in novelty, interest, or incentive, or high in complexity also deteriorate with fatigue (Folkard & Monk, 1985).

Prolonged military operations are believed to result in performance decrements and increased costs to the armed forces. With the increased use of technological advances, such as computer networking, and the placement of armed forces around the world, more military operations are being conducted in various locations at all hours of the day and night. Such operations lead to fatigue throughout the armed services (Caldwell, 2001). According to Hancock and Warm (1989), performance is especially degraded when an individual is cognitively overloaded. Individuals seek to meet task demands but as demands become excessive, the individuals become overloaded and performance decrements occur. Requiring officers to maintain awareness of their situation and make efficient decisions while serving long and intense shifts could lead to cognitive overload.

Although fatigue is an occupational hazard faced by military officers, it is also relevant for civilian professionals. Researchers have documented decrements in behavioral performance across the workday in a variety of different professions (Duchon & Smith, 1993). Extended work has been linked to accident frequency among railroad workers (Coplen & Sussman, 2000), firefighters (Glazner, 1996), and underground mine operators (Hossain et al., 2004). Time-on-task fatigue has been shown to impede the mental processes that are used to organize actions and direct goal-oriented behavior (Van der Linden, Frese, & Meijman, 2003).

Another profession that involves a prolonged performance of duty is medicine. The death of college student Libby Zion in 1984 at a New York teaching hospital brought attention to the prevalence of medical residents who are on-duty for several consecutive days. These fatigued residents were more likely to make life-threatening errors. The Accreditation Council for Graduate Medical Education (ACGME) developed several guidelines to reduce resident fatigue that were implemented in hospitals nationwide in July 2003. These regulations included a maximum work limit of 80 hrs per week, a 10 hr rest period after a 24 hr shift, and a day without hospital duty every seven days (Kort et al., 2004).

However many healthcare workers are still overworked. Due to the increasing scarcity of nursing professionals, extended hours have become a necessity in many hospitals. Surgeries can last over 20 hours, causing nurses, anesthesiologists, surgeons, and other specialists to perform intense procedures for an extended period of time. Performing several surgeries throughout the day and night causes very long work schedules. These conditions lead to a prevalence of fatigue and a higher probability of performance errors (Krueger, 1994). Gravenstein, Cooper, and Orkin (1990) showed that 61% of 2713 anesthesiologists and certified registered nurse anesthetists experienced fatigue and made errors in anesthesia administration during prolonged shifts. Krueger

(1994) stated that fatigued medical professionals could experience degraded ability to resolve problems, reduced reaction time, and increased mistakes.

One well-known historical demonstration of performance decrements due to extended performance is the Cambridge cockpit studies conducted by Bartlett (1943). In these studies, participants sat for long periods of time manipulating aircraft controls in reaction to changes in different instruments. Bartlett found that alertness, cognitive skills, and motor skills decreased over time while drifts in attention increased. Participants allowed the instrument readings to deviate before they implemented corrective actions. Attention to major instruments like the compass remained, but attention to secondary displays such as the fuel gauge decreased. The pilots' reports became less reliable as they became easily distracted. They also showed an increase in physical discomfort. Researchers also found that after two hours in the flight simulator, pilots' abilities to organize their actions decreased. The pilots focused on the flight instruments individually. In addition, control responses were performed out of sequence resulting in sequential errors (Hockey, 1983).

Researchers have also compared the performance of individuals who completed a standard workday with those who completed an extended workday to measure the extent of fatigue's influence on performance. Macdonald and Bendak (2000) compared performance in a continuous bioproducts production plant between workers who performed 12 hr shifts with those who worked 8 hr shifts. The researchers developed assessment battery measurements that included bodily discomfort ratings, workload ratings, grammatical reasoning, and choice reaction time. Assessment battery measurements were completed at the beginning, middle, and end of the shift. Participants who worked 12 hr workdays and had high workloads showed greater fatigue than those who worked 8 hr and those who had low workloads. These individuals showed increased ratings of bodily discomfort, increased errors on a grammatical reasoning task, and decreased alertness. Rosa and Bonnet (1993) compared gas utility and continuous processing plants workers who were working 8 hr shifts with those who were working 12 hr shifts. The 12 hr shift workers showed significantly more feelings of fatigue and less sleep than the 8 hr workers. These discrepancies were still present in a three to five year follow-up study (Rosa, 1991). These studies illustrate that there is a limit to one's ability to meet task demands. Once that limit is exceeded after the traditional 8 hr shift, performance decrements are likely to occur.

Even slightly extended workdays can lead to performance decrements. Josten, Ng-A-Tham, and Thierry (2003) examined nurses who worked a 9 hr shift to determine if this minimal increase over the traditional 8 hr shift might represent a reasonable compromise for nurses suffering fatigue and health problems on 12 hr shifts. The nurses indicated that they were still more fatigued, reported more health complaints, and felt less satisfied with their work than the nurses who worked 8 hr shifts. The nurses also completed self-report measures regarding the quality and quantity of tasks they performed during their shift. They reported completing their assigned tasks with less accuracy during the 9 hr shift. Performance particularly deteriorated in quality and quantity during the last hour of the 9 hr shift (Josten, Ng-A-Tham, & Thierry, 2003).

Empirical Studies of Fatigue in the Military

Research concerning fatigue in the military indicates officers undergo decrements in cognitive processes (Lieberman et al., 2005). Several researchers have examined subjective reports of fatigue and performance decrements due to time-on-task fatigue in military operations. Von Restorff, Kleinhanss, Schaad, and Gorges (1989) examined decrements in continuous operations over a 72 hr period. Participants were allowed to sleep for one hour after 32, 48, and 60 hrs. Greater decrements in performance were found for more complex tasks than for simple reaction time and vigilance tasks. In another study, measurements of blood glucose, memory, vigilance, and mood were taken once every 24 hr period for a group of military officers performing a four-day operation. After 48 hrs, participants experienced an increase in negative emotion and decreased ability to perform the cognitive tasks. Participants showed increased feelings of depression, anger, and confusion. Their ability to perform vigilance and memory tasks declined. These decrements remained at the completion of the 72 hr session (Owen, Turley, & Casey, 2004).

Lieberman and his colleagues (2005) assessed cognitive and physiological effects of stress before, during, and after a training exercise where soldiers faced severe conditions such as exposure to simulated explosions and gunfire for over 53 hours. Wrist activity monitors were used to measure rest and activity patterns throughout the exercise. These devices calculated that soldiers slept $3.0 \pm .3$ hours during the exercise. Reaction time, attention, memory, and reasoning were reduced. Participants also completed the Profiles of Mood States where they exhibited an increase in fatigue, confusion, and depression over the course of the experiment.

Another study by Neri, Shappell, and DeJohn (1992) evaluated variations in cognitive performance within sustained attack missions. During a simulated mission, twelve participants completed subtests of the Unified Tri-Service Cognitive Performance

Assessment Battery and the Walter Reed Performance Assessment Battery. The tests were administered eighteen times during the 9 hr planning session and 14 hr mission. On a pattern recognition test, they found that participants demonstrated linear increases in response rate and errors.

Theoretical Structure for Fatigue Effects

Despite the common occurrence of fatigue, researchers still question its' definition, underlying cognitive processes, and theories about why fatigue occurs (Broadbent, 1979; Desmond & Hancock, 2001; Hockey, 1997). One theory that has been used to explain the effects of fatigue is the unitary attention resource theory. Fatigue may be thought of as a deficiency in supplying adequate attention to complete a task (Broadbent, 1979; Meijman, 1997). As individuals must perform a task over a prolonged period of time, the cognitive resources decline (Bush, 2002).

Kahneman's resource theory. Attentional capacity or resource theories are often used to examine performance decrements in complex tasks. Kahneman's (1973) unitary resource theory indicates that the amount of attentional resources available for tasks is restricted. Parasuraman (1985) indicates that fatigue may limit the amount of cognitive resources available to complete tasks. These resources can be applied to various tasks until the maximum amount of resources is expended. Resources are expended based on several factors. One is enduring dispositions or involuntary attention such as attending to a new signal or sudden movement. Another is evaluation of demand (Kahneman, 1973). There is a "performance trade-off" when tasks are performed concurrently, in that performance of one task of greater difficulty or priority may be maintained at the expense of performance on the other task (Norman & Bobrow, 1975). Also, tasks that incite greater arousal in the individual receive more resources.

Kahneman's resource theory (1973) is based on several propositions. First, there is a limited capacity for resources (Norman & Bobrow, 1975). Task demands determine the amount of resources expended. Increased demand may limit or deplete available resources. Resources can be expended among several tasks. Also, the capability to allocate resources can be decreased by capacity and structural interference. Capacity interference occurs when simultaneous tasks compete for the same mental resources at the same time. Structural interference occurs when simultaneous tasks contend for the same mental structures. Norman and Bobrow (1975) specified that the ability of resources to be allocated to tasks was determined by whether the task was resource-limited or data-limited. When an increase in resources improves task performance, a task is resource-limited. Tasks are data-limited when only the quality of the data influences task performance. Increasing resources does not affect task performance. Thus, in these instances, it is the structure of the task, not the demands, which determine performance.

Wickens (1991) found several trends that contradict Kahneman's resource theory. One is difficulty insensitivity in which changes to primary task difficulty have no effect on secondary task performance. Another is structural-alteration effects, which occur when interference between primary and secondary tasks is decreased by altering the cognitive structures used to perform the primary tasks without adjusting primary tasks' difficulty. Difficulty-structure uncoupling occurs when the difficulty of the primary tasks increases but does not increase interference between primary and secondary tasks (Wickens, 1984). Allport (1980) showed that multiple cognitive resources could control multiple task performance. Wickens (1984) showed resources could be differentiated among several elements: stages of processing (perceptual/central vs. response processing), codes of processing (spatial vs. verbal processing), and input (visual vs. auditory processing) and output (manual vs. speech processing) modalities. However, Cowan (1995) indicates that unitary resource theory could still explain multiple task performance. Individuals could have enough prior experience with one or both of the tasks that they can perform automatically and require fewer resources.

Without appropriate cognitive resources, task performance declines. For example, Brown, Tickner, and Simmonds (1969) required participants to perform an auditory reasoning task as they drove. A series of sentences was transmitted over a radiophone. The letters A and B followed each sentence. Each sentence was supposed to depict the order in which the letters would be spoken. After the sentence and the letters were spoken, the participant specified whether the sentence was true or false. For example, the sentence "A follows B" might be spoken, followed by the letters "B, A". In this case, the participant would correctly respond, "true," because the sentence is a true indication of the relationship between the letters. Performing this additional task degraded participants' ability to judge whether they could maneuver the car through a narrow gap.

Recently, Young and Stanton have disputed the belief that resources are permanently set. They propose that resources decrease when individuals are performing tasks low in demand (Young & Stanton, 2001). If the task is prolonged or unexpectedly increases in complexity, individuals lack the resources to meet these demands and performance decreases. Thus, attention resources are changeable or malleable. Resources depend not on mental effort but on the workload of the task. Resources increase with increases in workload to a point and decrease with reductions to workload. To test this idea, Young and Stanton (2002) varied car automation on four different levels. For some levels of automation, mental workload decreased. With this loss of workload, attention resources decreased. They believed this finding supported their contention that resources changed based on the needs of the task. However, there has been little further research to support their claims.

Compensatory theory. Mental effort can also be conceptualized as a compensatory process employing cognitive-energetic control mechanisms to manage cognitive resources. The length and intensity of task performance can degrade this process (Meijman, 1997). Thorndike (1912) first proposed the compensatory theory of cognitive fatigue. He suggested that as people continue to direct effort toward their tasks, performance would be maintained. More recently, Hockey (1997) developed a cognitive-energetical framework for this theory. He extends the resource theory by focusing on individuals' attempts to control their behavior and preserve their resources. The model indicates two points of control (see Figure 1). The lower level of control (loop A) directs automatic learned behaviors. These behaviors are believed to require little mental effort. The second level (Loop B) is activated when high task demands require a large amount of resources. Loop A is used to make minor adjustments in allocating resources to tasks. Loop B is used to make major adjustments.

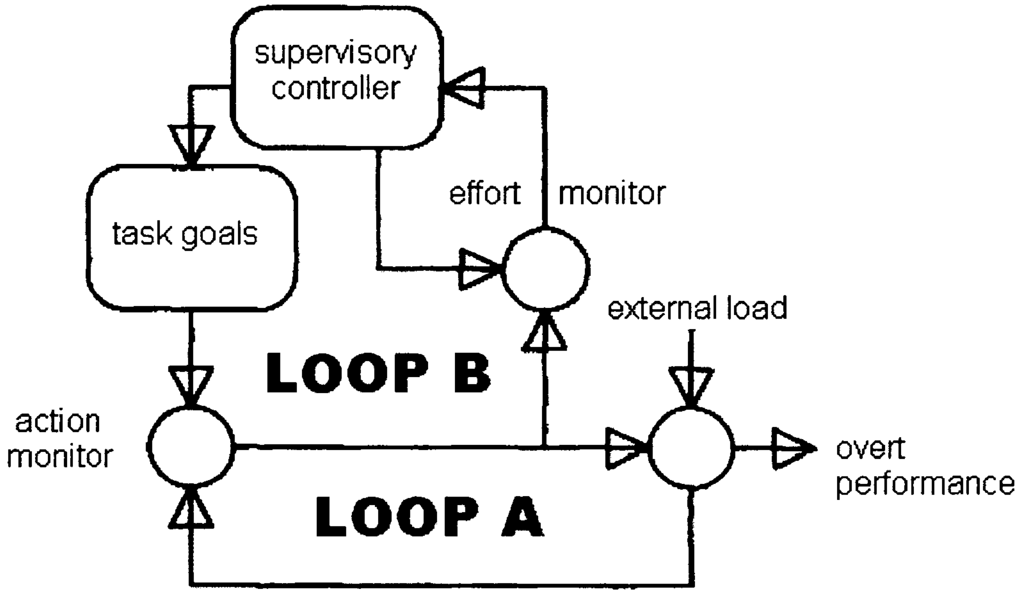

Fig.1. Compensatory control model (Hockey, 1997) states that individuals compensate for task demands to maintain performance (obtained from Hockey, 1997).

Individuals decide what behaviors to implement based on the goals that they want to accomplish. Loop A controls these behaviors. However, if individuals encounter opposing goals or varying workload they begin to lose mental effort and experience feelings of strain. Tasks that continue to demand a high amount of effort for a prolonged period of time lead to fatigue and performance decrement. Individuals may resolve this situation by lowering their goals to meet the amount of effort they can expend (Hockey, Wastell, & Sauer, 1998). They actively attempt to preserve their resources by engaging in a "performance protection strategy." Tasks that are high priority will be maintained, while secondary or lower priority task will decrease (Hockey, 1997). For instance, despite feeling mentally overloaded, military officers may continue to serve for days at a time. However, some discrepancies such as increased errors reveal the inner struggle of officers to maintain their performance.

Adaptation model. In addition to theories that proposed that the presence or absence of cognitive resources influenced behavior, Hancock and Warm proposed an adaptation model that indicated that individuals could adapt to changes in task demands. Hancock and Warm (1989) developed an adaptation model of stress and performance that was later applied to fatigue by Desmond and Hancock (2001). Desmond and Matthews (1997) established that fatigue is an example of a type of stress. The adaptation model is believed to be predictive of performance when individuals are exposed to extended stress. According to Hancock and Warm's model, individuals in a dynamic environment often find their plans or strategies interrupted due to changes in the environment. These changes can create stress at the input level, adaptation level, or output level. The prolongation of task performance influences the input level. Individuals are initially able to handle stress and change their behavior in their psychological zone of adaptability (see Figure 2). As they begin to perform the task they are able to maintain their performance.

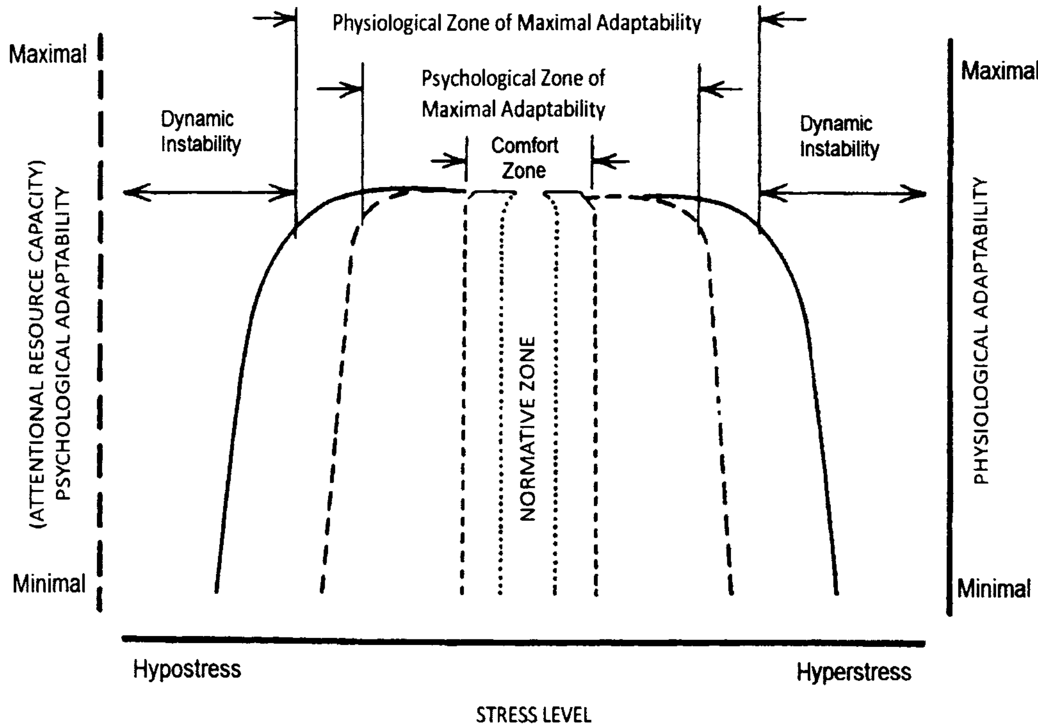

Figure 2. Hancock and Warm model (1989) proposes that people maintain performance unless they become under- or overloaded (obtained from Hancock and Warm, 1989).

However in hyperstress, individuals are exposed to the task for an extended period exceeding their zone of adaptability. They become mentally overloaded and task performance, which is the output level, declines (Hancock and Warm, 1989; Desmond & Hancock, 2001). Similarly in conditions of hypostress such as vigilance tasks, performance declines.

Desmond and Hancock (2001) propose that the adaptation model can be used to account for stress-induced performance effects. Desmond and Matthews (1997) used the model to explain the deterioration of vehicle control by fatigued drivers in several experiments. Fatigue was induced through a signal detection task in which participants had to search for an odd or even number in the signs they passed in the simulation. In one study, participants drove on both curved and straight roads. The distance between the participant's car and the car preceding the participant tended to decrease more on straight roads than on curved roads. Desmond and Matthews (1997) found that as drivers became fatigued they had more difficulty meeting the requirements of a simple task than a more demanding and complex one. They propose that on straight roads, participants failed to accurately organize their effort to complete the task. They expended more effort on the curved roads to meet the increased demands of the task.

Transactional model. Matthews (2001) later expanded upon the Hancock and Warm model (1989) and the transactional model of stress developed by Lazarus and Folkman (1984). Lazarus and Folkman's model indicates that how individuals perceive stress is based on the relationship between individuals and their environment. Individuals appraise the situation, based on their personality and stressors in the environment, and choose a coping strategy. Types of coping include problem or task-focused and emotion focused. In task-focused coping, individuals change their response to the environment to reduce stress. In emotion focused coping, individuals change their perceptions of the stressor (see Figure 3).

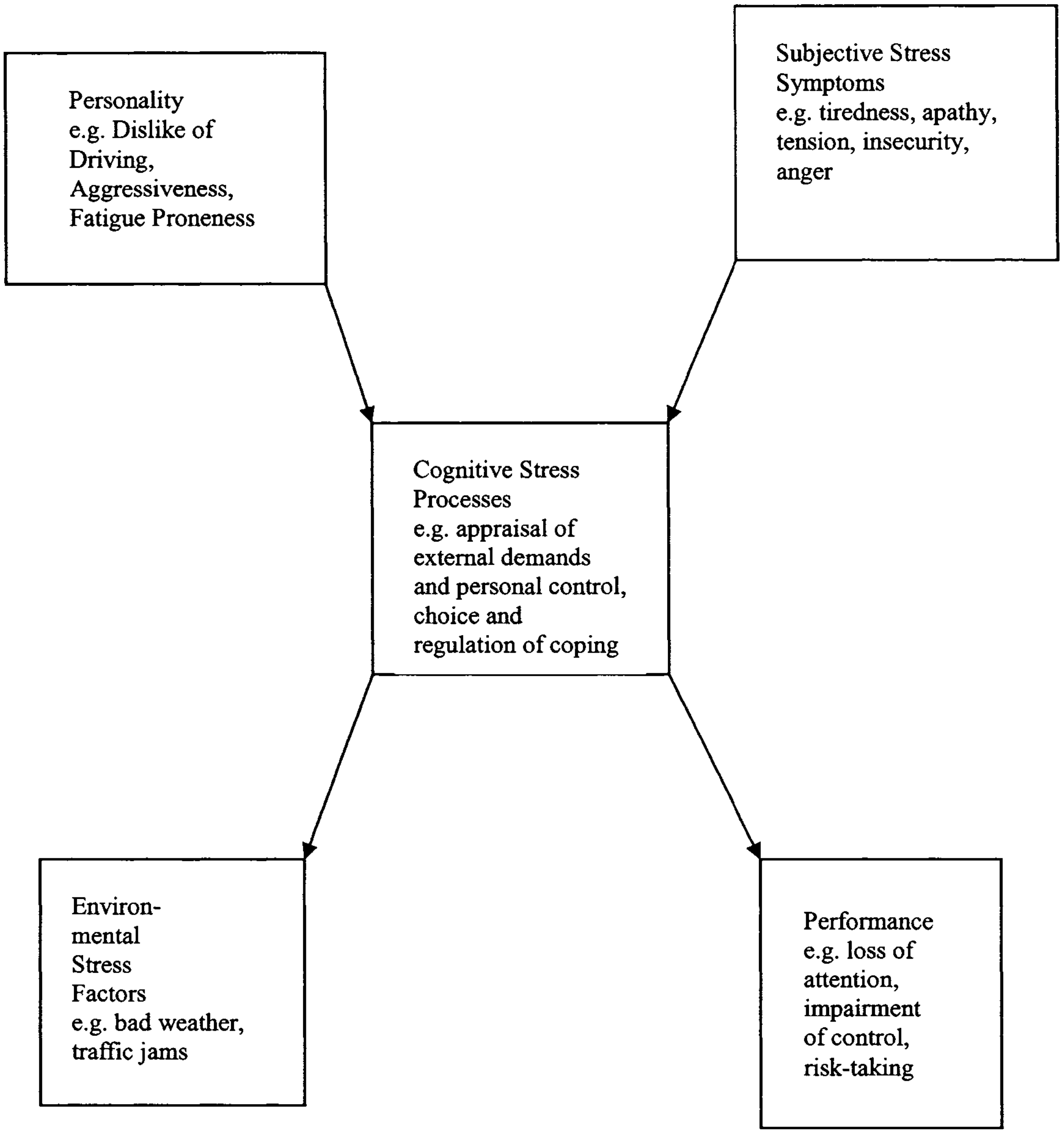

Figure 3. Transactional model (Matthews, 2002) proposes that an individual's performance depends on the demands of the environment.

Matthews (2001) indicates that if individuals feel that the needs of the environment exceed their ability to cope, they will experience stress symptoms such as negative moods, worry, and apathy. They may also experience performance decrements such as loss of attention. Individuals' assessments of their ability to cope and the coping style they implement are influenced by their personality and self-knowledge. Self-knowledge is an individual's belief about his or her aspirations and ability to reach his or her goals. It is a dynamic process in that as the situation changes individuals have to reappraise and implement an appropriate coping style. Matthews and his colleagues have investigated the influence of personality factors such as neuroticism and extraversion (Dorn & Matthews, 1992) and dislike of driving (Matthews et al., 1998) on performance under varying levels of task demand. Similar to the adaptive model, Matthews (2002) states that individuals evaluate the situation based on the needs of the task. Performance decrements occur for less demanding tasks when individuals implement less effort toward these tasks than for high demand tasks. However, there has been no explicit examination of the influence of elapsed time on performance or its interaction with task difficulty.

Both the cognitive resources theory and the adaptation models have been used to account for the relationship between mental workload and performance. Wickens (2001) demonstrated that as task demand increases, cognitive resources to process information decrease. This may result in an increase in mental workload, as individuals must work harder to maintain their performance (Wickens, 2001). Parasuraman and Hancock (2001) applied the Hancock and Warm adaptive model (1989) to workload. They showed that when workload is too low or too high, performance decreases. Brookhuis, Van Wisum, Heijer, and Duynstee (1999) proposed that low workload leads to a decrease in attention and awareness. An overload of workload leads to divided attention and a lack of time to process information.

Mental Workload

Mental workload refers to the extent to which task demands influence mental processes (Ryu & Myung, 2005). Workload can be varied by changing the numbers of tasks performed or the difficulty of the tasks. Parasuraman and Hancock (2001) indicate three types of associations between workload and task demands. Mental workload may increase or decrease as the demands of the tasks increase or decrease. Increasing task demands may also result in a decrease of mental workload. Mental workload may be unaffected by an increase or decrease in the task difficulty.

Fatigue has also been linked to mental workload. However, these concepts are not synonymous. MacDonald (2003) defines workload as the interaction between the demands of the tasks and an individual's ability to meet those demands. However, Lorist, Boksem, and Ridderinkhof (2005) define mental fatigue as an effect of task demands. High workload usually results in fatigue reactions. In addition, high fatigue increases perceived workload. Environments that require workers to perform for an extended period of time represent one situation where mental capacity can be exceeded. Individuals do not have an opportunity to recover from their effort, resulting in a depletion of available mental resources (Gaillard, 2001). For example, Bertram, Opila, and Brown (1992) evaluated resident physicians after they examined 92 patients in an ambulatory care clinic. Mental workload measures were positively correlated with fatigue, indicating that periods of great mental workload placed excessive demands on the physicians. In addition, self-ratings of performance decreased as mental workload increased.

Holding (1983) suggested that participants experiencing fatigue and high mental workload would make choices that would help them achieve their goals and avoid failure. He developed the COPE (choice of probability/effort) test. The device was designed as an "electrical fault-finding task". Participants were required to examine mechanisms containing 1, 2, or 3 resistors (Holding, 1983). If the fault was found then a buzzer sounded and the trial ended. If not, another component was examined and the procedure continued until the fault was found. This test was given before and after participants completed monitoring and cognitive tasks for 24 to 32 hrs. As fatigue increased, participants demonstrated a shift towards riskier choices to avoid failure even though these choices reduced the probability for successful performance (Holding, 1983).

Another construct that has been related to mental workload is situation awareness. Situation awareness can be degraded by mental workload. If an individual experiences high mental workload, situation awareness could be degraded as individuals have a reduced ability to collect and integrate cues from the environment. Conversely, individuals working under conditions of low mental workload may also suffer a degradation of situation awareness (Endsley, 1999).

Situation Awareness

Endsley indicates situation awareness concerns people's ability to perceive (Level 1), comprehend (Level 2), and project elements of the environment (Level 3) (Endsley, 1988). These three levels are relevant for battle command because officers must identify important aspects of their environment, understand how these elements create a cohesive picture, and use this information to predict upcoming changes in the environment.

Components of Situation Awareness

Situation awareness is attained through four phases: attention to cues, perception of cues, interpretation of cues, and decision making. These phases reflect the cognitive constructs that underlie situation awareness. These cognitive structures include attention, perception, memory, and mental models (Endsley, 1997). Fatigue can disrupt situation awareness at each of these phases. Cues in the environment are attended to and perceived through the senses (Endsley, 2000). Particularly, information is received from the auditory and visual modalities. Prolonged work has been associated with a decrease in vision capabilities. Simonson and Weiser (1976) showed that a progressive narrowing of the visual field and a decrease of visual acuity could result from prolonged observation. Also, they found a reduction of accommodation speed and an increase in blinking occurred with increases in task duration. These deficiencies reduce visual ability. Loss of visual ability can be problematic in battle, as officers are required to perform tasks such as border patrol and rely on information from their senses to receive information from the environment.

After information is received from the senses, it can be categorized based on its importance and frequency (Endsley, 1999). Items that are perceived to be most important and most likely to change receive more attention than less important elements. The capacity of attention is limited. This limit is quickly exceeded in complex environments. In a dynamic setting such as warfare, soldiers' attention can be exceeded as tasks increase in complexity and duration. This loss of attention limits SA and increases the possibility of errors and reduced decision making. Decrements in perception can lead to degradations at each level of SA. If the environment is not perceived accurately, information from the environment cannot be correctly integrated, and no credible predictions regarding the possible outcomes of the situation can be achieved.

Individuals who are overloaded can neglect or misunderstand information (Endsley, 1999). In extreme cases perceptual difficulty such as illusions and hallucinations can occur. For instance, Larsen (2001) found that after prolonged field exercises, soldiers mistook some of their fellow officers for members of enemy units. Cognitive constructs such as long-term and working memory influence perception (Endsley, 1999). Long-term memory stores play a significant role in the SA process. Over time individuals develop memories through training and experience. This information is stored and categorized in long-term memory and can be accessed when needed to assist with the perception and comprehension components of SA. The greater the similarities between the current situation and past experiences in long-term memory, the faster environmental cues can be accurately perceived and integrated (Endsley, 1999).

Working memory also plays an important role in this process, allowing the officer to adjust his/her attention level based on the cues of the environment. The ability to integrate information in Level 2 SA and the ability to develop plans of action in Level 3 rely on working memory (Durso & Gronlund, 1999). Owen, Turley, and Casey (2004) and Lieberman and colleagues (2005) found a decrease in working memory capability the longer military officers performed combat exercises. Consistently gathering information from the environment for a prolonged length of time may exceed the limits of working memory resulting in a decreased ability to accurately choose appropriate actions.

Other mechanisms that influence the attainment of SA are mental models or internal versions of an environment (Endsley, 1999). The information from mental models can be linked to experiences with previous similar situations stored in long-term memory. These internal examples assist individuals in discerning which information in the environment needs attention, how that information should be integrated, and what possible changes could occur in the environment in the future. Even when the situation is not an exact replica of a previously encountered situation, mental models still provide quick access to information in long-term memory that guides attention and directs projection (Endsley, 1999). This is an important feature for the battlefield, where information must be quickly processed to make decisions.

Firefighters, police officers, and military personnel rely on SA. They must accurately examine the important aspects of different environments and use this information to decide what responses to implement (Durso & Gronlund, 1999). Research was first conducted to examine situation awareness during World War II. SA research is relevant for complex task performers such as combat pilots (Endsley, 1993), video game players (Vidulich, McCoy, & Crabtree, 1995), and military commanders (Federico, 1995).

Challenges to the Maintenance of Situation Awareness

Several factors can limit the ability to maintain SA. The limitations of mental models and long-term memory could degrade SA (Endsley, 1999). Mental models and memory stores have a limit on the amount of information that can be retained. An incorrect mental model could be used if individuals rely too heavily on past similar experiences stored in long-term memory. Individuals could fail to comprehend or integrate cues from the environment. Also, using an incorrect mental model may result in difficulty making predictions of the environment's future state. These deficiencies would be expected to degrade SA Levels 2 and 3 (Endsley, 1999).

Stress can also degrade SA. Stress can sometimes be beneficial to performance. Individuals can be motivated by stress to concentrate more on accurately performing their tasks. However, a high amount of stress and fatigue can lead to problems (Endsley, 1999). Overloaded individuals are less able to accurately complete the four phases of situation awareness. They may focus more on negative information. They may become less attentive to information in the environment. Ignoring certain elements of the environment can lead to premature closure in which only a portion of information is included in decision making. These tendencies are all likely to reduce Level 1 SA (Endsley, 1999). This problem may be compounded in complex environments that present an overabundance of information.

Situation awareness is presumably degraded by the presence of fatigue but there has been little research that directly examines the effect of fatigue. Endsley (2000) indicates that common conditions such as fatigue and sleep deprivation could reduce the ability to sustain SA. Makeig and Inlow (1993) found a decrease in performance of a signal detection task and variations in EEG readings under conditions of fatigue. This is particularly relevant for the battlefield where long periods of duty lead to sleep deprivation and fatigue. These conditions impede an individual's ability to accurately recognize and integrate environmental cues.

Fatigue may limit the attentional ability needed to form a mental picture of the surroundings. As previously mentioned Bartlett (1943) found that lapses in attention increased in pilots over the prolonged flight task and increased the probability of performance errors. Similarly, Brown (1994) showed that as drivers drove for a prolonged period of time, they removed their attention from the road and traffic. This inattention led to reduced ability to maneuver the car and avoid collisions. In both of these studies, as participants became fatigued they were less able to maintain attention to the task. Fatigue may also serve as a detriment to adequately using mental models. As fatigued individuals fail to process information, individuals may be less aware of their surroundings and less likely to implement the correct mental model for the situation.

Computer Game Simulations

Computer technology is one way to examine the relationship between fatigue, workload, situation awareness, and performance. Traditionally, military instruction and training have been conducted through lectures and field exercises. However, computerized war games are regarded as an innovative training instrument for military officers. These games provide a realistic and more effective training environment and tend to be less time-consuming to conduct than field exercises (Russell, 2005). Many current officers have been exposed to computer games since childhood. Over 50% of Americans interact with computer games. Of these, 38% are men over 18 and 26% are women over 18 years of age (LoPiccolo, 2003). Computer-generated opponents tend to be more unpredictable than human opponents. Encountering these individuals allows officers an opportunity to practice developing and implementing tactics. The games often present feedback so that officers can discover what actions will lead to success (Peck, 2004). Visual feedback presents performance information in a symbolic format using pictures, charts, or graphs. Auditory feedback presents performance information in a lexical manner such as through spoken words or letters (Rieber et al., 1996).

War games have been in existence in some form for centuries. The German military in the late 18th century is reported to have played war games that were similar to chess using movable pieces and replications of terrain (Burenheide, 2007). The military has used simulation since the 1930s (Moshell, 1993). Over time war games have become an increasingly popular training tool. War game simulations are less expensive and more flexible than actual simulated missions. Also, officers are able to replay scenarios multiple times to become more proficient in developing strategies and tactics (Wise & Iverson, 1989). Another reason computer-based training may be valuable is its motivational appeal. It is believed to be more engaging than traditional training techniques. This increased interest is due to features such as active participation and competition (Ricci, Salas, & Cannon-Bowers, 1996). Providing immediate feedback can also improve performance (Bilodeau, Bilodeau, & Schumsky, 1959). Feedback can be provided through auditory cues indicating correct or incorrect responses. Performance can be evaluated through a point system with points added or subtracted for correct or incorrect responses. Additionally, setting goals to win points and avoid detractions can influence performance (Ricci, Salas, & Cannon-Bowers, 1996).

Research has also investigated the use of computer games to study decision making and fatigue (Puscheck & Greene, 1972). During a 54 hr period of wakefulness, 12 college students were required to continuously monitor and act on information transmitted over a communication network while their performance on cognitive tests was constantly evaluated. Tests included subtraction, short-term memory, logical reasoning, and paired-associate learning. Results showed that this cognitively demanding environment produced greater mood and performance decrements as a function of fatigue

(Angus & Heslegrave, 1985). In the past, computer-based games were developed primarily for recreational purposes. However, current developers of combat games are creating games in collaboration with military divisions such as the Defense Modeling and Simulation Office (Morris, Hancock, & Shirkey, 2004; Brewin, 1999). Morris, Hancock, and Shirkey (2004) indicate many benefits can be gained from aligning the games more closely to actual military engagements. These games will have higher face validity. Also, they can be used to inform the public about military operations and encourage recruitment. There is one drawback to the use of games for experimentation. Most military tasks include a high amount of intense and unpredictable stress. This level of anxiety is difficult to recreate in a laboratory or simulation environment (Morris, Hancock, & Shirkey, 2004).

Goals of the Study

There are many explanations for the occurrence of fatigue. Kahneman's (1973) unitary resource theory maintains that task performance should decrease as task demands increase and attentional resources are depleted. On the other hand, Hancock and Warm (1989) found that individuals are able to adapt their behaviors to match the complexity of the task without experiencing fatigue or loss of performance. However, also according to Hancock and Warm (1989) this ability to adapt can eventually be compromised by prolonged exposure to stressors such as extended time on task. The transactional model of stress proposed by Matthews (2001) focuses on how performance is influenced by the environmental stressor and the individuals' personality. Desmond and Matthews (1997) indicate that fatigue is a form of stress. One stressor that has not been explored specifically by the transactional model is extended performance of tasks. Sanders (1998) suggests that performing a task longer than 30 minutes may lead to performance decrements such as increased reaction time and errors. The current study examined the experience of fatigue under varying levels of task difficulty over a three hour time period. It revised Matthews' transactional model by examining the relationship between environmental stress and task performance as participants attempted to maintain their performance over time during varying task demand (see Figure 4).

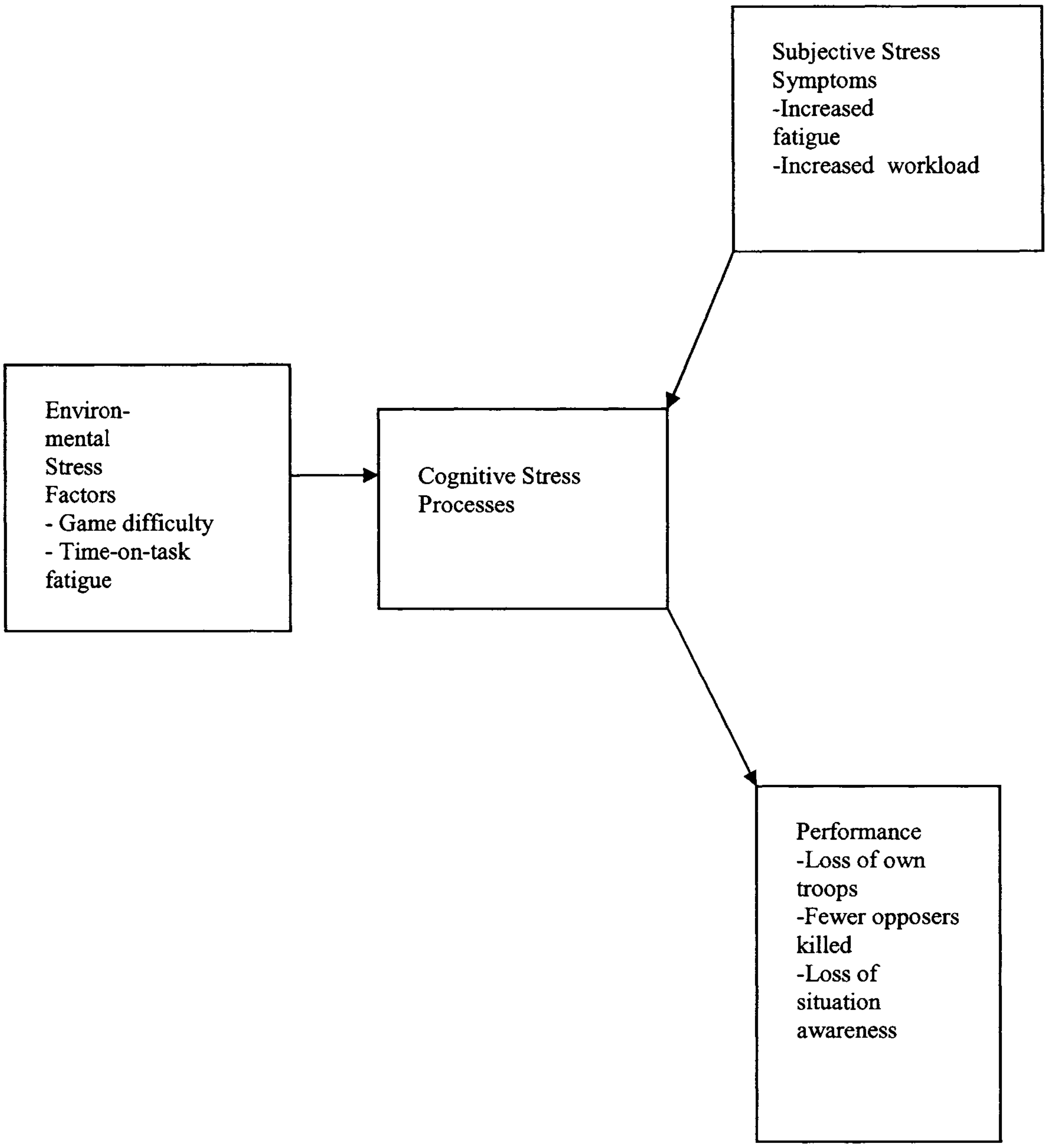

Figure 4. Revised transactional model examining extended task performance as an environmental stressor.

Hypotheses

Hypothesis 1 – As time on task increased, ratings of fatigue on the Yoshitake Fatigue Checklist were expected to significantly increase. Sanders (1998) indicated that extended performance of tasks leads to perceptions of fatigue.

Hypothesis 2 – As time on task increased, ratings of workload on the NASA TLX were expected to significantly increase. Environments that require workers to perform for an extended period of time have been shown to result in a depletion of available mental resources and an increased perception of workload (Gaillard, 2001).

Hypothesis 3 - As time on task increased, participants were expected to lose an increased percentage of their own troops. Lieberman and his colleagues (2005) found a reduction in attention and reasoning after soldiers were exposed to simulated combat for 53 hours. After extended exposure to the simulation, individuals in the current study were expected to have greater difficulty attending to the opposers and protecting their forces from the opposers.

Hypothesis 4 - After participants were exposed to the simulation for three hours, they were expected to kill a decreased percentage of opposers. Extended performance has been associated with decreases in problem-solving abilities (Van der Linden, Frese, & Meijman, 2003). After extended exposure to the simulation, individuals were expected to kill less opponents (see Figure 5).

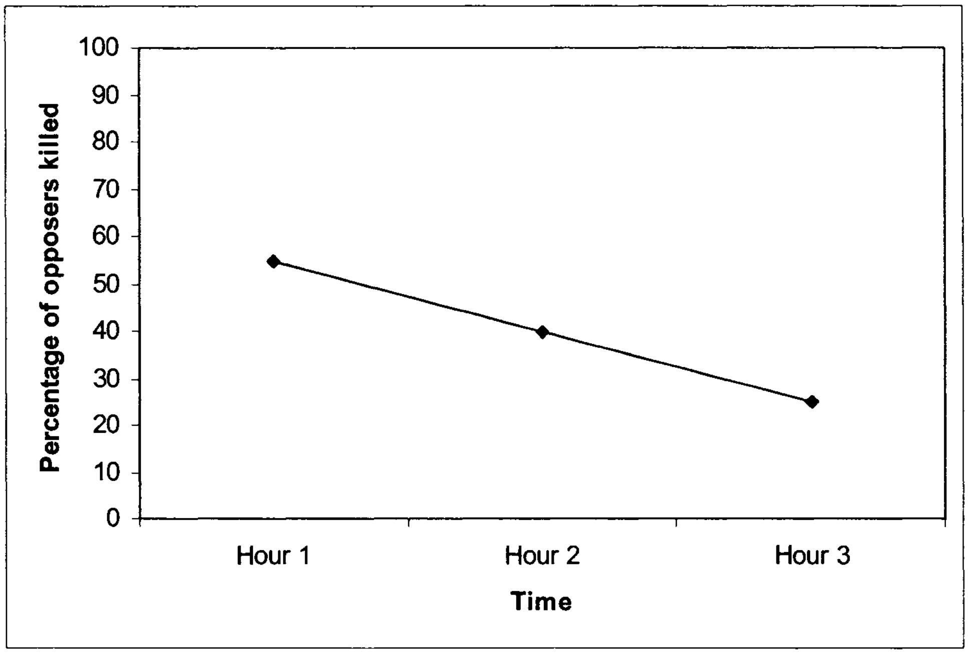

Figure 5. Hypothesis 4 – Expected percentage of opposers killed as a function of elapsed time.

Hypothesis 5 - As participants were exposed to the simulation over three hours, their ratings of situation awareness on the Situation Awareness Global Assessment Technique (SAGAT) were expected to significantly decrease. With extended performance, perceptions of the environment can be degraded leading to reduced ability to accurately comprehend the situation (required for Level 2 SA). Lack of comprehension would also reduce the ability to project the future state of the situation (required for Level 3 SA) (Endsley, 1999).

Hypothesis 6 - Ratings of fatigue on the Yoshitake Fatigue Checklist were expected to differ as a function of game difficulty and time on task. Individuals opposing the difficult army were expected to have increasingly higher ratings of fatigue than those opposing the easy army as exposure to the simulation increased. Macdonald and Bendak (2000) found an increase in fatigue ratings with increased task difficulty.

Hypothesis 7 - Ratings of workload on the NASA Task Load Index (TLX) were expected to differ as a function of game difficulty and time on task. Individuals opposing the difficult army were expected to give increasingly higher ratings of workload than those opposing the easy army as exposure time to simulation increased. Desmond and Hoyes (1996) found that the ability of air traffic controllers to direct planes was better in a high workload condition than in a low workload condition. However, subjective ratings of workload were higher for those in the high workload condition. A similar relationship was expected in the current study as participants directed forces to combat an increasing number of opposers.

Hypothesis 8 – According to Matthews' (2001) transactional model of stress, performance decrements can occur under lower task demand when individuals fail to exert effort to meet the needs of tasks. Based on this model, percentage of own troops killed was expected to differ as a function of game difficulty and time on task. Individuals opposing the easy army were expected to lose an increased percentage of troops than individuals opposing the difficult army as exposure time to the simulation increased.

Hypothesis 9- Based on the transactional model, individuals opposing the easy army were expected to kill a decreased percentage of opposing forces than individuals opposing the difficult army as exposure time to the simulation increased (see Figure 6).

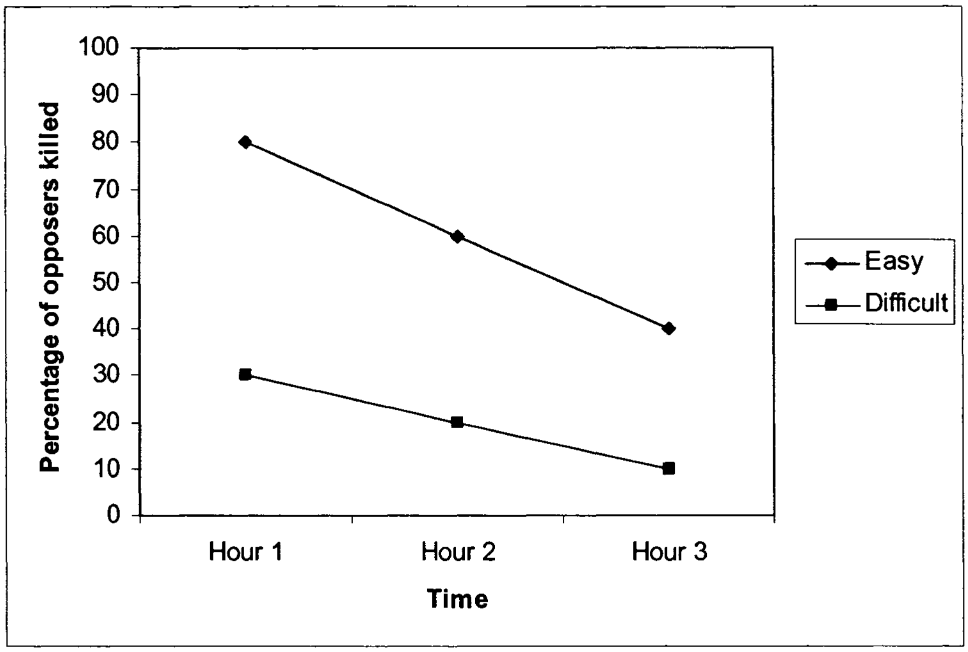

Figure 6. Hypothesis 9 – Expected percentage of opposers killed as a function of elapsed time and game difficulty.

Hypothesis 10- Individuals opposing the easy army were expected to have increasingly lower situation awareness scores on the SAGAT than those opposing the difficult army as exposure time to the simulation increased. The adaptation model suggested that performance would be maintained with increased game difficulty.

METHOD

Design

This experiment followed a 2 (game difficulty) X 3 (elapsed time) mixed factorial design. Game difficulty was the between-subjects independent variable. It was manipulated by varying the number of opposers faced by participants in each group. The Command and Conquer ™ game specifies a "normal" army level and a "hard" army level. In this study, the "normal" army is referred to as the easy army and the "hard" army is referred to as the difficult army. The "normal" army began with 5 troop opponents, which upon attrition are followed by 2 tanks, then 3 tanks, and 9 teams of 2 tanks. The "hard" army begins with 12 troops, then 4 tanks, 8 troops, 4 teams of 4 tanks and 5 troops. All participants interacted with the game for three hours. Elapsed time was the within-subjects independent variable.

Five dependent variables were measured: percent of opposing forces killed, percent of own troops lost, fatigue scores on the thirty-item Yoshitake Symptoms of Fatigue Checklist (see Appendix A), workload scores on the six-dimension NASA Task Load Index (TLX) (see Appendix B) and situation awareness scores on the eight-question situation awareness global assessment technique (SAGAT) (see Appendix C). Game performance was measured through two measures in the game: the percentage of opposing forces the participants killed and the percentage of their own troops lost. These measures were collected at the end of each hour. Situation awareness scores were collected periodically during each hour of battle. Within hour 1, the scenario was paused after 10 minutes and 30 minutes. The scenario was paused after 15 minutes and 40 minutes during hour 2 and after 20 minutes and 45 minutes during hour 3. The other dependent variables included fatigue and workload, which were examined using the Yoshitake Fatigue Checklist and NASA TLX, respectively. Both subjective scales were administered at the end of each hour.

Participants

Eighty-one participants were recruited from the Psychology, Computer Science, Army and Navy ROTC, and Modeling and Simulation departments of Old Dominion University. To be eligible to participate, participants had to have interacted with the Command and Conquer™ game on a weekly basis for three months prior to their participation. All participants received financial compensation in return for their participation. Additionally, participants enrolled in Psychology courses received research credits. All participants had normal or corrected-to-normal vision and hearing. Participants were also asked to rate their experience level with the Command and Conquer™ game. Due to a high proportion of novices in the easy group and intermediates in the difficult group, fifteen participants were eliminated to equalize the number of novices and intermediates in each level of game difficulty. This resulting sample size of 66 met the requirement suggested by Sample Power to ensure power of .80 for individual comparisons (Cohen, 1988). The Sample Power program is a commercially available statistical package. Thirty-three participants were assigned to the difficult condition. Thirty-three participants were assigned to combat the easy opponents. Fifty-two percent of the easy group participants were novices, 42% percent were intermediates, and 6% were experts. Forty-four percent in the difficult group classified themselves as novices, 50% were intermediates, and 6% were experts.

Eighty-two percent of participants slept 7-9 hours the night before their experimental session and 71% of participants regularly sleep 7-9 hours each night. Participants were also asked about their coffee consumption. Caffeine from coffee consumption did not appear to confound the results. Sixty-eight percent of the participants did not consume coffee prior to their participation. Thirty-two percent of the participants indicated that they had one cup of coffee prior to participating in the study. However, ninety percent of these participants indicated that they usually drink coffee.

Materials

Command and Conquer ™ is a series of real-time strategy computer games. In Command and Conquer: Generals ™, the American and Chinese forces are presented as the two major military powers (see Appendix D). The game specifies that the major military powers battle each other and combat the Global Liberation Army (GLA), a Middle Eastern terrorist organization. Each of the three military groups is represented in a different manner. The Americans use advanced technology such as jets with bombs and a mobile ambulance unit. The Chinese force relies on teamwork with different types of soldiers such as front guards, tank drivers, and computer hackers. The GLA has few modern weapons and relies on terrorists, angry mobs, and technicals (makeshift machine guns loaded on trucks) to attack opposing forces. The game scenarios have been developed for a single person to play, including 21 missions and battles that can be resolved over 15 hours of play (Honeywell, 2002).

Participants must amass troops and deploy forces against the opposition. A count is kept of how much money was spent on supplying the troops, how many buildings were created, how many troops were created, how many opposing forces were killed, how many of the participant's troops were killed, and how many buildings were destroyed. Participants begin the game with \$10,000. The buildings built include a cold fusion reactor (power plant) for \$800, barracks for \$600, and a supply center for \$2000. Rangers cost \$225 and missile defenders cost \$300. The purpose of the game is to defeat the opposition with a minimal loss of money and soldiers and minimal damage to buildings (Honeywell, 2002). For this study, participants portrayed an American army and combated the Chinese army.

The options for military officers are missile defenders and rangers. Participants in the easy condition were directed to choose 10 rangers and 40 officers with missiles (missile defenders). They used these troops to oppose the easy army. The easy army began with 5 troop opponents, which upon attrition are followed by 2 tanks, then 3 tanks, and 9 teams of 2 tanks. Participants in the difficult condition were directed to choose 20 rangers and 80 missile defenders. They used these troops to oppose the difficult army. The difficult army begins with 12 troops, then 4 tanks, 8 troops, 4 teams of 4 tanks and 5 troops. The difficult army has approximately double the number of opposers presented than the easy army. Participants in the difficult level were given twice the number of troops as those with the easy army to cope with the larger number of opposers. They were instructed to use their ground forces to combat the opposers.

Fatigue Measures. Participants were asked to sleep 7-8 hours the night prior to their participation to control for pre-existing fatigue. However, this could not prevent the students from being influenced by previous nights with less sleep and a resultant sleep debt from that time. This does not appear to have been an issue since participants

This does not appear to have been an issue since participants indicated little fatigue prior to the experiment. Even after the first hour, 70% of individuals indicated fatigue ratings of 5 or less on the Yoshitake checklist. Nine percent indicated no fatigue. Participants indicated on the demographic survey (see Appendix E) the number of hours they typically sleep and the number of hours they slept on the night prior to their participation. Game performance was evaluated to examine the effect of fatigue. The percentage of the participants' troops lost and the percentage of opponent forces killed were calculated after each hour. These data were examined to determine whether fatigue reduced performance. Factors other than fatigue such as lack of comprehension of the game or previous knowledge of the game could also influence performance. Therefore, only individuals who had previous experience with the game were eligible to participate.

Many fatigue studies rely primarily on self-report measures of fatigue. Such measures have reliably shown perceptions of fatigue. However, because they are subjective they may be more prone to bias than objective measures (Belz, Robinson, & Casali, 2004). Participants completed Yoshitake's Symptoms of Fatigue Checklist (1971). Yoshitake's checklist of subjective symptoms of fatigue provides a quantifiable measure of the participants' perceptions of fatigue (Stark, 1999). The checklist includes 30 items that require dichotomous (yes/no) responses. One point was given for each "yes" answer to the items with a maximum possible total of 30 points. The more fatigued the respondent the higher the score.

The items on Yoshitake's checklist were based on a survey of 9575 workers in 18 industrial jobs. Yoshitake (1978) proposed that if people perceived that they were fatigued, these feelings would be reflected in their behaviors. He used the checklist to examine feelings of fatigue in bank employees. He divided the checklist into three ten-item sections: A- feelings of dullness, B- decline of work motivation, and C- feelings of bodily discomfort. He found high correlations between each section and the employees' frequency of reported fatigue symptoms (section A $r = .63, p < .05$; section B $r = .71, p < .01$; section C $r = .58, p < .05$). Fields and Loveridge (1988) and Mills, Arnold, and Wood (1983) also used the Yoshitake to compare feelings of fatigue held by nurses who worked 8-hr shifts with those who worked 12-hr shifts. The comparison indicated that nurses who worked the longer shift experienced more fatigue.

Once the data for this study was collected, Cronbach's α was calculated to examine the reliability of the Yoshitake fatigue scale. Cronbach's α was calculated for each hour. For Hour 1 $\alpha = .68$, Hour 2 $\alpha = .73$, and Hour 3 $\alpha = .78$.

NASA TLX Workload Measure

Subjective measures can also be used to determine the workload people experience as they perform a task. Workload can be measured using a structured rating scale to obtain ratings along a single dimension or several dimensions. The most well known example of a multidimensional scale of workload is the NASA Task Load Index (TLX) scale. It examines workload along six 7-point dimensions: mental demand, physical demand, temporal demand, performance, frustration, and effort (Hart & Staveland, 1988). By adding together the individual scores of the workload components, a total subjective workload score may be calculated.

Hart and Staveland (1988) examined the variance in total workload accounted for by the six items and correlations between the items and overall workload. The items accounted for a highly significant percentage of the variance in overall workload with r^2 values ranging from .67 to .84. There were high correlations between overall workload and each of the items. However, there was little correlation among the items. This showed that each item measures a unique component of workload. The correlations between each item and overall workload were: mental demand (r = .84), physical demand (r = .70), temporal demand (r = .67), performance (r = .84), effort (r = .84) and frustration (r = .70). The test-retest reliability coefficient was .83 (Hart & Staveland, 1988). The TLX's multiple items allow it to provide more information and present a more reliable measure of workload than a unidimensional measure. A disadvantage is the concern that workload could be confounded by other aspects of the participants' experiences (Mayes, Sims, & Koonce, 2001). For example, intrinsic task enjoyment tends to reduce workload scores. This was an important issue in this experiment, as participants were required to be individuals who previously played the game. Presumably, they already enjoyed playing computer-based games.

The NASA TLX was a relevant measure for this study because it provided quantifiable data regarding the effect of cognitive demands on perceived workload. Cronbach's α for each hour was calculated to examine the reliability of NASA TLX. For Hour1 α = .72, Hour 2 α = .72, and Hour 3 α = .71.

Situation Awareness Measure

The Situation Awareness Global Assessment Technique (SAGAT) developed by Endsley (1987) is one example of an objective measure of SA. In the SAGAT, a task simulation is randomly stopped and individuals are asked about their understanding of the current situation (Jones & Endsley, 2004). In the current experiment, SAGAT queries examined each level of situation awareness including the status of the current environment, what it meant, and how it would change in the future. The SAGAT provides immediate information about the participants' perception of the situation. Participants do not know what they will be asked or when the questions will be asked, so they are not prompted to focus on any specific aspect of the environment (Klamklay, 2002).

For each specific environment, the SAGAT queries are developed to measure individual elements. Task analysis is often used to develop each form of the SAGAT. Researchers determine the goals and subgoals for a specified task. Afterwards, they create queries based on these objectives. Queries may also be based on direct observations of individuals performing the tasks and interviews with experts. However, the SAGAT technique can be applied to a variety of positions such as pilots or military commanders. The researcher determines when the scenario will be stopped and the range of acceptable answers (Endsley, 2000).

Endsley (1990) found the SAGAT to be predictive of performance in a combat situation. Pilots who indicated greater awareness of enemy aircraft were more likely to destroy the target. Also, Endsley and Rodgers (1994, as cited in Endsley, 2000) found that air traffic controllers became less accurate in answering queries as the number of planes they monitored increased. Endsley and Bolstad (1994) indicated high test-retest reliability between two flight simulations with coefficients ranging from .92 to .99. Although Sarter and Woods (1991) indicated that stopping the simulation to administer the SAGAT is intrusive, Endsley (1995) found no effect on performance for stopping the simulation from 30 seconds to 2 minutes. Again in 2000, she found no significant difference in performance between participants who were told to expect a stop in the simulation to complete the SAGAT and those who were told no stops in the simulation would occur.

The SAGAT measure in this study was developed following the procedure outlined by Endsley (2000). A list of the tasks that would be performed in the game was created. The tasks included selecting troops, constructing buildings, arranging troops, and deploying troops to attack opposers and their buildings. The goals of the tasks and the features of the game were examined. The goal of the study was to examine performance in a simulated scenario. The goals of the game were to kill the opponents and protect one's own troops and base. Creating buildings allowed the participant to build their base. Selecting and arranging troops to attack the opposer and the opposer's buildings facilitated defeating the opponent. The game also tracked the amount of money in the treasury so participants knew how much money was spent selecting troops and constructing buildings. Items were created to reflect these aspects and goals of the game.

The list of SAGAT items was created to measure achievement of each level of situation awareness. Included were items that were both necessary to complete the game and those that measured more general perception and comprehension of the game. Knowledge of how many troops one has at a particular time in the game and how many opposers are present may influence the strategy one uses to combat the opposing army. This knowledge also reflects one's ability to achieve perception, Level 1, of situation awareness. The amount of money in the treasury is constantly depicted on the screen. However, one does not need to constantly know this information to combat their opposers. Measuring this feature could indicate if participants are focusing on other aspects of the scenario in addition to information they immediately need to combat their opponents.

In the game, participants had both missile defenders who could fire missiles and ground troops who could shoot at opposers. They were asked which type of troops was depicted to measure comprehension (Level 2). Knowledge of officer type could influence their combat strategy. For instance, they may put their missile defenders in front of their base and put their ground forces in the back. Asking participants to identify the specific buildings present measured more general comprehension of the scenario. Prediction (Level 3) was also measured. Participants were asked from what direction they expected the next attack and what buildings they thought would be attacked next. These items were used to measure if the participants were adequately able to predict the opponents' movements. Also, the final item regarding what they planned to do and what they thought would happen as a result of their actions sought to measure if the participants were making plans to counter the enemy and were able to predict what would happen based on the implementation of their plan. The prediction items were used to measure if participants were using the information that they perceived and comprehended to predict their movements and their enemies'.

Pilot study participants consisted of graduate students from the Psychology department from Old Dominion University. They included three females and one male who ranged in age from 22-40. There was one African-American and the rest were Caucasians. They were observed interacting with the scenario for four hours. Two participants were assigned to the easy condition and two were assigned to the difficult condition. They also completed all the study measures. At the end of the study, they were asked to evaluate the measures and provide any suggestions for modifying or removing items from the SAGAT. Their suggestions were included in the final version of the SAGAT.

During the sessions of the current experiment, the scenario was paused and participants answered SAGAT queries. Eight questions were asked at each pause. A screenshot of the scenario was also collected and used to check the answers to the queries. The queries asked participants about the current status of the scenario such as the number of troops they had and the number of troops their opponents had. They were also asked about their comprehension of the situation and projection of the future state of the scenario. If the question had only one correct answer, such as "From what direction will the opposers attack?" then the participants received one point if they answered correctly and no points if they answered incorrectly. For example, if they predicted the opposers would come from the North and they came from the South, these responses are clearly opposite directions so no point would be given.

If the question required them to give a numerical estimate such as the current number of troops, answers between five increments above and below the desired response were accepted as accurate. For instance, if there were twenty-three officers depicted on the screen, answers between18-28 were counted as correct and one point was given. Because the participants would not know when the scenario would be stopped and the number of troops and opposing forces would continually change as the battle progressed, this band of ten was determined to give participants a reasonable range of correct answers. For example, if participants estimated that they had twenty-eight troops when they actually had twenty-three, they were probably actively monitoring their troops.

However if they indicated that they had fifty troops, that would be nearly doubling the actual amount of troops and indicate that they were not accurately monitoring their troops. With regard to the amount of money in the treasury, answers were correct if they were within $500 in either direction. For example, if participants were asked how much money was currently in the game treasury and $2500 was the current amount, then answers between $2000-3000 were counted as correct. Answers outside of this band were counted as incorrect and no point was given. The game tracks money in the treasury in $500 increments. Again it would be difficult to expect participants to know the exact amount of money in the treasury as they are more likely focusing on dispatching their troops to kill the opposers. But they should have some idea of their financial resources. Estimating that one has $2500 when one actually has $3000 is more reasonable than estimating that one has $5000 which is double the actual amount.

After the study was completed, a content validity evaluation of the SAGAT measure was performed. Five individuals who played the game an average of 4 times a week and rated themselves as intermediate or expert players served as game "experts". Five individuals from the ROTC program served as military "experts." They were all asked to examine each question on the SAGAT. The participants were all men. Three were aged 18-21 and the rest were aged 22-26. Three were sophomores, two were juniors, two were seniors, and the rest had graduated. For each item they rated its' importance to battle situations on a three-point scale: "1 = not necessary;" "2 = useful but not necessary;" "3 = necessary." Items were evaluated to determine if the "experts" felt they were necessary. Validity was evaluated based on the percentage of individuals who rated the item as necessary. Percentage of agreement of 70% or above was the standard for high content validity (Blacha & Fancher, 1977; Xie et al., 2000). Based on the group's ratings, high validity was found for knowledge of the amount of money in the treasury (80%), predicting from what direction opposers would attack (80%), and predicting what would happen if their plans were implemented (70%). Sixty percent of the panel indicated that predicting which structure would be attacked next and which buildings were depicted was necessary. Fifty percent indicated that knowing how many troops the player had and the types of officers was important. Forty percent indicated that knowing the number of opposers present was important. Ratings were also examined between the two groups to determine if items considered necessary by game experts were also considered necessary by ROTC cadets (see Table 1). The game experts' ratings indicated that half of the items had high content validity. Two were given moderate ratings. The military experts indicated high validity for one of the items, knowledge of the amount of money in the treasury. Five other items were rated moderately.

Table 1.
Game experts' and Military experts' SAGAT Queries Validity Ratings.

SA Queries	Game Experts	ROTC Officers
Own officers	60%	40%
Opposing officers	20%	60%
Money	80%	80%
Officer type	40%	60%
Buildings depicted	60%	60%
Structure next attacked	100%	20%
Direction of next attack	100%	60%
Plan	80%	60%

Reliability was also examined. Cronbach's α was calculated for the original eight SAGAT items for each hour. For Hour 1 $\alpha = .53$, Hour 2 $\alpha = .30$, and Hour 3 $\alpha = .47$.

Subsets of the original eights items were examined for each hour to determine if removing some of the items would lead to higher reliability. The three items that met the content validity criteria (knowledge of the amount of money in the treasury, prediction of which direction opposers would attack, and prediction of what would happen if their plans were implemented) were then combined to create a composite situation awareness measure. The reliability of the combined items was examined. In Hour 1, the Cronbach's α found was .24. In Hour 2 a Cronbach's α of .29 and in Hour 3 the Cronbach's α was .12. As the reliability of the composite measure was still below the reliability standard, each of the items was measured individually and used to examine the effect of time and its interaction with game difficulty on situation awareness.

As aforementioned, situation awareness is believed to lead to increased performance (Endsley, 1999). Pearson correlations were used to examine the relationship between the performance measures and the three situation awareness items. No significant correlation was found between forces lost or opposers killed and any of the situation awareness items.

Procedure

Convenience sampling was used to recruit participants who were knowledgeable about the Command and Conquer™ game. Approval to conduct the study was obtained from the Old Dominion University Human Subjects Institutional Review Board (IRB). Announcements were made in Psychology, Computer Science, and Army/Navy ROTC courses. Flyers were placed on the Psychology Department research board (see Appendix F) and across campus, announcements were posted in the University email announcements and information was posted on the Psychology research website.

Students signed up for sessions that were compatible with their schedules. Participants were advised to get a full night (7-9 hours) of sleep prior to participating. They were also asked to abstain from alcohol 24 hours prior to the study and to have no more than one cup of coffee prior to the study. In the demographic survey, they were asked to indicate the amount of coffee they normally drank and how much coffee they drank prior to the study.

Once participants arrived for the study, they completed an informed consent form (see Appendix G) and a demographic survey. Participants were informed that their participation was voluntary and they could leave the experiment at any time without incurring any penalties. Participants were randomly assigned to either the easy or difficult condition. Each participant entered the game with $10,000 in their treasury and they had access to one bulldozer. The participant then left clicked on the bulldozer and selected a cold fusion reactor, barracks, and a supply center. Within the barracks, the participant chose the military forces that he or she would use to fight the opponent. Participants in the easy condition were directed to choose 10 rangers and 40 officers with missiles (missile defenders). Participants in the difficult condition were directed to choose 20 rangers and 80 missile defenders. The game was reset at the end of each game session, so a new set of troops was created each session. Once troops were selected and armed, the participant placed a rally point anywhere on the screen where the troops should assemble.

Throughout this process the game provided visual and verbal feedback. Once the bulldozer was selected, its operator asked where the player wanted to build. Once the location for the building was selected, the operator said, "That's a good spot." The player witnessed the building being erected. Once officers were selected, they appeared as avatars on the screen and verbally responded "Ready for action." Opposing forces suddenly appeared as the message "The base is being attacked!" appeared on the screen. The player deployed the troops to attack the opposing forces. If the opposing forces were hit, they would grunt and fall to the ground or their tank would explode. If the participant's force was killed, the message "Unit lost!" was announced. Performance metrics including the number of troops lost and the number of opposers killed were recorded at the end of each hour. The percentages of troops lost and opponents killed were calculated. Participants completed the Yoshitake checklist and NASA TLX at the end of each hour (see Figure 7). During hour 1, the scenario was paused after 10 minutes and 30 minutes and the SAGAT queries were presented. The scenario was paused after 15 minutes and 40 minutes during hour 2, and after 20 minutes and 45 minutes during hour 3. At the end of the experiment, participants completed a simulation questionnaire regarding the strategy that they used and if they were able to focus throughout the study (see Appendix H). They were then given a debriefing statement (see Appendix I) that indicated the game difficulty level that they were assigned to and reiterated the purpose of the study. They also received their financial compensation for the study. Individuals enrolled in Psychology courses received credit forms verifying their participation for their instructor. The experimenter set the speed of opponent action to level 16 to help participants survive each session. The game's speed of play ranges from 15 to 45. The speed was set uniformly for each participant. Speed of action was empirically determined through pilot testing.

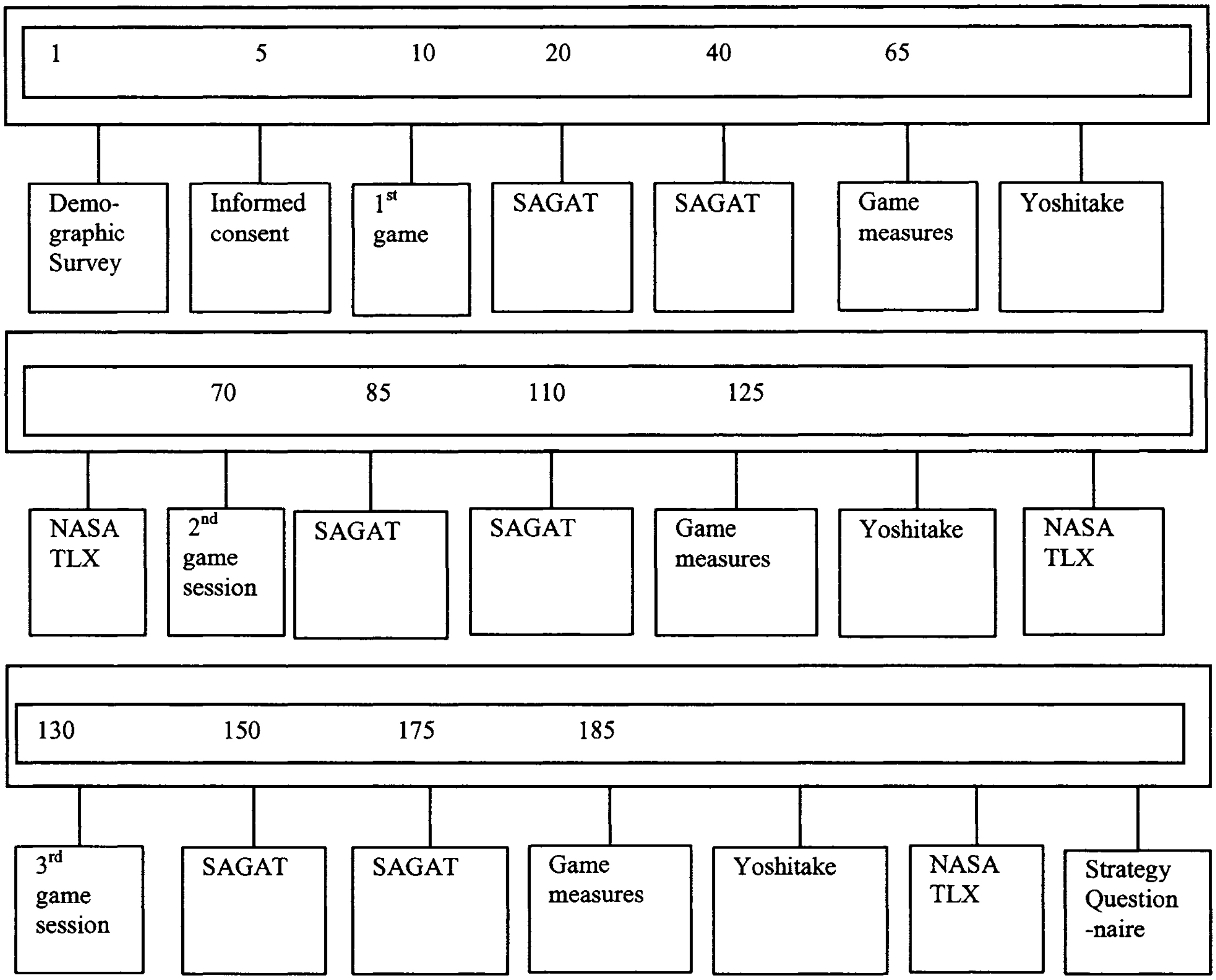

Figure 7. Timeline (in minutes) of study procedure. Steps participants completed each minute of the study.

RESULTS

Demographic data

Demographic data were analyzed using descriptive statistics that included means and percentages. Participant sex, ethnicity, age, and past experience with Command and Conquer™ were of particular interest. Thirty-three participants were assigned to combat the difficult opponents. Seventy-nine percent of these participants were Caucasians. Nine percent were African-American. Additionally, one participant was Hispanic, one was Asian, and one was of unknown ethnicity. Seventy-three percent of the participants in the difficult group were aged 18-21 and 15% were aged 22-25. Additionally, 3% were aged 26-30, 3% were over 30, and two participants did not indicate their ages. Forty-eight percent of the participants in the difficult group were freshmen, 27% were sophomores, 12% were juniors, 6% were seniors, and two participants did not indicate their classification. Also, participants rated their experience level with the game. Forty-four percent in the difficult group classified themselves as novices, 50% were intermediates, and 6% were experts.

Thirty-three participants were assigned to combat the easy opponents. Seventy percent of these participants were Caucasians, 18% were African-American, 6% were Asian, and the remaining participants' ethnicity was not indicated. Seventy percent of the participants in the easy group were aged 18-21, 12% were aged 22-25, 15% were aged 26-30 and the remaining 3% were over 30. Fifty-eight percent of these participants were freshmen, 27% were sophomores, 3% were juniors, 9% were seniors, and 1 was a graduate student. Fifty-two percent of the easy group participants were novices, 42% percent were intermediates, and 6% were experts.

Nine percent of the participants were women. Seventy-one percent of the participants routinely played simulation games like Command and Conquer ™ each week for an average of four hours each week.

Analyses

The skewness and kurtosis of the data were examined to determine their normality. Two variables were kurtotic: the Yoshitake fatigue ratings for the first hour and the physical demand dimension scores of the NASA TLX for the first hour. Since only one score was an outlier in each of these variables the outlying scores were assigned scores that were one unit smaller than the next most extreme score as recommended by Tabachnick and Fidell (2001). In the Yoshitake Fatigue Checklist the outlying score of 14 was changed to 8. After the outliers were changed, the kurtosis value for the Yoshitake fatigue scores decreased from 2.97 to .01.The outlying score of 7 was changed to 6 in the physical demand dimension. The kurtosis value decreased for physical demand from 3.47 to 1.80. Independence of errors is not believed to be violated because participants performed the same tasks and interacted with the same experimental materials. Sphericity was violated for Yoshitake checklist and NASA TLX ratings. The *F*- ratio for the Greenhouse-Geisser correction was examined to determine significant effects for these variables. Differences between groups and across time were judged significant at the alpha level of $p < .05$. Four of the participants lost all of their troops prior to the end of the first hour and their percentage of troops lost was recorded as 100%. They then completed the fatigue and workload surveys and proceeded to the next game session, at which time their troop levels were reset.

Mixed factorial 2 X 3 ANOVAs were used to examine the differences between participants opposing the easy and difficult armies and the differences among groups across time. ANOVAs were conducted for each dependent variable: percentage of opposers killed, percentage of own troops lost, situation awareness scores, fatigue ratings, and workload ratings.

Fatigue

As predicted by Hypothesis 1, Yoshitake Fatigue Checklist ratings increased as a function of elapsed time, $F\,(2, 64) = 31.70, p < .01, \eta^2 = .33$. Participants experienced an increase in fatigue from Hour 1 ($M = 3.33$, $SD = 2.32$) to Hour 2 ($M = 4.73$, $SD = 3.23$) to Hour 3 ($M = 5.98$, $SD = 4.15$) (see Figure 8). Post-hoc paired t-tests were conducted to examine significant effects on fatigue ratings between each hour. A significant increase in fatigue was found between Hour 1 and Hour 2, $t(65) = -4.70, p < .01$. A significant increase in fatigue was also found between Hour 1 and Hour 3, $t(65) = -6.81, p < .01$. A significant increase in fatigue was found between Hour 2 and Hour 3, $t(65) = -4.22, p < .01$.

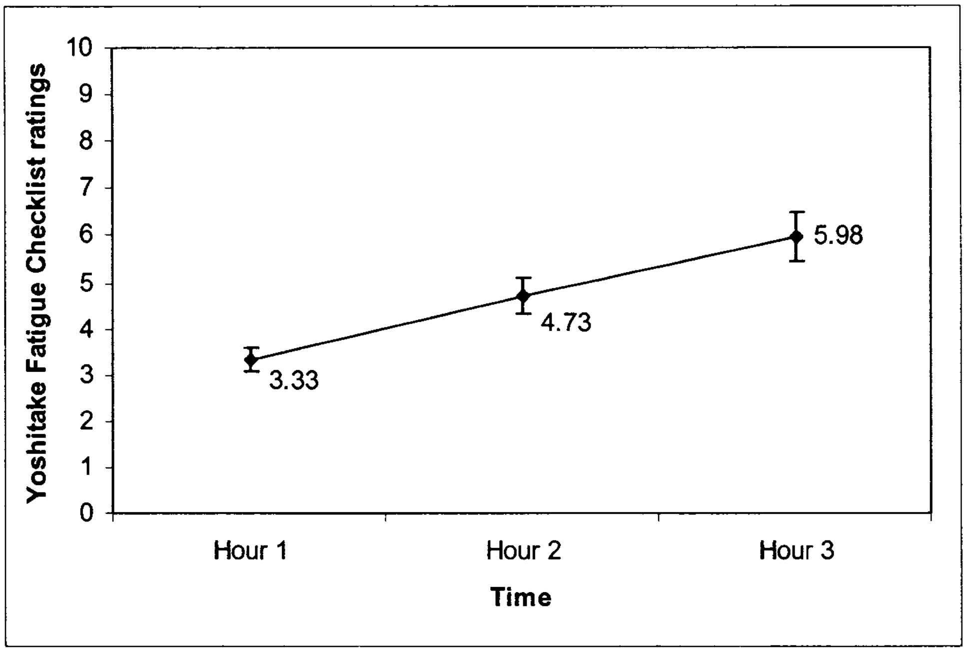

Figure 8. Yoshitake Fatigue Checklist ratings (+ *SE*) as a function of time.

Mental Workload

For Hypothesis 2, a significant main effect for time was found for workload ratings, F (2, 64) = 3.76, p =.04, η^2 = .06 (see Figure 9). Perception of workload decreased from Hour 1 (M = 23.21, SD = 6.30) to Hour 2 (M = 22.55, SD = 6.73) to Hour 3 (M = 21.67, SD = 7.21). A significant decrease in mental workload occurred between Hour 1 and Hour 3, t(65) = 2.19, p = .03.

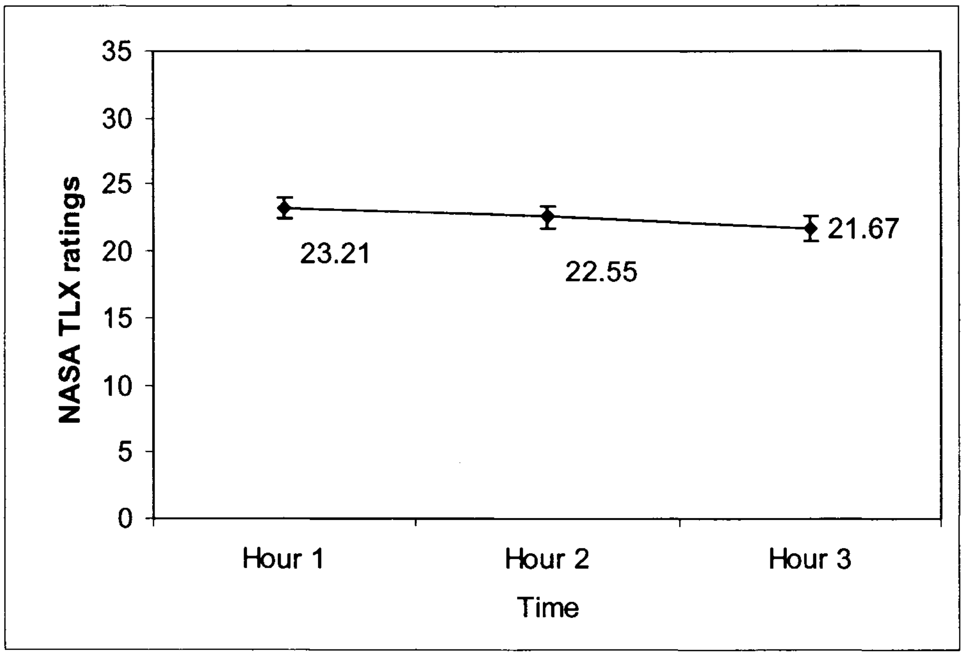

Figure 9. NASA TLX ratings (+ *SE*) as a function of time.

ANOVAs were then conducted to investigate each dimension of NASA TLX. A significant main effect of time was found for physical demand, F (2, 64) = 7.75, $p < .01$, $\eta^2 = .11$. Perception of physical demand increased from Hour 1 ($M = 2.33$, $SD = 1.11$) to Hour 2 ($M = 2.67$, $SD = 1.40$) to Hour 3 ($M = 2.89$, $SD = 1.70$). Post-hoc paired t-tests were conducted to examine the effect on physical demand for each hour. A significant increase in physical demand occurred between Hour 1 and Hour 2, $t(65) = -2.90$, $p < .01$. A significant increase in physical demand also occurred between Hour 1 and Hour 3, $t(65) = -3.22$, $p < .01$.

A significant main effect occurred for performance, F (2, 64) = 4.45, $p = .02$, $\eta^2 = .07$. Participants' perception of their performance improved from Hour 1 ($M = 3.58$, $SD = 1.63$) to Hour 2 ($M = 3.08$, $SD = 1.73$) to Hour 3 ($M = 2.88$, $SD = 1.84$). (Performance is inversely scored.) Post-hoc paired t-tests were conducted to examine the effect on performance for each hour. A significant improvement in perception of performance occurred between Hour 1 and Hour 2, $t(65) = 2.22$ $p = .03$. Perception of performance also improved between Hour 1 and Hour 3, $t(65) = 2.44, p =.02$.

A significant main effect occurred for frustration, $F(2, 64) = 5.06, p = .01, \eta^2 = .07$. Participants' experience of frustration decreased from Hour 1 ($M = 4.09$, $SD = 1.73$) to Hour 2 ($M = 3.99$, $SD = 1.82$) to Hour 3 ($M = 3.49$, $SD = 1.86$). Post-hoc paired t-tests were conducted to examine the effect on frustration for each hour. A significant decrease in frustration occurred between Hour 1 and Hour 3, $t(65) = 2.52, p = .01$. A significant decrease in frustration also occurred between Hour 2 and Hour 3, $t(65) = 2.60, p = .01$. No significant effects were found for the effort, temporal, and mental demand dimensions of workload.

Performance

For Hypothesis 3, a main effect for elapsed time was found for the loss of participants' own troops, $F(2, 64) = 5.07, p = .01, \eta^2 = .07$. However contrary to the stated hypothesis, the percentage of troops lost by participants decreased from Hour 1 ($M = 66.56$, $SD = 24.15$) to Hour 2 ($M = 59.88$, $SD = 28.12$) to Hour 3 ($M = 53.92$, $SD = 29.68$) (see Figure 10). Post-hoc paired t-tests were also conducted to examine the effect on percentage of forces lost for each hour. A significant decrease was found between Hour 1 and Hour 3, $t(65) = 2.92, p = .01$.

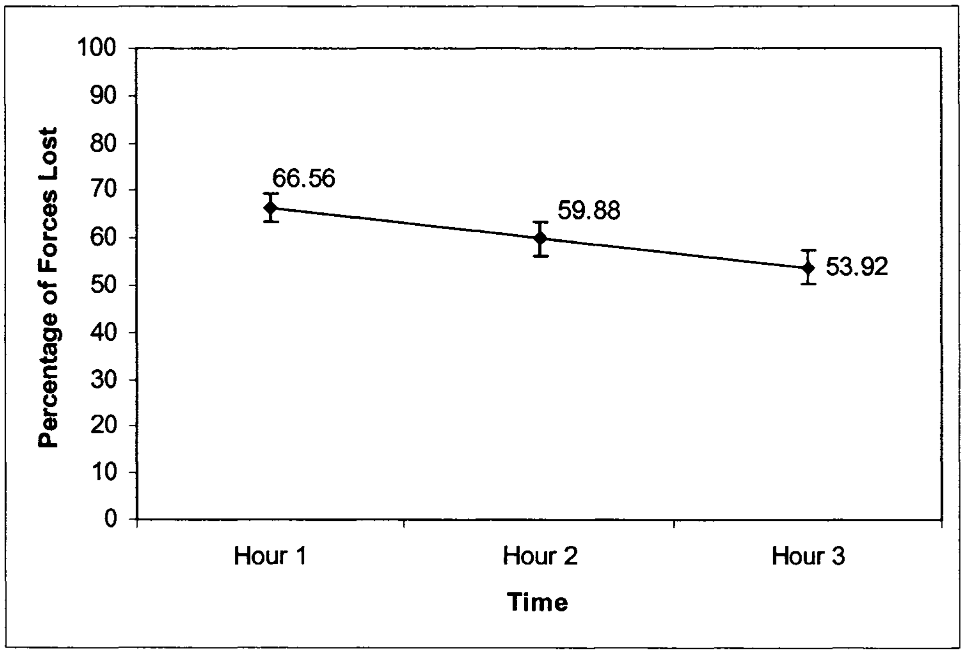

Figure 10. Percentage of own forces lost (+ *SE*) as a function of time.

For Hypothesis 4, a main effect was found for opposing forces killed, F (2, 64) 7.99, $p < .01$, $\eta^2 = .11$. This was the opposite of expected results as the ability of participants to kill opponents increased from Hour 1 ($M = 63.48$, $SD = 24.00$) to Hour 2 ($M = 74.71$, $SD = 23.58$) to Hour 3 ($M = 77.68$, $SD = 25.00$) (see Figure 11). Post-hoc paired t-tests were also conducted to examine the effect on percentage of forces killed for each hour. A significant increase in percentage of forces killed was found between Hour 1 and Hour 3 $t(65) = 2.92$, p =.01.

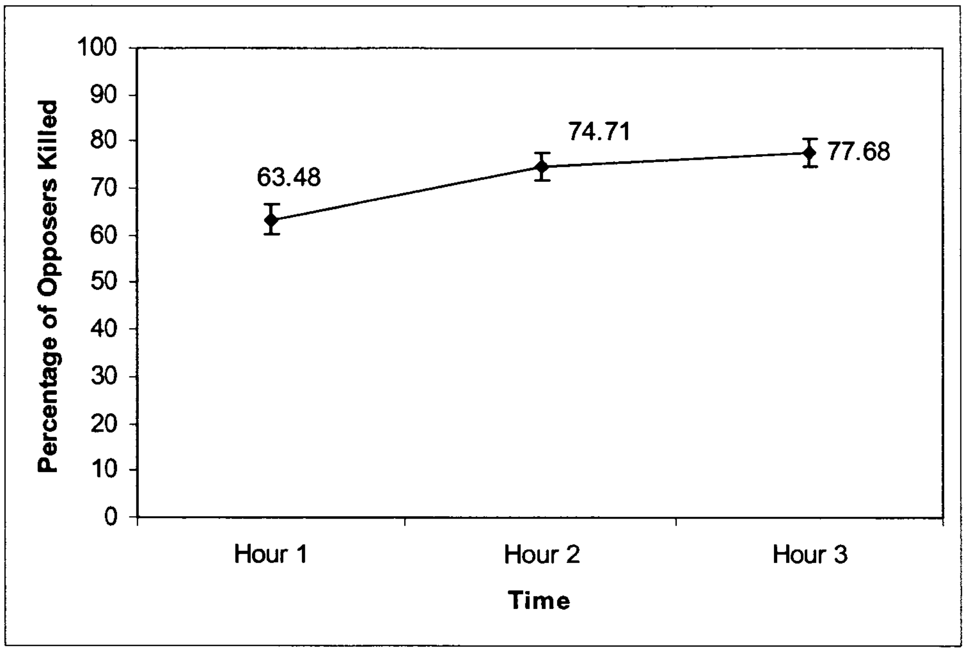

Figure 11. Percentage of opposers killed (+ *SE*) as a function of time.

Situation Awareness

In addition to the workload and performance data reported above, subjective ratings of situation awareness were also analyzed. Situation awareness was measured through three individual items that were identified through the content validity study: knowledge of the amount of money in the treasury, prediction of which direction opposers would attack next, and prediction of what would happen if their plans were implemented. Contradictory results were found. A main effect for time was found for knowledge of money in the treasury, F (2, 64) = 20.80, $p < .00$, $\eta^2 = .25$ which supports Hypothesis 5 that situation awareness decreases over time (see Figure 12). It decreased from Hour 1 (M = 2.27, SD = .69) to Hour 2 (M = .64, SD = .72) to Hour 3 (M = .53, SD = .68). Post-hoc tests were performed to examine the effect for each hour. Individuals' ability to recall the amount of money in their treasury significantly decreased between

Hour 1 and Hour 2, $t(65) = 4.74$, p <00. Recall also decreased between Hour 1 and Hour 3, $t(65) = 5.79$, p <.00.

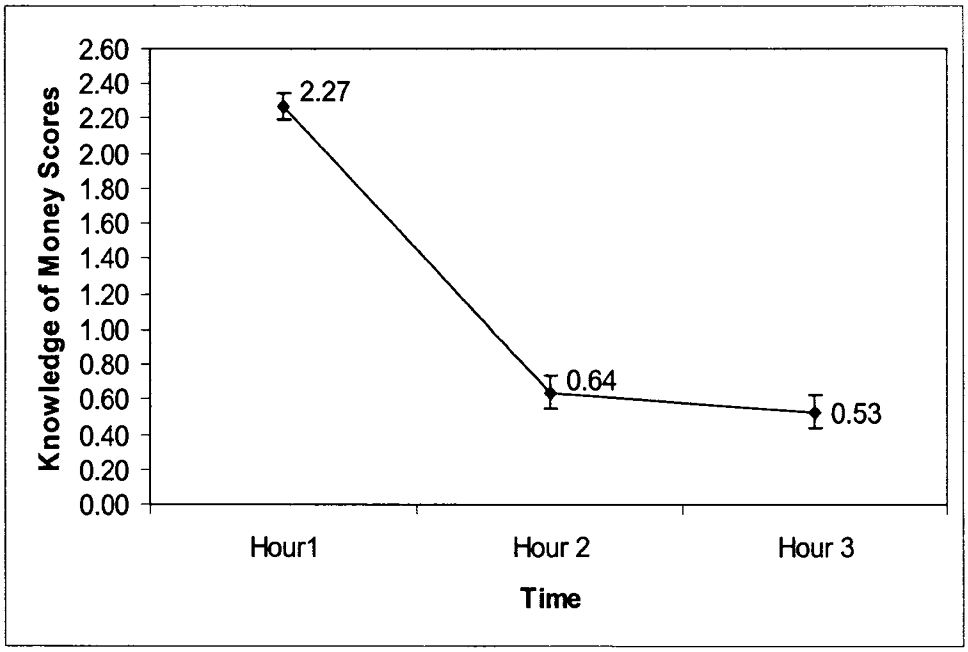

Figure 12. Knowledge of money (+*SE*) as a function of time.

However, their ability to predict the effects of their plans significantly increased over time, $F(2, 64) = 15.23$, $p < .00$, $\eta^2 = .19$ (see Figure 13). Their prediction ability increased from Hour 1 ($M = .80$, $SD = .79$) to Hour 2 ($M = 1.17$, $SD = .78$) to Hour 3 ($M = 1.52$, $SD = .59$). Post-hoc tests were performed to examine the effect for each hour. Individuals' ability to predict the effects of their plans significantly increased between Hour 1 and Hour 2, $t(65) = -2.52$, $p = .01$. Prediction also significantly improved between Hour 1 and Hour 3, $t(65) = -5.52$, p <.00 and between Hour 2 and Hour 3, $t(65) = -3.14$, p <.00.

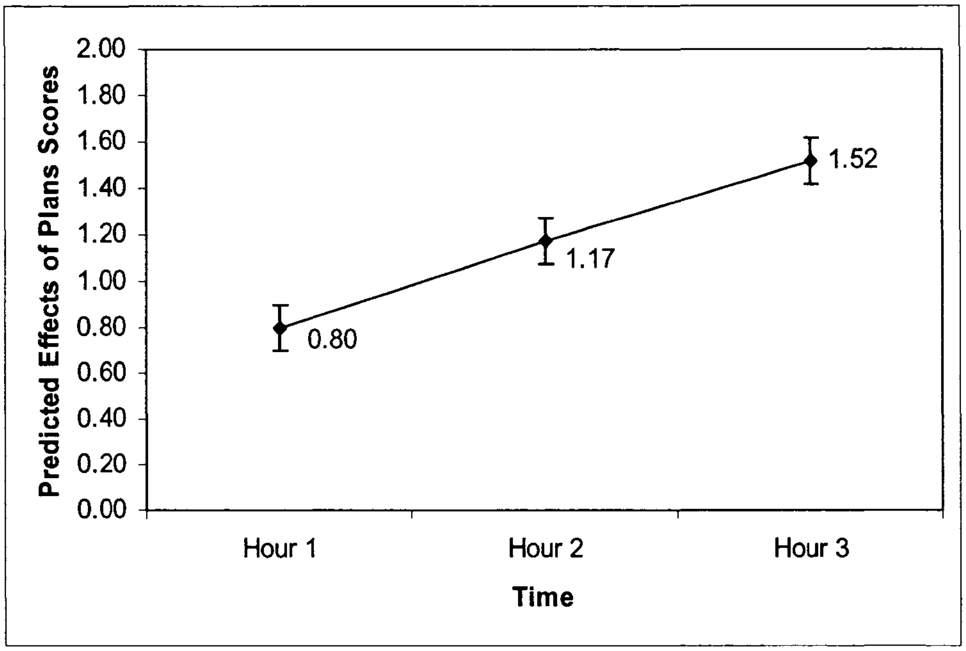

Figure 13. Predicted effects of plans scores (+*SE*) as a function of time.

A main effect for time was found for prediction of the next attack, F (2, 64) = 125.89, $p < .00$, $\eta^2 = .66$. The direction of the next attack significantly increased from Hour 1 ($M = .33$, $SD = .51$) to Hour 2 ($M = 1.71$, $SD = .52$) but slightly decreased in Hour 3 ($M = 1.50$, $SD = .59$) (see Figure 14). Post-hoc tests were performed to examine the effect for each hour. Individuals' ability to predict the direction of the next attack significantly increased between Hour 1 and Hour 2, $t(65) = -16.62$, $p < .00$. and between Hour 1 and Hour 3, $t(65) = -11.63$, $p < .00$. Prediction significantly decreased between Hour 2 and Hour 3, $t(65) = 2.17$, $p = .03$.

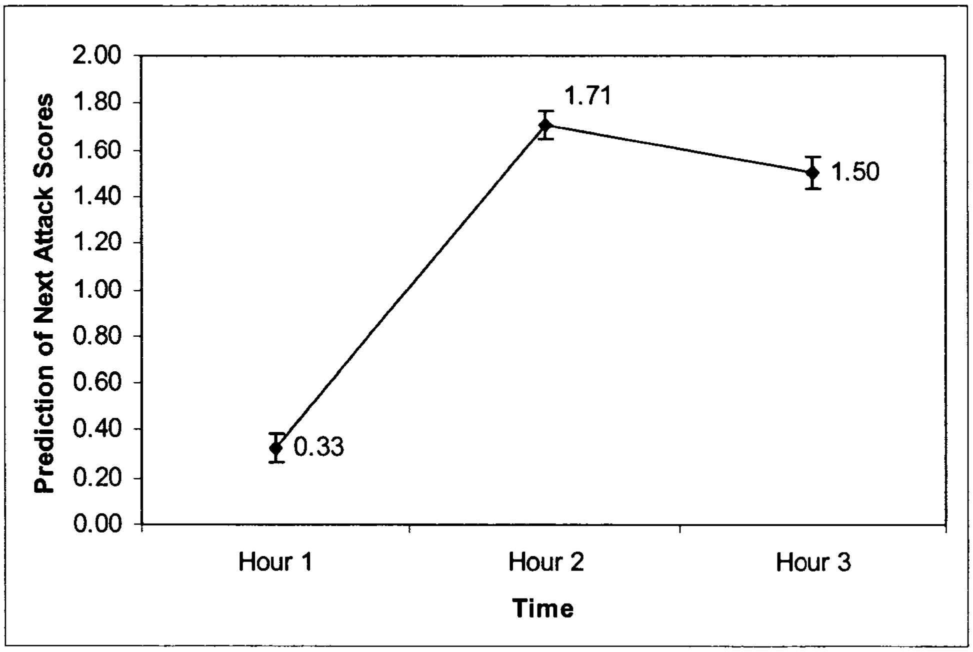

Figure 14. Prediction of next attack scores (+*SE*) as a function of time.

Game Difficulty

A main effect of game difficulty was also found, F (2, 64) = 4.08, p = .04, η^2 = .06. Participants in the difficult group (M = 5.39, SD = 2.93) indicated higher fatigue than those in the easy group (M = 3.97, SD = 3.37) (see Figure 15). No main effect for difficulty was found for the remaining dependent variables: workload, forces lost, opponents killed, and situation awareness.

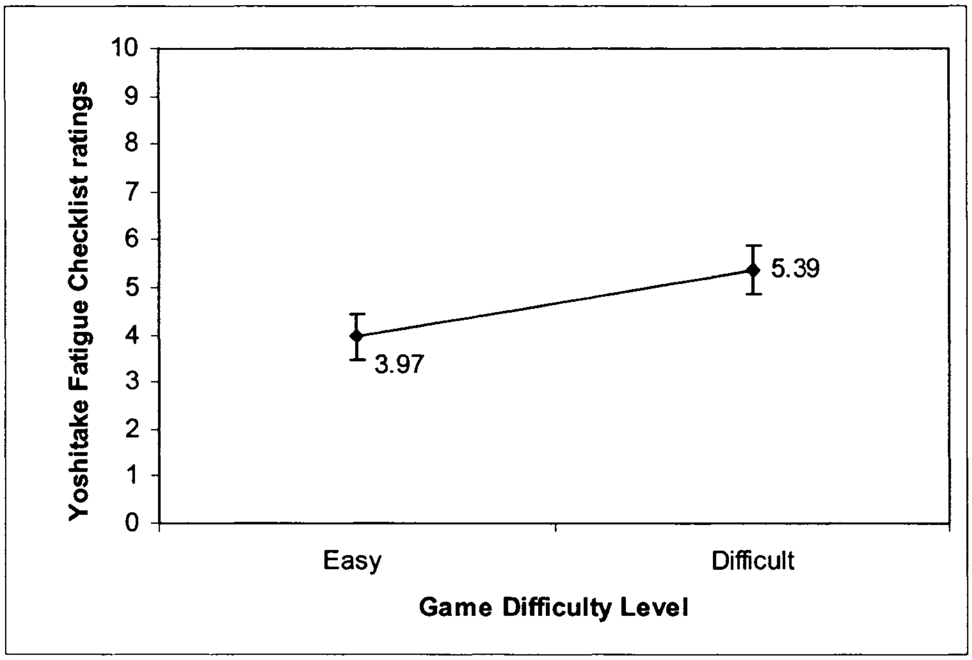

Figure 15. Yoshitake Fatigue Checklist ratings as a function of game difficulty level.

Interactions

No significant interactions were found between game difficulty and time on task for the dependent variables: fatigue, workload, forces lost, opponents killed, and situation awareness as predicted by Hypotheses 6-10, respectively.

Workload and Situation Awareness

Pearson correlations were used to examine the relationship between the three situation awareness items and NASA TLX. Past research (Endsley, 1999) has indicated that situation awareness and workload are related constructs. The correlations revealed no significant relationship between situation awareness and mental workload.

Simulation Questionnaire

On the simulation questionnaire, 48% of the participants indicated that their usual strategy was to both protect their forces and kill their opponents. Twelve percent (12%) indicated that they focused on killing their opponents and 41% indicated that they focused on protecting their troops. Although participants were instructed to focus equally on the goals of protecting their forces and killing their opponents throughout the experiment, participants largely chose a defensive strategy and focused on protecting their own troops (see Table 2).

Table 2.
Strategies Implemented During the Experiment.

Strategy	Hour 1	Hour 2	Hour 3
Protect Troops	61%	62%	47%
Kill Opponents	18%	23%	33%
Both	18%	14%	17%

Participants were asked if they had previously opposed the Chinese army in the Alpine scenario before. Seventy-nine percent of the participants had not been in that specific situation previously. Participants were also asked if they felt overwhelmed in each hour of the scenario. A Mixed ANOVA indicated a significant decrease in feelings of being overwhelmed over the course of the study, F (2, 63) = 16.10, p <.00, η^2 = .20 (see Figure 16.) Feelings of being overwhelmed decreased between Hour 1 (M =.60, SD =. 49), Hour 2 (M = .23, SD = .42), and Hour 3 (M = .22, SD =.41). Post-hoc t-tests indicated a significant decrease in feelings of being overwhelmed between Hour 1 and Hour 2, t(64) = 4.75, p <.00. A significant decrease also occurred between Hour 1 and Hour 3, t(64) = 4.43, p <.00.

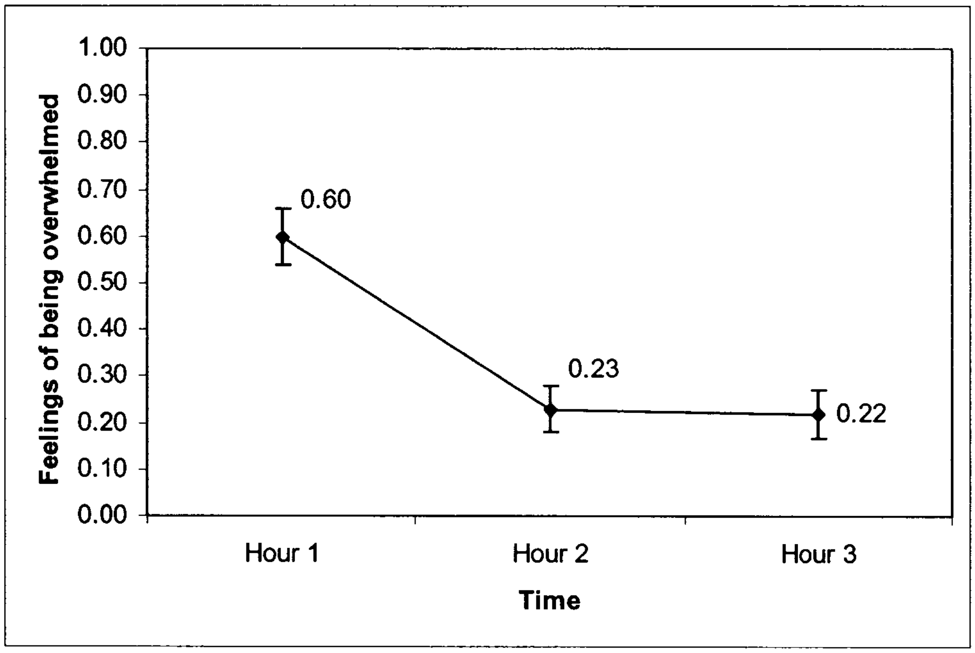

Figure 16. Feelings of being overwhelmed (+*SE*) as a function of time.

A significant difference in game difficulty was also found, $F = 4.55$, $p = .04$, $\eta^2 = .06$ (see Figure 17). Individuals in the difficult group ($M = .41$, $SD = .45$) indicated they felt more overwhelmed than those in the easy group ($M = .28$, $SD = .44$).

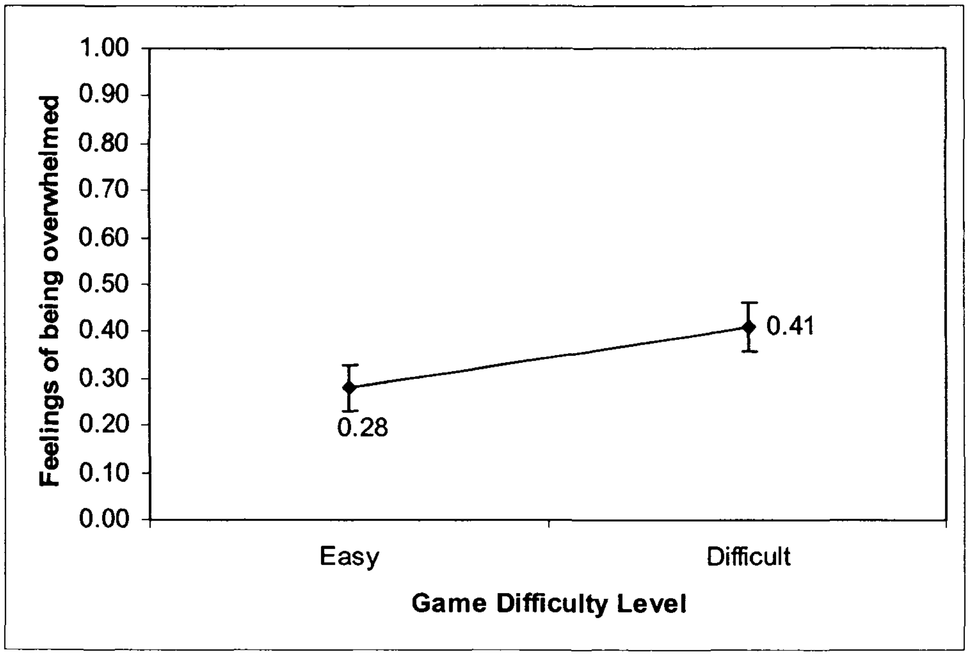

Figure 17. Feelings of being overwhelmed (+*SE*) as a function of game difficulty level.

DISCUSSION

This study addresses both theoretical and practical concerns of fatigue management. It explored the ability of the transactional model to explain the influence of elapsed time and task difficulty on participant fatigue, workload, performance, and situation awareness. The study examined how and when fatigue occurred over the course of a task. Kahneman's (1973) unitary resource theory is often used to explain performance decrements. Hancock and Warm first proposed the theory to explain decrements in task performance using driving operations. Their findings focused on people consistently performing a task in intervals of time up to several hours. In the studies that they used to support the transactional model of stress, Matthews and Desmond (1998) required participants to perform a "fatiguing" drive for 24 minutes in which they had to follow a vehicle and complete a signal detection task. Participants would then interact with the driving simulator for a total drive of 33, 38, or 40 minutes. Those studies, however, focused more on the after effects of fatigue instead of how perceptions of fatigue were affected while performing a task as explored in this study.

Fatigue

As expected in this study, individuals' perceptions of fatigue increased over time. This finding is consistent with other studies in military exercises as well as aviation and medicine that individuals experience more fatigue the longer they are exposed to a task (Macdonald & Bendak, 2000; Meijman, 1997; van der Linden, Frese & Meijman, 2003).

Performance

Contrary to past research, performance in this study improved over time. Participants killed more opponents and lost fewer troops. Several explanations could account for this unexpected finding. One explanation for this increase in performance could be attributed to the amount of time participants interacted with the game. Although Sanders (1998) indicated that performance decrements could occur after thirty minutes of task performance, most existing military fatigue studies reviewed required officers to perform over several days (Neri, Shappell, & DeJohn, 1992; Owen, Turley & Casey, 2004). Participants in this study were student volunteers. A three hour session was chosen to provide significant time over 30 minutes to interact with the scenario and ease of scheduling for participants. However, if participants were exposed to the environment for an even longer period of time such as 8 or 12 hours, perhaps their performance would have decreased. Hancock and Warm's (1989) model of stress presents the idea of a threshold to performance. They indicate that individuals can continue to perform effectively as long as the task demand falls within their "zone of maximal adaptability." Once that zone is exceeded, performance decrements will occur. Although Hancock and Warm (1989) give no specific indication as to when the limit of adaptability is reached, researchers have examined performance over time to discern when performance begins to decline in different tasks. Josten, Ng-A-Tham, and Thierry (2003) found performance decrements after a 9 hr nursing shift. Macdonald and Bendak (2000) found performance decrements for production plant workers after 12 hours. Performance declined even though these individuals were familiar with their work tasks. Similarly, despite participants in this study's familiarity with the game, performance could have eventually declined.

Past research has also indicated an increase in performance during exposure to stress. Yerkes and Dodson (1908) indicated an inverted U represented stress' influence on performance. Initially stress can lead to an improvement in performance. Stress may serve as a motivator for performance and facilitation occurs as individuals increase their performance under stress. Ultimately performance reaches an optimal level where the maximum performance occurs with exposure to the stressor. Once stress becomes overwhelming, degradation of performance occurs. Hancock and Warm's adaptation model suggests a similar relationship. As the individual is exposed to the task their performance can improve. Eventually performance will reach a limit where performance no longer improves. Once the "zone of maximal adaptability" is breached, performance will decrease. Matthews' transactional model indicates that individuals can cope with tasks based on their interpretation of the situation. As individuals appraise the situation, they develop ways to cope with it. Performance decrements would occur when individuals are no longer able to effectively appraise and cope with the situation.

Matthews indicates that factors such as liking or disliking the task influence the appraisal of the situation. He classifies these feelings toward the task as "personality factors." Participants' feelings toward the game likely influenced their appraisal of the scenario and their subsequent performance. Overall, the individuals likely enjoyed the game and were perhaps attracted to its competitive nature. That made it easier for them to ignore their feelings of fatigue and focus on the game objectives of killing their opposers and safeguarding their own troops. As the participants were able to successfully appraise the needs of the task, they developed strategies to combat their opposers based on the difficulty level they were assigned and the length of time they interacted with the scenario. As they implemented these strategies their performance improved. If participants had greatly disliked the task they may have been more susceptible to feelings of fatigue leading to a decrease in performance.

Additionally, participants may have maintained their performance due to intrinsic motivation. Motivation has been found to enhance cognitive abilities, despite fatigue (Boksem, Meijman, & Lorist, 2006). Seventy-one percent of the participants indicated that they play simulation games like Command and Conquer ™ once a week for an average of 4 hours. Such regular interaction with the game (and associated enjoyment) could have helped to decrease the influence of fatigue on their performance. Hancock and Warm's (1989) model of stress indicates that previous exposure to the task influences how the person responds to stress.

Harackiewicz and Elliot (1993) indicated that having performance goals increases intrinsic motivation. Perhaps being informed of their goals to protect themselves and kill their opponents added to their own preexisting motivation to play the game and resulted in an increase in performance. Being given extrinsic reinforcement may also have increased their intrinsic motivation and thus their performance. Highly motivating tasks combine both extrinsic and intrinsic motivation particularly if they enhance the individual's competence and self-determination (Deci & Ryan, 1985). Receiving financial compensation and extra credit as well as extended time for strategy development could have prevented fatigue decrements. As participants' strategies became more successful this increased their feelings of competence and desire to continue playing the game.

Another plausible influence on the improvement of performance is practice effects. Practice effects occur when task performance increases as a result of repeated exposure to the task (Smith, McEvoy, & Gevins, 1999). This increase in performance due to extended exposure to the task is supported by learning theories. Fitts and Posner (1967) indicated three stages of learning. The first stage is the cognitive stage where individuals learn the basic steps of the task and receive feedback on their performance. They begin to develop the different components of the task and are likely to make many errors in this stage. The next stage is the associative stage where individuals obtain procedural knowledge as they learn the rules of the task and when to apply them. They continue to refine their performance with practice and feedback. The third stage is automaticity where individuals are able to perform the task automatically. This is the most difficult level to obtain and is not reached by all individuals. The more automatic the skill is the less performance is influenced by stressors. Since the participants were required to have previous exposure to the game, they were beyond the cognitive stage when one is learning the basic steps of the tasks. They were likely at the associative level. More expert players may even have been at the automatic level. The extended interaction with the task helped them to continue to develop their skills in the game rather than decrease their ability. If the participants had been individuals in the cognitive stage when they were just beginning to learn the task, extended time might have resulted in a decrease in performance that varied based on the game's difficulty level.

Rasmussen (1983) also indicated that performance can be controlled by skills, knowledge, and rules. Skill-based performance is automatic, while rule-based performance is controlled by knowledge of rules and procedure. Knowledge-based performance is determined by knowledge of the system and its current state. Individuals begin to learn a task at the knowledge-based level, and then proceed to the rule-based level which is followed by the skill-based level. Individuals with past experience tend to operate at the skill-based level but they can also operate at the rule-based or knowledge-based level in a new situation. This theory can possibly apply to this study. The participants were likely at the skill-based or rule-based level. They knew how to play the game and had strategies created that they had previously employed. However, most of the participants indicated that they had not played this particular scenario of the game before so perhaps performance was initially knowledge-based as participants had to examine the scenario and then determine how their usual strategies would work in the experiment scenario. They still had a pre-existing structure of the game and knowledge of the rules and procedure. They amended their mental structure of the game to handle the current scenario as their exposure increased. The longer they interacted with the game, the more their performance improved.

Practice effects commonly occur if retesting occurs after a short interval (Anatasi, 1981). At the end of the hour, participants briefly completed the surveys and then they were placed back into the scenario. They retained information from the previous hour about the scenario, their actions, and the outcomes of those actions. Another explanation for practice effects is decreased anxiety (Baird, Tombaugh, & Francis, 2007). No measure of anxiety was given, but participants indicated that their feelings of being overwhelmed and frustrated decreased in the study. The less frustrated and overwhelmed they felt, the more they were able to focus on refining their game strategies. An improvement in response strategies can also result from practice effects (Smith, McEvoy, & Gevins, 1999). Participants were also able to improve their plans to attack their opposers. They likely developed or refined strategies accordingly as they reengaged the opposers. Being continually exposed to the scenario allowed participants more opportunities to develop strategies that would help them improve their performance in each session.

The lack of interaction between elapsed time and difficulty could have been influenced by practice effects. Participants in both groups were continually exposed to their scenario and improved their performance. Individuals did not become highly fatigued which may have prevented the expected differences in performance between groups over time. The use of different scenarios that required the same level of difficulty might have prevented this effect. Thus participants in the easy group, for example, are still being exposed to easy tasks but not the exact same task over the course of the simulation. Another way to examine this possible confound would be to measure the performance of individuals who had not played the game previously. If they experience the same improvement in performance over time, this would provide evidence that practice effects did confound the study. If a similar increase in performance is not found, this could provide more support for the contention that the participants' preexisting experience with the game helped them to maintain their performance. Also, extending the study time may have overcome practice effects and led to a decrease in performance.

It is interesting to note specific performance strategies. Even though protecting own forces and killing enemy forces were stressed equally to participants, they typically adopted a defensive strategy during Hours 1 and 2 of the experiment. In Hour 3, however, some participants became more offensive and focused on killing the opposing forces. Perhaps their improvement in performance from Hour 1 to Hour 2 gave some participants the confidence to take an offensive position in Hour 3. Another possibility suggested by Hockey (1997) is that they chose a riskier strategy as they became more fatigued. As fatigue increased it became harder for the participants to defend themselves so they decided to directly attack the opposers so that there would be fewer opposers left to mount an attack against them.

Mental Workload

The results for perceived workload did not support the stated hypothesis that workload would increase over time. On the contrary, workload ratings decreased over time. Some previous research can explain this finding. Hancock and Warm's adaptation model indicates that individuals can adjust their actions to meet the needs of the task, such as a soldier effectively shooting targets despite several hours of duty. Parasuraman and Hancock (2001) suggest a similar capability for workload. Despite exposure to heavy workload for a long period of time, individuals can adjust to their environment and maintain task performance. Even as participants expended more of their effort over time, as a whole they did not indicate feeling overloaded by the task on the NASA TLX. The NASA TLX ratings were further supported by responses to the strategy questionnaire. When asked directly if they felt overwhelmed: 61% percent indicated that they felt overwhelmed in the first hour but only 21% feel overwhelmed in the second hour, and 20% felt overwhelmed in the third hour. Near the end of the experiment, participants felt that the task was less demanding even though it remained the same throughout the experiment. This finding differs from Kahneman's (1973) contention that mental resources become depleted over time. Kahneman indicates that there is a limited capacity for mental resources (Norman & Bobrow, 1975). As resources decline over time, less attention is available for task and performance declines. If participants had experienced this loss of mental resources, they would have experienced increased feelings of being overwhelmed as it became more difficult for them to allocate attention to the task.

Participants' decreased workload may also reflect problems with the NASA TLX indicated by Macdonald and Upsdell (1996). They indicated that aspects of individuals' experience including autonomy, perception of the task, control of the task, and feedback could influence participants' ratings of workload. The participants' preexisting enjoyment of the game could have led to their perceptions of decreased workload.

Situation Awareness

Situation awareness was expected to decrease over time. Situation awareness was originally measured using the initial eight items that composed the SAGAT. Then it was examined using the combined score of the three items identified in the content validity study. However, an overall composite score of situation awareness was not used due to the low reliability of the SAGAT measures. Instead, the three items identified in the content validity study were individually used to examine situation awareness. Knowledge of the amount of money in the treasury decreased, while the ability to predict the effect of their plans increased. Their ability to predict the direction of the next attack increased between Hour 1 and 2, but slightly decreased in Hour 3.

The lack of a reliable composite situation awareness measure limits the application of the situation awareness findings. Several factors could explain the low level of reliability of the SAGAT. Often long measures result in higher alphas (Shevlin, Miles, Davies, & Walker, 2000). However, for this study the SAGAT originally consisted of eight items. This brief measure was created so that information about participants' perception of situation awareness could be collected quickly and then the participants could return to the scenario. A variety of responses also increases alpha (Shevlin, Miles, Davies, & Walker, 2000). However, the measure in this study was dichotomous so answers were rated as either 0 or 1. The use of a dichotomous scale restricted the range of responses. Another explanation for this low reliability is that the measure examined different aspects of the construct, resulting in a decreased alpha (Bernardi, 1994).

Another limitation to the application of the SAGAT was the use of graduate students to develop the measure. The individuals who participated in the pilot study were graduate students from the Old Dominion University Psychology department. These students were chosen through convenience sampling to examine the feasibility of interacting with the simulation for several hours and provide information on the tasks performed in the game. Information on the tasks was used to develop the measure. However, these individuals did not have prior experience with the game and were advanced-level students. The aspects of the game that they focused on could have been different from the aspects focused on by the participants in the experiment. Contrary to the experiment participants, they exhibited the expected decreases in performance. Individuals in the difficult condition also exhibited slightly better performance. The participants in the experiment were required to have had experience with the game and were largely freshmen and sophomores. Since these individuals had previous experience with the game, they likely focused on aspects of the game they usually attended to and less of their attention was given to the situation awareness queries. The use of student participants also limits the SAGAT's validity. The same level of sensitivity was not observed as would most likely occur with the use of active duty officers. The initial scope of the study was to recruit only military participants. However, requests for Army and Navy ROTC cadets were largely denied due to their lack of available time to participate in the three hour study.

A content validity evaluation of the SAGAT was conducted after the data was collected. It indicated that several of the items provided relevant information about situation awareness. However, when the responses were examined between the two groups, differences in ratings were found. Based on the game experts' ratings, half of the items were regarded as necessary. By contrast, based on the military experts', one item, the amount of money in the treasury met the validity requirement. This indicates an important issue regarding external validity. Even though the questions were appropriate for this scenario, they may be less relevant for real battles.

In general there is difficulty in developing adequate SAGAT queries. Endsley indicates that the use of queries that match the operator's thought process is fundamental for measuring SA. Queries are developed based on the identification of the tasks that are performed and the goals and subgoals of those tasks. Developing queries can take over a year and can be expensive and time-consuming for organizations (Endsley, 2000). The steps of task analysis were followed to create the queries in this study and these queries were supported by the content validity study. These queries were also similar to the type of information explored in other studies examining situation awareness in the military. For instance, Strater, Endsley, Pleban and Matthews (2001) examined situation awareness in a military simulation. They queried military officers about the location of their troops and their enemies and prediction of future attacks. However, despite the similarity between the SAGAT measure used and the situation awareness queries in previous research, the composite measure was not internally consistent and underscores the difficulty in capturing the thought process for situation awareness.

Another drawback to the SAGAT is that it places equal importance on all the elements in the scenario. However, Hauss and Eyferth (2003) and Kaber, Perry, Segall, McClernon, and Prinzel (2006) indicate that individuals may need to focus on different aspects of the scenario at different points in time. This discrepancy is relevant for this study in that at different points in the battle and depending on the strategies used, knowledge of money in the treasury could be more important than knowledge of how many opposers there are and the reverse could be true at another point in time. But, both elements were questioned at each query and correctly or incorrectly answering each item contributed to the total situation awareness score. A person could have adequate knowledge of the scenario to play the game but not feel that knowing the amount of money in the treasury is important. They could consistently ignore that aspect and answer it incorrectly resulting in low situation awareness scores.

This could also explain the lack of significant correlations between situation awareness and performance. Even though participants developed a mental model of the situation and used it to make decisions and guide their performance, if this model was not reflected in their situation awareness scores then the relationship between situation awareness and performance could not be revealed. For example, if the participants had recently dispatched troops to successfully engage the opposer, they may correctly indicate the number of their troops and incorrectly indicate the amount of money in the treasury which they checked earlier.

Although situation awareness could also have been examined through other measures such as the Situation Awareness Rating Technique (Taylor, 1991), the SAGAT is primarily used in research because it provides an objective evaluation of situation awareness. It is created to examine the elements of an individual scenario. It also provides information about each of the three levels of situation awareness (Endsley, 2000).

Game Difficulty

No statistically significant interactions were found between task difficulty and elapsed time. Individuals were assigned to either the easy or difficult condition. The varying difficulty levels influenced the participants' interaction with the simulation. Individuals in the difficult group experienced significantly more fatigue than those in the easy group. On the Military Simulation Questionnaire, they indicated they felt significantly more overwhelmed than those in the easy group. These findings may be explained by Matthews' transactional model. According to Matthews' model, individuals appraise a situation and develop a coping strategy. Implementing a coping strategy results in effects on subjective feelings and performance. The difficult level of the game was more demanding and was appraised as such leading to participants feeling more fatigued and overwhelmed in that level. Based on these subjective measures, individuals in the easy and difficult groups experienced the scenario differently based on the difficulty level they were assigned.

The difficult level led to no significant difference in performance over time. Perhaps if the brutal level of the game had been used, the expected improvement in performance for those in the higher level of task difficulty would have occurred over the course of the study. The increased tasks demands of the brutal level would require the participants in that level to increase their effort to protect their troops and attack opposers over time.

Practical Significance

Another issue that should be considered is the practical significance of the findings. Cohen's (1988) standards for effect size were used to determine the strength of the relationships found between fatigue, workload, and performance. The finding for the fatigue ratings indicate that time had a moderate effect on participants' increased perceptions of fatigue. This finding further confirms past studies that have found a relationship between time and fatigue. Another moderate effect for time was found as participants felt less overwhelmed over the course of the game. Statistically significant effects for time were found for the NASA TLX composite score and its components of frustration, physical demand, and performance. Composite ratings of workload and feelings of frustration decreased, while feelings of physical demand increased and perceptions of performance improved. Statistically significant effects were also found for percentage of troops lost and percentage of opposers killed. Percentage of troops lost decreased over time, while percentage of opposers killed increased. The effect sizes for time on task ratings on the NASA TLX, frustration, performance, and percentage of troops lost were below Cohen's standard for small effects. The effect sizes for physical demand and percentage of forces killed indicated small effects.

The findings for differences in fatigue ratings and feelings of being overwhelmed were also statistically significant for difficulty. Individuals in the difficult group indicated that they felt more fatigued and overwhelmed than those in the easy group. However, the effect sizes for these findings were below Cohen's standard for small effects. This indicates limited practical application of these findings. Although extended time on task did influence workload and performance, applying these findings outside of this population is restricted. Differences between groups in feelings of fatigue and overwhelm was also limited.

The situation awareness items were also statistically significantly influenced by time. Individuals' ability to predict the effects of their plans increased over time, while their knowledge of money in their treasury decreased. Their ability to predict the next direction of their attack increased and then slightly decreased. Time had a moderate effect on participants' ability to predict the direction of the next attack and a small effect on knowledge of money in the treasury. Time's effect on individuals' prediction of their plan's effect was below Cohen's standard for small effects. These differences in effect size for situation awareness indicate how time can influence different aspects of situation awareness in different ways. The more time individuals spent with the scenario the better their ability to predict the effect of their actions, while time had a small effect on their ability to perceive elements of the scenario and minimal effect on participants' ability to predict the opposition's actions. The lack of a stronger effect of time on the variables and the absence of a significant interaction between time and difficulty could be due to the previously mentioned influences of motivation, practice effects, and previous experience. Perhaps more extended interaction with the scenario and a higher level of difficulty could have led to more robust findings for time and its interaction with game difficulty.

Implications

This research provides additional information to the fatigue literature by exploring the relationship among fatigue, workload, situation awareness, and performance. The use of simulation to examine performance is becoming common practice in the military and other arenas. This study also contributes to this growing body of literature. The findings support the adaptation and transactional model because individuals adjusted their behaviors to meet the needs of the task. It further confirms past studies showing that feelings of fatigue increase with continued exposure to tasks. Interestingly, it differs from previous research demonstrating that increases in time on task automatically resulted in performance decrements (Macdonald & Bendak, 2000; Meijman, 1997; Van der Linden, Frese & Meijman, 2003).

This was one of the few attempts in literature (see Endsley, 2006) to explore the relationship between extended time and situation awareness. However, the original SAGAT measure used indicated low reliability. When a modified version of the SAGAT was created based on the results of the content validity study, reliability was still below the reliability criterion. Knowledge of money in the treasury, the predicted effects of the participants' plans, and the predicted direction of the opposers' next attack were examined individually to measure situation awareness. The significant findings for these items support the contention that extended time on task influences aspects of situation awareness. However, the lack of a reliable composite measure of situation awareness limits the application of these findings.

In this study, no significant relationship was found between perceptions of workload and situation awareness scores. This study also contradicts the typical relationship between fatigue and workload. High workload usually results in fatigue reactions. In addition, high fatigue increases perceived workload (Gaillard, 2001). In this research, no causative relationship was explored between fatigue and workload. However, an increase in time on task resulted in decreased perceptions of workload and a corresponding increase in perceptions of fatigue.

Factors such as past experience and enjoyment of the game likely assisted the improvement in performance despite increased feelings of fatigue. Thus, using more experienced motivated officers can likely help improve performance over an extended amount of time. Even though individuals opposing the difficult army indicated feeling more overwhelmed and fatigued than those opposing the easy army, this led to no significant differences in performance between the groups. This study's findings indicate that whether exposed to situations of high or low task difficulty, people with past experience and interest in the task can still perform adequately for an extended periods of time.

The use of simulation-based training can be enhanced based on the findings of this study. Simulation has become a popular method of military recruiting and training. This study used primarily young college students who enjoyed interacting with a simulated environment. It further confirms the use of this tool as an innovative method to appeal to young recruits. The discrepancy between the military and game experts suggests that the military should develop scenarios that closely replicate the situations that will be confronted in combat. They should confirm that the tasks trained in the simulation will be transferable to the battlefield.

FUTURE RESEARCH AND CONCLUSION

This study explored a complex relationship with a simple experimental design. The length of exposure to the task and its influence on situation awareness and workload should be further explored in future research. Examining performance for a longer period of time may determine if and when the threshold of performance improvement is reached. In an extended session, the expected maintenance of performance for those opposing the difficult army may also be discovered. Redesigning the SAGAT measure with more input from military officers and computer game experts may provide increased understanding of the relationship between time on task and situation awareness. The examination of three of the situation awareness items individually indicated a relationship between time on task and situation awareness. A more reliable measure of situation awareness could further explore this implication. Since the military is using simulation for recruitment and training practices, it is paramount that the simulation scenario corresponds with actual battle. The discrepancy between the items regarded as necessary by game experts and military experts suggests further research should be conducted to examine the transfer validity of skills learned in simulation to actual military situations.

The fact that the perception of physical demand initially significantly increased despite the reduction of total perceived workload could also be explored. Using a live simulator of battle in which participants have to physically direct the officers' movements would increase the physical demand of the task. Examining performance of a more physically demanding task over time could provide information about whether physical demand is particularly vulnerable to time on task deterioration. Perhaps over time the other scales of workload may also decrease.

Participants with previous experience with the game were selected in an attempt to avoid confounds such as a learning effect. However, this prior knowledge of the game could have also insulated participants from the negative time on task effects. Individuals without previous experience could be tested to determine if they also experience an improvement of performance over time. The influence of extrinsic and intrinsic motivation could also be explored. The participants previously enjoyed playing the game. Some participants indicated that they liked receiving the financial compensation and extra course credit so these were extrinsic motivators. Determining how much these factors influenced performance could also assist the military. Although these factors might be difficult to replicate in a military environment, other types of extrinsic reinforcement such as honors and recognition are available. Fiorta, Middendorff, and McMillan (1992) examined the effect of extrinsic motivators in four experiments of simulated flight. They found that indicating the top 10 scorers and the top 4 average scorers led to increased performance in subsequent trials. Tauer and Harackiewicz (2004) found that cooperation and competition increased intrinsic motivation and task performance. Discovering what type of extrinsic motivation influences behavior and how intrinsic motivation can be cultivated provides additional information that the military can use to help their officers maintain their performance during extended missions.

Fatigue is an important issue for the military as the U.S. is continually involved in operations around the world including the current missions in Afghanistan and Iraq. This study suggests that mental workload, performance, and in some cases situation awareness, can actually improve over time, despite feelings of subjective fatigue. The relationship between fatigue, situation awareness, workload, and performance should be analyzed further to assist in the military's development of practical training.

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Appendix A

Yoshitake Symptoms of Fatigue Checklist

The following list presents phrases describing how you may feel after a given task. Please read each item carefully and place a check mark next to those items that describe how you feel after completing the previous task. There are no right or wrong answers. You may check as many items that apply.

1. _____ Head feels heavy.
2. _____ Feel tired over the whole body.
3. _____ Feel tired in the legs.
4. _____ Feel like yawning.
5. _____ Confused.
6. _____ Drowsy.
7. _____ Eye strain.
8. _____ Become clumsy.
9. _____ Unsteady in standing.
10. _____ Want to lie down.
11. _____ Have difficulty thinking.
12. _____ Weary of talking.
13. _____ Nervous.

14. _____ Unable to concentrate.

15. _____ Unable to take interest in things.

16. _____ Forgetful.

17. _____ Lack self-confidence.

18. _____ Anxious about things.

19. _____ Unable to straighten my posture.

20. _____ Lack patience.

21. _____ Have a headache.

22. _____ Feel stiff in the shoulders.

23. _____ Feel back pain.

24. _____ Have difficulty breathing.

25. _____ Feel thirsty.

26. _____ Feel hoarse.

27. _____ Feel dizzy.

28. _____ Have tremor of the eyelids.

29. _____ Have a tremor in the limbs.

30. _____ Feel ill.

Appendix B

NASA TLX WORKLOAD QUESTIONNAIRE

NASA TLX Rating Instructions

We are not only interested in assessing your performance but also your experiences during the different task conditions. In the most general sense, we want to examine the "workload" you experience. Workload is a difficult concept to define precisely, but a simple workload may come from the task itself, your feelings about your own performance, how much effort you put in, or the stress and frustration you felt. The workload contributed by different task elements may change. Physical components of workload are relatively easy to conceptualize and evaluate. However, the mental components of workload may be more difficult to measure.

Since workload is something that is experienced individually by each person, there are no effective "rulers" that can be used to estimate the workload of different activities. One way to find out about workload is to ask people to describe the feelings they experienced. Because workload may be caused by many different factors, we would like you to evaluate several of them individually rather than combining them into a single global evaluation of overall workload. A set of six rating scales was developed for you to use in evaluating your experiences during the simulation.

If you have any questions about any of the scales, please ask the experimenter about them. It is extremely important that they be clear to you.

After performing each of the sessions, you will be presented with a set of rating scales. You will evaluate the task by circling each of the six scales at the point that matches your experience. Each line has two endpoint descriptors that describe the scale. Note that "own performance" goes from "good" on the left to "bad" on the right. Please consider your responses carefully in distinguishing among the different task conditions. Consider each scale individually. Your ratings will play an important role in the evaluation being conducted, thus, your active participation is essential to the success of this experiment and is greatly appreciated.

NASA TLX

1. Mental Demand

Low High

1	2	3	4	5	6	7

2. Physical Demand

Low High

1	2	3	4	5	6	7

3. Temporal Demand

Low High

1	2	3	4	5	6	7

4. Performance

Good Poor

1	2	3	4	5	6	7

5. Effort

Low High

1	2	3	4	5	6	7

6. Frustration

Low High

1	2	3	4	5	6	7

Appendix C

SAGAT

Please answer the following questions.

1. How many of your officers are currently depicted on the screen?
2. How many opposing officers are currently depicted on the screen?
3. How much money is currently left in your treasury?
4. What types of officers are currently depicted on the screen?
5. What are the buildings currently depicted on the screen?
6. What structure do you think the opposing army will attack next?
7. From what direction do you think the opposing army will attack next? North, South, East, West?
8. What do you plan to do next? What do you think will happen if you implement this action?

Appendix D

COMMAND AND CONQUER INFORMATION

(http:// www.ea.com/redesign/games/pccd/ccgenerals)

Command & Conquer Generals puts your trigger finger on the pulse of modern warfare.

Key Feature

- **Modern Military Warfare** - Unleash your fury using modern and near-future military weaponry on the cutting-edge of technology.

The United States has the most sophisticated arsenal. From its well-equipped and expertly trained Rangers to the top-secret Particle Cannon, the USA side is rarely caught at a technological disadvantage.

The Chinese forces have a resource that cannot be matched: population. Built to rely on the pride and nationalism of its people, the Chinese side can overwhelm the opposition with sheer numbers.

A loosely aligned worldwide network of terror, the Global Liberation Army (GLA) prizes speed and low-tech ingenuity over destructive force. Relying heavily on the dedication of fanatics, the GLA sends soldiers into the teeth of its enemies and always has an escape route for its hardcore veterans.

Appendix E

Demographic Survey

Participant No.___

Please place an X in the blanks to answer the following items.

Age:_____

Sex:
___ Male ___Female

Ethnicity:
___Caucasian
___African-American
___Asian American
___Hispanic
___Other

Classification (Please check all that apply.)
___Freshman
___Sophomore
___Junior
___Senior

Do you have normal or corrected-to-normal vision?
___ Yes
___ No

Do you have normal or corrected-to-normal hearing?
___ Yes
___ No

How many hours did you sleep last night?
__ over 9
__ 7-9
__ 6 or less

How many hours a night do you normally sleep?
___over 9
___7-9
___6 or less

How many cups of coffee did you drink today?
__ 0
__ 1-3
__ 4-6
__ over 6

How many cups of coffee do you normally drink?
___ 0
___1-3
___4-6
___over 6

Mark the following systems you own or regularly play video games with. You may mark more than one system.

PC/Macintosh ☐	Nintendo 64 ☐	PlayStation ☐
PlayStation 2 ☐	Xbox ☐	Other game platform ☐

Mark the type of games you play. You may mark more than one game type.

Sports/racing ☐ E.g., Madden 2003	Role-playing ☐ E.g., Diablo II	Shooter ☐ E.g., Half-life
Adventure ☐ E.g., Myst III: Exile	Simulation ☐ E.g., Command and Conquer	Strategy ☐ E.g., Starcraft

How much time per week do you spend playing each type of game?

Sports/racing _______hrs/wk E.g., Madden 2003	Role-playing _______hrs/wk E.g., Diablo II	Shooter _______hrs/wk E.g., Half-life
Adventure _______hrs/wk E.g., Myst III: Exile	Simulation _______hrs/wk E.g., Command and Conquer ™	Strategy _______hrs/wk E.g., Starcraft

Rate your experience level with Command and Conquer: Generals ™.

__ Novice

__ Intermediate

__ Expert

Appendix F

Research Study Flyer

Date Posted: ____________ IRB/COSHSC #: 06-059

Fatigue in the Military

Description: This study examines the effect of fatigue on military performance. By examining the effect of fatigue on performance, insight into how military officers perform under stress can be obtained. This information can then be used to improve training for military operations. In this laboratory study, you will be presented with a simulated military environment where you will direct military forces in the completion of a mission. You will complete several surveys throughout the study.

Participants: You must have played Command and Conquer: Generals ™ on a weekly basis for three months in order to participate. You must have normal or corrected-to-normal vision and hearing.

Time Requirements: This study will require approximately 3 hours.
Sign-up Information: Please sign up in the SONA Research Participation System to schedule a participation day and time.

Research Participation Credits: You will receive 3 Psychology Department research credits.
Researchers and Contact Information:
Carlotta Boone cmboone@odu.edu
Dr. James Bliss jbliss@odu.edu

Appendix G

INFORMED CONSENT FORM
Old Dominion University

PROJECT TITLE: Fatigue's Influence on Situation Awareness and Performance in a Military Simulation of Combat

INTRODUCTION
The purpose of this form is to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES.

RESEARCHERS
Dr. James Bliss, PhD, Old Dominion University
Carlotta Boone, M.S., Old Dominion University

DESCRIPTION OF RESEARCH STUDY

Military officers encounter stressful and intense conditions on the battlefield. They are often required to perform missions for days at a time without rest or sleep. They are also required to be aware of their surroundings, the location of their compatriots, and the presence of enemy forces. They must use this information to make quick decisions in critical situations to protect themselves and their colleagues. If you agree to participate, approximately 3 hours will be needed. You will first complete a background questionnaire. Then you will be presented with a simulated military environment in the Command and Conquer: Generals ™ computer game where you will direct military forces in the completion of battles. You will complete several surveys throughout the study measuring fatigue, situation awareness, and workload. You must have played the game Command and Conquer: Generals ™ on a weekly basis for three months in order to participate. A total of 90 students will participate in this study.

EXCLUSIONARY CRITERIA
You must have played the game Command and Conquer: Generals ™ on a weekly basis for three months in order to participate.

RISKS AND BENEFITS
BENEFITS: If you decide to participate in this study, you will receive $15. If you are a Psychology student, you will also receive 3 Psychology Department research credits, which may be applied to course requirements or extra credit in certain Psychology courses. Equivalent credits may be obtained in other ways. You do not have to participate in this study, or any Psychology Department study, in order to obtain this credit. The main benefits to you for participating in this study are an opportunity to obtain $15, 3 Psychology research credits (if applicable), and provide information that may be used to improve training for military duty.

RISKS: If you decide to participate in this study, then you may face a risk of eyestrain, muscle strain, and frustration similar to that encountered with video game interaction. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.

COSTS AND PAYMENTS

The researchers want your decision about participating in this study to be absolutely voluntary. You will be paid $15 for your participation in the study.

NEW INFORMATION

If the researchers find new information during this study that would reasonably change your decision about participating, then they will give it to you.

CONFIDENTIALITY

All information obtained about you in this study is strictly confidential unless disclosure is required by law. The results of this study may be used in reports, presentations and publications, but the researcher will not identify you.

WITHDRAWAL PRIVILEGE

It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study -- at any time.

COMPENSATION FOR ILLNESS AND INJURY

If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of harm, injury, or illness arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a result of participation in this research project, you may contact Carlotta Boone at (757) 889-1619 or Dr. James Bliss at (757) 683-4222 or Dr. David Swain the current IRB chair at (757) 683-6028 at Old Dominion University, who will be glad to review the matter with you.

VOLUNTARY CONSENT

By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. The researcher should have answered any questions you may have had about the research. If you have any questions later on, please contact Carlotta Boone at (757) 889-1619 or Dr. James Bliss at (757) 683-4222.

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Dr. David Swain, the current IRB chair, at (757) 683-6028.

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

Subject's Printed Name & Signature	Date

INVESTIGATOR'S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws, and promise compliance. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

Investigator's Printed Name & Signature	Date

Appendix H

Military Simulation Questionnaire

The following questions relate to your experience interacting with the Command and Conquer: Generals ™ simulation. Different people have different experiences and we are interested in assessing your experience.

1. What strategy do you usually use to play the game?

___Focus primarily on killing opposers
___Focus primarily on protecting your own forces
___Focus equally on protecting your forces and killing opposers
___Other
If other please explain:

2. For hour 1, what strategy did you use to play the game?

___Focus primarily on killing opposers
___Focus primarily on protecting your own forces
___Focus equally on protecting your forces and killing opposers
___Other
If other please explain:

3. Did you change your strategy for hour 2? If so, how? Why?

4. Did you change your strategy for hour 3? If so, how? Why?

5. Were you able to pay attention to the combat scenario in Hour 1?

6. Was it harder to pay attention in Hour 2 and Hour 3?

7. Were you able to adequately focus on both protecting your troops and killing your opposers or did you feel overwhelmed by the game in Hour 1?

8. Were you able to adequately focus on both protecting your troops and killing your opposers or did you feel overwhelmed by the game in Hour 2?

9. Were you able to adequately focus on both protecting your troops and killing your opposers or did you feel overwhelmed by the game in Hour 3?

10. Were you able to use your past experience with the game to help you maintain your performance?

11. Have you ever opposed the Chinese army in the Alpine scenario before?

Appendix I

Debriefing Script:

Thanks for your participation in Fatigue in the Military!

Military operations routinely require military officers to continuously perform their duties. The prolonged performance can lead to mental fatigue and decreased performance. They must be aware of their surroundings and make critical decisions with usually little or no rest. The difficulty level of the task is also expected to influence performance. The use of a computer simulation game, such as Command and Conquer: Generals ™ provides a unique opportunity to examine fatigue in an interactive environment. The purpose of this study is to examine the influence of fatigue on situation awareness, workload, and performance. Participants were assigned to combat either an easy or difficult army. You combated the _________ army. Your ratings of fatigue and workload and your performance over the course of the game and your answers to the situation awareness measure will be analyzed to determine if fatigue influenced your performance. The data obtained will ultimately be used to aid in the development of procedures, tools, technologies and training mechanisms to improve scheduling and training for military officers.

VITA

Carlotta M. Boone
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Telephone: (615) 417-1365

Professional Objective: Employment in the field of human factors psychology as a research analyst and consultant where I will use my reasoning and analytical skills to resolve human performance issues.

Education:

2002-present	Old Dominion University Norfolk, Virginia Doctoral Candidate in the Department of Psychology Human Factors Concentration Dissertation: Fatigue, Workload, Situation Awareness, and Performance in a Military Simulation of Combat
2002	Graduated from the University of Memphis Memphis, Tennessee M. S. degree in General Psychology Master's Thesis: Assessment of an Online Strategy for Collecting Critical Incident Statements
2000	Graduated from Xavier University of Louisiana New Orleans, Louisiana B.S. degree in Psychology Magna Cum Laude Honor Honors in History Minor: Psychology

Awards and Honors:

2003-2005	Human Factors and Ergonomics Society Student Chapter Treasurer