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Sleep logistics as a force multiplier: an analysis of reported fatigue factors from Southwest Asia warfighters

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THESIS

SLEEP LOGISTICS AS A FORCE MULTIPLIER: AN ANALYSIS OF REPORTED FATIGUE FACTORS FROM SOUTHWEST ASIA WARFIGHTERS

by

Shaun W. Doheney

September 2004

Thesis Advisor: Nita Lewis Miller
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The purpose of this thesis is to analyze data related to sleep patterns of warfighters deployed to the Southwest Asia (SWA) Area of Operation. To this end, we collected subjective survey data from warfighters operating in Iraq and Kuwait from 25 August - 15 October 2003 (n = 273). Participants were asked about unit-level sleep planning, sleep/wake patterns, and lifestyle factors. Using the survey results, we are able to gain insight regarding the four primary research questions: 1) Is sleep deprivation a significant problem for forces in the SWA region; 2) Do current sleep logistics support a unit's ability to accomplish assigned missions; 3) Are there differences in sleep patterns between subset populations; and 4) Does the current survey method support the research objectives. To address these questions, we used analysis techniques such as principal components analysis, factor analysis, and parametric and nonparametric hypothesis testing. We tested the reliability of the subjective survey results by comparing self-reported survey data with actigraphy data corresponding to the same time period (n = 34 paired observations). This thesis also provides insight regarding the use of sleep logistics as a force multiplier during continuous/sustained operations by discussing known fatigue countermeasures and their role in improving individual and unit performance effectiveness.

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The purpose of this thesis is to analyze data related to sleep patterns of warfighters deployed to the Southwest Asia (SWA) Area of Operation. To this end, we collected subjective survey data from warfighters operating in Iraq and Kuwait from 25 August - 15 October 2003 (n = 273). Participants were asked about unit-level sleep planning, sleep/wake patterns, and lifestyle factors. Using the survey results, we are able to gain insight regarding the four primary research questions: 1) Is sleep deprivation a significant problem for forces in the SWA region; 2) Do current sleep logistics support a unit’s ability to accomplish assigned missions; 3) Are there differences in sleep patterns between subset populations; and 4) Does the current survey method support the research objectives. To address these questions, we used analysis techniques such as principal components analysis, factor analysis, and parametric and nonparametric hypothesis testing. We tested the reliability of the subjective survey results by comparing self-reported survey data with actigraphy data corresponding to the same time period (n = 34 paired observations). This thesis also provides insight regarding the use of sleep logistics as a force multiplier during continuous/sustained operations by discussing known fatigue countermeasures and their role in improving individual and unit performance effectiveness.

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LIST OF ABBREVIATIONS AND ACRONYMS

AFRL	Air Force Research Laboratory
BAC	Blood Alcohol Content
CONOPS	Continuous Operations
FAST	Fatigue Avoidance Scheduling Tool
FM	Field Manual
IED	Improvised Explosive Device
MCDP	Marine Corps Doctrinal Publication
MCRP	Marine Corps Reference Publication
NHRC	Naval Health Research Center
NPS	Naval Postgraduate School
NREM	Non-Rapid Eye Movement
OIF	Operation Iraqi Freedom
PVT	Psychomotor Vigilance Tasks
REM	Rapid Eye Movement
SAFTE	Sleep, Activity, Fatigue, and Task Effectiveness
SAIC	Scientific Applications International Corporation
SUSOPS	Sustained Operations
SWG	Survey Working Group
TDG	Tactical Decision Game
USAARL	U.S. Army Aviation Research Laboratory
WAM	Wrist Actigraphy (or Activity) Monitor
WRAIR	Walter Reed Army Institute of Research

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EXECUTIVE SUMMARY

MCDP 1 (1997) states, “War is both timeless and ever changing. While the basic nature of war is constant, the means and methods we use evolve continuously.” Like war itself, our approach to warfighting must evolve. If we cease to refine, expand, and improve our profession, we risk becoming outdated, stagnant, and defeated.

The purpose of this thesis is to provide further insight into the nature of our profession and provide commanders and decision-makers the information they need to lead their warfighters to victory.

In this thesis, we consider the impact of Sleep Logistics during Phase IV operations of Operation Iraqi Freedom (OIF). Shortly after the commencement of OIF, multiple sources within Iraq reported that fatigue and sleep deprivation in this high-stress environment were taking a significant toll on warfighter performance and were contributing factors to an operational pause during the march to Baghdad. While there is no doubt that the warfighters of OIF adapted to the combat environment, met every challenge, and superbly executed their mission, there are still lessons to be learned from all phases of OIF. One major lesson learned during OIF is that leaders at all levels must face the effects of sleep deprivation and strive to implement sleep/rest plans during continuous/sustained operations in order to minimize those adverse effects.

In order to understand the scope of the problem, we collected subjective survey data from warfighters (n = 273) operating in Iraq and Kuwait from 25 August to 15 October

2003. The survey tool, which was initially designed and later refined at NPS, asked questions relating to unit-level sleep/rest planning, sleep/wake patterns, warfighter fatigue and sleep latency, symptoms of sleep deprivation, and confounding lifestyle factors that impede sleep and rest. Using the subjective data obtained, we can gain insight regarding the four primary research questions: 1) Is sleep deprivation a significant problem for forces currently deployed to the Southwest Asia (SWA) region; 2) Do current sleep logistics of forces operating in SWA support a unit's ability to accomplish assigned missions; 3) Are there statistically significant differences in sleep patterns and predicted performance effectiveness between subset populations, such as units with clear sleep/rest plans, by location, by Military Occupational Specialty, by rank, or by gender; and 4) Does the current survey method support the research objectives. In order to properly address these four questions, we use analysis techniques such as principal components analysis, factor analysis, regression analysis, parametric hypothesis testing, and nonparametric hypothesis testing.

In order to test the reliability of the subjective SWA data, we collected additional subjective survey data and objective activity data, which are used to accurately monitor sleep/wake histories. By comparing the subject and objective data, we are able to determine the overall reliability of the survey method. Finally, this thesis addresses ways of improving the warfighter's performance effectiveness through the use of sleep logistics planning by providing detailed recommendations for improving unit-level sleep/rest plans through known fatigue countermeasures. By continuing to refine, expand, and improve in this area of warfighting, we ensure victory on future battlefields by learning to maximize individual and unit performance effectiveness through the use of sleep logistics, and degrading the enemy’s ability to fight effectively by understanding how to denying him the ability to rest. Simply stated, this thesis provides additional insight regarding the use of sleep logistics as a force multiplier during continuous/sustained combat operations.

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I. INTRODUCTION

A. OVERVIEW

The following is a Tactical Decision Game (TDG) adapted from TDG #04-2, Tropical Gold, originally published in the Marine Corps Gazette (Miller, 2004).

You are the company commander of an infantry company that has been conducting continuous and sustained combat operations in the country of Rambada for the past 30 days in order to reestablish the legitimate Rambadan Government after the Revolutionary Forces of Rambada (ReFor) took control by force.

At present, your battalion is executing a blocking mission along a supply route, and your company's mission is to secure the town of Bulverde and the main road intersection nearby to ensure that the enemy is unable to resupply or reinforce the insurgent force operating in the town. After securing the main road intersection early this morning, you immediately established a checkpoint and defensive positions outside of the town.

It is now 0200, nearly 24 hours after you secured the intersection, and you decide to walk the defensive perimeter to check on your men. As you approach 1st Platoon's position, you hear laughing and yelling. You reach the source of the laughter and find dozens of beer cans scattered all over the area. It's obvious that your men are drunk. The platoon commander, 1stLt Jones, comes up, puts his arm around you and slurs, "Hey, shir, the men gots some beer from the town, how bouts yous join us for a drink?" Just as you open your mouth to unleash your fury, flares from the perimeter trip wire launch into the sky.

You collect your thoughts and begin to think about what to do next, when mortar rounds start to hit the deck and enemy machine guns open up on your position. Suddenly, you sit straight up on your cot with your heart racing and your shirt soaked from sweat. It was only a dream.

With the thoughts of that vivid dream still on your mind, your get out of your cot and decide to check on your men. This time, as you approach 1st Platoon's position, you're relieved to find everything is quiet and your men manning their positions. One by one, you talk to your men and ask them how they're doing. You also ask them how much rest they've gotten in the past week. While you're pleased to find that morale seems high and your men seem focused, you're a bit disturbed to learn that most of your men haven't slept for at least 36 hours. Your mind flashes back to your college days when your Human Performance professor told you that a person's performance after going 24 hours without sleep is equivalent to having a 0.10 Blood Alcohol Content (BAC) level and that going 48 hours without sleep equates to a 0.15 BAC level. Just as you wonder to yourself what the BAC equivalent is for 36 hours, flares from the trip wire launch skyward. What now, Captain?

While this TDG scenario may seem a bit extreme, it illustrates the seriousness of fatigue and sleep deprivation on the battlefield. While it is extremely unlikely for any military commander to send warfighters into battle intoxicated, it is very likely that commanders will send warfighters into battle with little or no rest. As we will see in our review of the literature in chapter 2, research has shown that the performance of individuals on cognitive psychomotor tasks after 24 hours of sustained wakefulness is equivalent to a BAC of 0.10 (Dawson & Reid, 1997). If, as the research suggests, human performance is significantly degraded such that performance is equivalent to that of an intoxicated person, then the consequences of a warfighter's inability to get adequate rest may potentially have strategic consequences. While this statement may seem counterintuitive initially, we only need to think of the potential actions of a soldier on patrol in an urban environment to recognize the validity of this statement. With Cable News Network (CNN) cameras following the military's every move in modern warfare, a warfighter who mistakenly shoots a civilian may find that the tragic accident has strategic consequences when it is broadcast worldwide. Since sleep deprivation has a significant impact on continuous and sustained operations, it seems fair to suggest, as most military doctrinal publications do, that commanders at all levels should consider implementing fatigue countermeasures and sleep management procedures because "sleep logistics" planning is an important factor to ensuring mission accomplishment and can potentially be a force multiplier on the battlefield. Perhaps, if military leaders at all levels seriously considered sleep and rest as required logistics for optimizing warfighter performance, and thus, a combat multiplier, perhaps we can significantly reduce the number of events with strategic consequences such as prison abuse scandals, friendly-fire incidents, and needless non-combat related deaths. In addition to the desire to minimize the number of incidents that have negative strategic consequences, it may be possible to consider sleep as a weapon. Specifically, when our combat forces are alert, clearly thinking, and reacting efficiently because they are sufficiently well rested, it is reasonable to assume that they would be able to outmaneuver and overwhelm sleep-deprived and fatigued enemy forces through superior cognitive skills.

B. BACKGROUND

On 19 March 2003, The President of The United States, George W. Bush, addressed the nation and announced the commencement of Operation Iraqi Freedom (OIF). On G-Day, 20 March, coalition forces crossed the borders of Iraq with the mission “to disarm Iraq, to free its people, and to defend the world from grave danger” (Bush, 19 March, 2003).

By G + 7, 27 March, major media were reporting that sleep deprivation and exhaustion in this high-stress environment were beginning to take a significant toll on coalition ground forces and that coalition forces were operationally paused due to the significant degradation of performance as a result of fatigue (Squeo & Kulish, March 27, 2003; Bebow, J., March 23, 2003; Givan, May 8, 2003; Crawley, March 29, 2003; Smith, March 27, 2003). On G + 10, 30 March, Army General Tommy Franks addressed concerns about an operational pause in the march to Baghdad as a result of fatigue by stating that forces were, in fact, not “paused,” but rather prepared to “continue to surprise the enemy by attacking at all times, day and night, all over the battlefield” (Garamone, 30 March, 2003). In fact, we know that coalition forces were able to accomplish extraordinary feats throughout the major combat phase of OIF. Despite the harsh desert environment, the lack of sleep, and the stress of combat, “Operation Iraqi Freedom was carried out with a combination of precision, and speed, and boldness the enemy did not expect, and the world had not seen before” (Bush, 1 May, 2003).

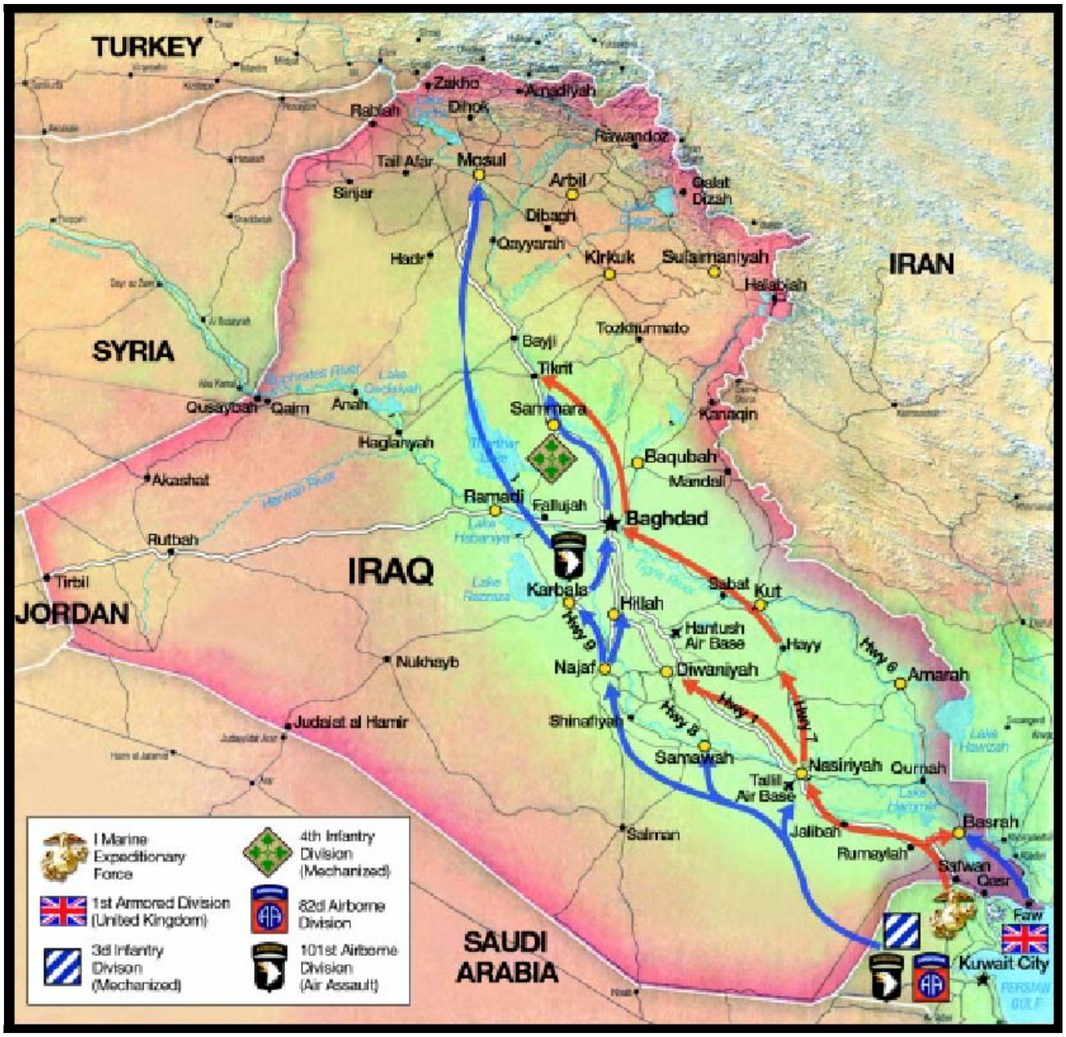

Figure 1. Map of OIF Area of Operation (From: Field Artillery, 2003).

Marine Corps Doctrinal Publication (MCDP) 1 (1997) states, “war is both timeless and ever changing. While the basic nature of war is constant, the means and methods we use evolve continuously.” We, as warfighters, must refine, expand, and improve the way we approach warfighting or we risk becoming “outdated, stagnant, and defeated” (MCDP 1, 1997). There is no question that the warfighters of OIF met every challenge, adapted to the combat environment, and superbly executed their mission. However, we must understand that with the advancement of technology on the battlefield, the future warfighter will face new and different challenges. One of the challenges facing today's warfighter, which must be understood and overcome in order to ensure the success of the future warfighter, is the effective use of sleep logistics on the battlefield. With the potential of one private's momentary lack of judgment due to fatigue or sleep deprivation having strategic consequences, commanders cannot afford to neglect the importance of sleep logistics.

While there is no question that the major combat phase of OIF was superbly executed, there are still significant lessons to be learned from OIF. A major lesson learned during OIF is that commanders must face the effects of sleep deprivation and deal with the importance of implementing sleep/rest plans during continuous and sustained operations. We know that sleep deprivation and fatigue can have deadly consequences for warfighters. One example of the deadly consequences of sleep deprivation was revealed when we learned that fatigue was a significant contributing factor to the capture of U.S. forces from the 507th Maintenance Battalion on 24 March 2003. As the details of that day came to light, we learned that vehicle drivers from the battalion were falling asleep during convoy operations and subsequently getting lost in the desert of Iraq only to later be ambushed and captured (U.S. Army, July 17, 2003). This thesis will address the concern that sleep deprivation seemed to be a growing threat to warfighters operating in Iraq (Squeo & Kulish, March 27,

2003) and discuss how we, as warfighters, might refine, expand, and improve in this area of warfighting to ensure victory on future battlefields.

C. OBJECTIVES

The purpose of this study is to collect and analyze data directly related to sleep patterns, fatigue issues, and predicted performance effectiveness of warfighters deployed to the Southwest Asia Area of Operation, specifically Iraq and Kuwait. This thesis addresses ways of improving our warfighter's ability to rest, function, and handle stress, which ultimately result in a warfighter's overall ability to accomplish the missions assigned. To this end, we collected subjective survey data from warfighters currently operating in Iraq and Kuwait. This survey included questions that focused on unit-level sleep plans, 24-hour sleep histories, 7-day sleep histories, potential confounding lifestyle factors, and other descriptive questions designed to give us a better understanding of the warfighter's sleep environment. The survey questions were designed to consider demands on troops operating in a combat environment, as well as to identify problems with a person's ability to recover from sleep deprivation. In order to study the effects of recovery from sleep deprivation, we collected survey data from military units that were previously operating under difficult sleep conditions, but which may have had the opportunity to fully recover from any sleep-related issues. Additionally, we used survey data from military units stationed in Kuwait as a base line for the study in order to quantify the differences of sleep patterns between personnel operating in Iraq and personnel operating in Kuwait.

D. PROBLEM STATEMENT

The primary questions investigated by this research are:

Question 1: Is sleep deprivation a significant problem for forces currently deployed to the SWA region?

Question 2: Do current sleep logistics of forces operating in SWA support a unit’s ability to accomplish assigned missions?

Question 3: Are there statistically significant differences in sleep patterns and predicted performance effectiveness between subset populations, such as units with clear sleep/rest plans, by location, by MOS, by rank, or by gender?

Question 4: Does the current survey method support research objectives?

This study provides military commanders with a better understanding of the sleep-related problems their units face and provides military commanders with recommendations for improving policies and procedures regarding sleep planning and sleep logistics.

E. SCOPE, LIMITATIONS, AND ASSUMPTIONS

Data collection for this thesis was limited to military personnel currently operating in Kuwait and Iraq on a strictly voluntary basis. The data were collected in a minimally invasive manner. While a simple random sample is the preferred sampling approach for most studies, participants for this observational study were sampled by convenience due to the nature of the environment. Specifically, leaders from military units throughout Iraq and Kuwait were asked if their units might be willing to participate in this study. If the unit leader provided consent, then individual members of that unit were asked to participate in the study. Participation in the observational study was strictly voluntary and included the completion of one survey. Detailed assumptions will be discussed when we report the results of the analysis in Chapter IV.

F. THESIS ORGANIZATION

Chapter II reviews the literature on the major concepts related to sleep deprivation and the performance of warfighters in combat environments. The methods used in this paper are presented in Chapter III. The results of our analysis are presented in Chapter IV. Finally, conclusions and recommendations, as well as potential follow-on research, will be presented in Chapter V.

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II. LITERATURE REVIEW

A. OVERVIEW

The purpose of this literature review is to gain insight into the current knowledge and understanding of the effects of fatigue, sleep deprivation, and related stressors on the performance of military personnel engaged in diverse military tasks. As stated by the Joint Chiefs of Staff in Joint Vision 2020 (2003, p. 1), "[t]he U.S. military today is a force of superbly trained men and women who are ready to deliver victory for our Nation. . . . and stands ready to respond across the full range of potential military operations." Since this full range, or spectrum, of potential military operations include complicated tasks such as non-combat humanitarian missions, peacekeeping missions, peace enforcement missions, and full-scale major conflict, we, as leaders, need to understand the role of fatigue on warfighter performance.

We know that war is ultimately a human enterprise portrayed as the clash of two opposing wills (Clausewitz, 1984). Therefore, as a human enterprise, it is often the individual human warfighter that is the source of friction on the battlefield since one wrong decision can have strategic implications and life-and-death consequences. During all stages of CONOPS/SUSOPS, the mental and physical fatigue of the individual warfighter must be taken into account in order to ensure success on the battlefield.

Extensive research has been done to assess the effects of fatigue on the performance of warfighters during CONOPS/SUSOPS. These studies thoroughly evaluate both the mental and physical fatigue of warfighters in order to quantify the performance effectiveness of an individual warfighter in a high-stress environment. Much of the research that has been done in this area of interest has been collected, reviewed, and summarized in detailed, unclassified, and publicly accessible reports for the U.S. Army Research Institute (Evans et al., 1991), Walter Reed Army Institute of Research (Belenky et al., 1987), and the Office of Naval Research (Woodward & Nelson, 1974). These literature reviews thoroughly summarize the hypotheses, conclusions, and recommendations of a wide range of studies on the effects of fatigue, sleep-loss, and CONOPS/SUSOPS on individual and unit performance. Rather than duplicating those literature reviews here, we will focus this review on the findings and opinions of experts regarding the overall importance of sleep, the effects of fatigue on warfighter performance, and the ability to model human performance as a function of sleep-wake history.

B. THE IMPORTANCE OF SLEEP

According to the National Sleep Foundation (2000), sleep is essential for good health and mental functioning. Sleep is a basic necessity of life, as important to our health as air, food, and water. Getting enough continuous quality sleep contributes to how we feel and how we perform. Sleep also has a huge impact on the overall quality of our lives. While the need for sleep may vary by individual, researchers believe that in general, most healthy adults need between seven and nine hours of sleep per night. The normal human sleep cycle, or “sleep architecture” (Chokroverty, 2000, p. 1), is a mix of Rapid Eye Movement (REM) sleep and non-REM sleep. As we sleep, we pass through different states and stages of sleep. These predictable sleep cycles that make up our total sleep architecture alternate approximately every 90 minutes.

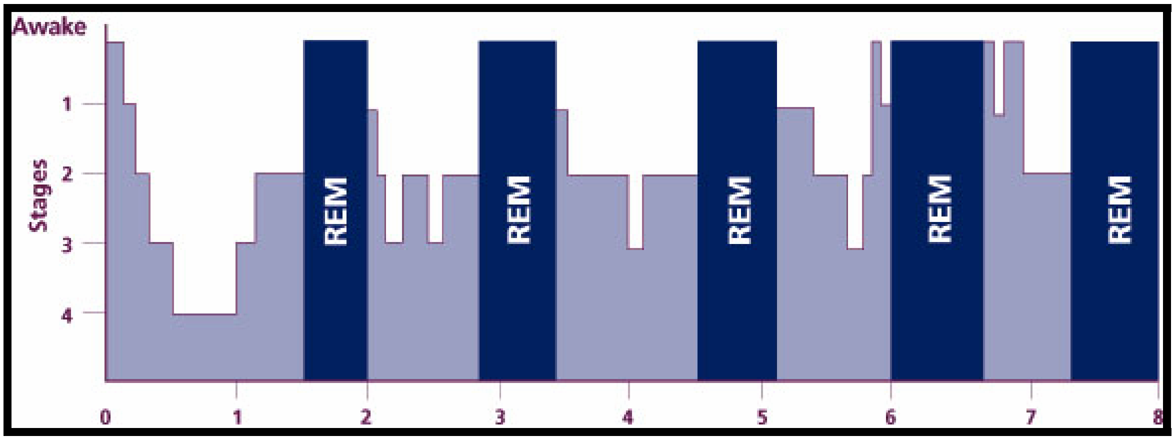

Figure 2. The Sleep Architecture (From: NSF, 2003).

Warfighters are faced with multiple confounding factors to healthy sleep architecture, such as stress, alcohol, using caffeine too close to bedtime, working out too close to bedtime, irregular work schedules, environmental interferences, medications, and physical factors such as pain and discomfort. While we will review the significance of these lifestyle factors in greater depth later, it is important to understand that these confounding factors can disrupt an individual's sleep architecture and may adversely affect the individual's health and mental functioning (McCallum et al., 2003).

While the specific function of sleep remains obscure, many researchers agree with Dr. James Maas (2001, p. 26), that, "[r]ather than being a vast wasteland of monotonous inertness, sleep is a diverse, complex, multifaceted series of stages that make important contributions to our daytime functioning." Some of the benefits of sleep may seem obvious and others may not seem quite so obvious, but the theories regarding the function of sleep that seem to be universally found throughout the literature include physical and psychological rest, growth and repair of muscle and organ tissue, enhancing the body's immune responses, conservation of physical and mental energy, reinforcement and consolidation of memory functions, maintenance of mental and physical health, and to maintain our body's natural biological rhythm (Maas, 2001; Moore-Ede & LeVert, 1998; Dement & Vaughan, 1999; Chokroverty, 2000; Borbely & Tobler, 1989).

1. Non-Rapid Eye Movement (NREM) Sleep

The literature shows that researchers are in agreement that healthy adults generally spend 75% of their sleep in NREM sleep, which is composed of four stages. We will briefly summarize the characteristics of these four stages.

Stage 1 sleep is considered light sleep and is described as the period between being awake and entering sleep. During this stage, the individual maintains an awareness of the environment and can still respond quickly to situations. This stage can last from ten seconds to ten minutes and it is during this stage that the muscles and breathing rate begin to relax. As a result of the sudden relaxation of the body, individuals might experience a sensation of falling, causing a sudden jerk into wakefulness (Maas, 2001; NSF, 2003, Moore-Ede & LeVert, 1998).

Stage 2 sleep is characterized as the onset of sleep. That is, it is believed that this is the stage where the individual clearly disengages from the environment and becomes blind and deaf to most outside stimulation. During this stage, the individual's body temperature decreases, and breathing and heart rate become regular. In general, this stage lasts between 10 and 20 minutes (Maas, 2001; NSF, 2003, Moore-Ede & LeVert, 1998).

Stage 3 and stage 4 sleep are the deepest and most restorative sleep stages. It is during these stages that growth hormones are released for restoration and development of the body; also the individual's breathing becomes slower and the blood pressure lowers. It is believed that the individual's energy is regained during these stages of sleep (Maas, 2001; NSF, 2003, Moore-Ede & LeVert, 1998).

It is during this deep sleep that we are most vulnerable. If an individual is awakened during these stages of sleep, they generally feel mentally groggy and usually need several minutes in order to regain situational awareness. This groggy and disorienting feeling is commonly referred to as sleep inertia (Maas, 2001; NSF, 2003, Moore-Ede & LeVert, 1998).

2. Rapid Eye Movement (REM) Sleep

After an individual has been asleep for approximately 90 minutes, he or she begins to awaken from deep sleep and pass back through stage 2 sleep to a state similar to wakefulness. Instead of returning to the light sleep of stage 1, the sleeper passes into an active stage known as Rapid Eye Movement (REM) sleep. In REM sleep, the nervous system is significantly active, blood flow is increased to the brain, pulse, respiration, and blood pressure increase, and body temperature rises. It is also during this stage that the eyes begin to rapidly dart back and forth, hence the name rapid eye movement. Researchers believe that this stage of sleep is necessary for providing energy to the brain and body, effecting daytime performance and memory consolidation (Maas, 2001; NSF, 2003, Moore-Ede & LeVert, 1998).

Sleep architecture consists of several cycles through these stages of sleep, which generally last approximately 90 minutes each. As shown in Figure 2, the amount of time spent in each stage of sleep varies throughout the course of sleep. Typically, we get most of our stage 3 and stage 4 sleep early in our sleep, and we get most of our REM sleep during the latter part of our sleep. Therefore, if we have a short night of sleep, we are eliminating a significant amount of REM sleep, which is believed to have serious consequences for learning, thinking, memory, and performance (Maas, 2001; NSF, 2003, Moore-Ede & LeVert, 1998).

3. The Circadian Rhythm

The term circadian is derived from the Latin *circa*, meaning “around” and *dies*, meaning “a day” (Maas, 2001) and refers to the natural 24- to 25-hour rhythm that acts as a biological clock to control sleep and wakefulness in all humans (Chokroverty, 2000; Dement & Vaughan, 1999). Research suggests that this biological clock regulates a number of physiological functions, such as body temperature, hormone secretion, heart rate, blood pressure, respiration, digestion, and mental alertness (Czeisler et al., 1980; Maas, 2001; Moore-Ede & LeVert, 1998; Dement & Vaughan, 1999).

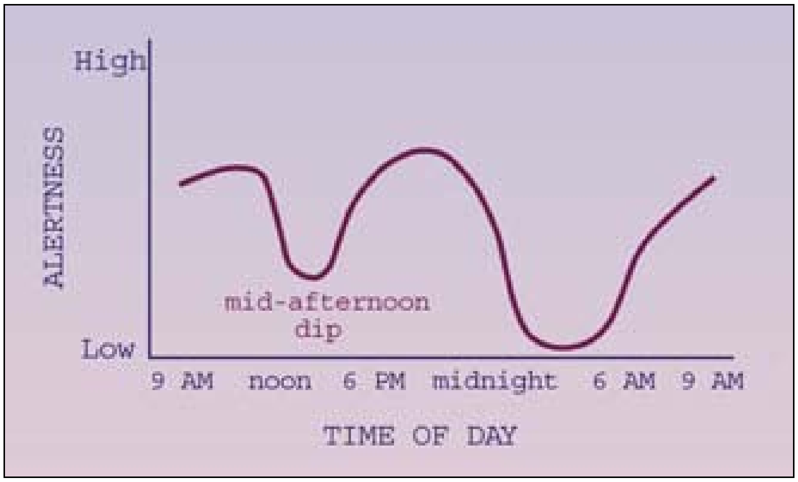

Figure 3. The Circadian Rhythm (From: NSF, 2003).

As shown in Figure 3, the circadian rhythm has two peaks and two troughs throughout the normal 24-hour day. A peak in the circadian rhythm corresponds to a period when the individual is the most awake and has the highest level of mental alertness. A trough in the circadian rhythm corresponds to a period when the individual is the sleepiest and has a low level of mental alertness. The first peak in alertness usually occurs around 0800 or 0900 and then again around 1900 or 2000. The lowest point of alertness occurs around 0300 to 0400 and a lesser low point occurs in the afternoon around 1300 to 1400. While afternoon sleepiness may often occur immediately after eating lunch, it is not a result of eating a large lunch. While the meal may be an aggravating factor, this feeling of sleepiness is the result of the body reaching a natural low point in the circadian rhythm (Maas, 2001; NSF, 2003, Moore-Ede & LeVert, 1998).

An individual’s natural circadian rhythm can be disrupted when he or she is required to be awake during unconventional hours (e.g. 2200 – 0600), as is regularly required during CONOPS/SUSOPS. These changes in sleep patterns can cause a disruption to the natural circadian rhythm, which in turn causes the natural circadian rhythm to shift in order to meet the new sleep patterns. However, this circadian shift does not occur easily and some people feel the ill effects of such a shift almost immediately. These negative effects include increased fatigue, mood deterioration, decreased performance, and possible long-term health consequences (Costa, 1996; Moore-Ede & LeVert, 1998).

Not every person has the exact same circadian rhythm, and not every person is able to adapt their circadian rhythm to match a work schedule that has them working late at night. Individuals who feel their best in the hours after noon and into the night are characterized as evening people, or “owls,” whereas individuals who feel their best in the early morning are characterized as morning people, or “larks.” Those individuals who have fairly flexible sleep patterns, and who can adapt fairly easily to changes in their schedules, are referred to as “robins” (Moore-Ede & LeVert, 1998, pp. 55-59). In addition to having distinct chronotypes or sleep personalities, some individuals are less able to adapt to changes in sleep patterns than others. This sleep personality (lark, owl, or robin) and flexibility type (flexible, regular, or rigid) together form an individual’s “Circadian Profile” (Moore-Ede & LeVert, 1998, p. 57).

C. FATIGUE AND PERFORMANCE

Now that we have a basic understanding of sleep, sleep personalities, and the importance of sleep, we will now turn our attention to the affects of fatigue on performance. While this research and associated literature review focus on the warfighter's performance during continuous combat operations (CONOPS) and sustained combat operations (SUSOPS), we can apply this research across the spectrum of military operations.

In order to understand the warfighter's performance during CONOPS/SUSOPS, we first need to consider some of the combat-related tasks required of the warfighter. Marine Corps Reference Publication (MCRP) 6-11C (2000) outlines some of the general tasks encountered by a majority of the warfighters throughout the battlefield that are not necessarily dependent on military occupational specialty (MOS). These tasks include (MCRP 6-11C, 2000, pp. 57-58):

- Orientation with friendly and enemy forces, which includes knowledge of a unit's location and maintaining camouflage, cover, and concealment.

- Coordination and information processing, which includes coordinating firing with other vehicles and/or dismounted elements, reporting vehicle readiness, and communicating with headquarters elements.

- Combat activities such as firing from bounding vehicles, checking the condition of weapons, and observing the terrain for enemy presence.

- Force preservation and regrouping, which includes covering disengaging units, marking routes between locations, and conducting reconnaissance.

- Command and control activities such as directing location repositioning, directing mounted defense, and assigning firing zones and targets.

While the list of tasks outlined above is not all-inclusive, it is clear that warfighters must perform mental and physical tasks that require concentration, attention, vigilance, and quick reaction or response time. The literature reviewed universally shows that sleep loss, and the resultant mental and physical fatigue on the human system, can significantly impact the warfighter's performance effectiveness in each of the task areas mentioned.

The effects of sleep loss on human performance are clearly outlined in publications and manuals used by the U.S. Army (FM 90-44/6-22.5, 2000), U.S. Marine Corps (MCRP 6-11C, 2000), and the U.S. Navy (NTTP 1-15M, 2000), to provide small-unit leaders the tactics, techniques, and procedures for preventing, identifying, and managing combat stress. They state that sleep loss affects memory, reasoning, mental assessments, decision-making, problem-solving, and overall effectiveness. These claims are based on the extensive research, and numerous studies, done on human performance during combat-like conditions.

One such study, conducted by Ainsworth and Bishop (1971), measured the effectiveness of tank crews during 48-hour periods of sustained field activities. The authors concluded that activities demanding high levels of alertness or complex perceptual motor activity were the most sensitive to sleep loss (Ainsworth & Bishop, 1971).

Another study, conducted by Agnus and Heslegrave (1985), measured the effects of sleep loss on sustained cognitive performance during command and control simulations. The authors reported significant degradation in logical reasoning, auditory vigilance, reaction time, and overall performance as a result of prolonged sleep loss (Agnus & Heslegrave, 1985).

A further study, conducted by Haslam (1981), measured the performance effectiveness of soldiers during continuous operations. In this study, all of the participants who were designated to stay awake continuously withdrew from the study after four nights. The author found that there was rapid deterioration in vigilance and performance on cognitive tasks over a 4-day period of receiving no more than 3 hours of sleep per night. Haslam concludes that even small amounts of sleep were beneficial to the soldiers with respect to performance (Haslam, 1981).

Finally, another study, conducted by Naitoh, Englund, and Ryman (1987), measured the performance of Marines conducting reconnaissance missions during simulated SUSOPS conditions. The authors reported that mission start times had a major effect on the Marine’s performance throughout the mission and that allowing only 3-4 hours of sleep resulted in a 30% degradation of performance during a second 20-hour continuous work episode compared to the baseline (Naitoh et al., 1987).

It seems clear from the research mentioned above, and from the numerous similar studies reviewed, that sleep loss negatively affects warfighter performance. While this information is important, it does not clearly stress the seriousness of the problem. Therefore, we will look at fairly recent research that has compared the performance of a sleep-deprived person with the performance of an intoxicated person. Several researchers, such as Dement and Vaughan (1999), Dawson and Reid (1997), and Roehrs et al. (1994), have conducted studies that have looked at this very issue. They have reported similar findings, which suggest that drowsy driving is just as dangerous as driving while intoxicated because the cognitive psychomotor performance of an individual with sleep loss is similar to that of an intoxicated person. Specifically, when subjects were kept awake for 17 hours, their performance on a cognitive psychomotor test was the same as that of a rested person with a blood alcohol concentration (BAC) of 0.05 percent. At 24 hours of sustained wakefulness, the performance on the psychomotor test was equivalent to that of a rested person with a BAC of 0.10 percent, which is the legal limit for drunken driving in all of the U.S. states (Dawson & Reid, 1997). Moreover, sleepiness has been shown to exacerbate the sedating effects of alcohol so that even low levels of alcohol make the sleepy driver much more impaired and much more likely to fall asleep at the wheel (NHTSA, 1998; Roehrs et al., 1994; Dement and Vaughan, 1999). When we consider that a person performs as though drunk when sleep deprived, the seriousness of fatigue on our warfighters becomes clear.

D. FATIGUE COUNTERMEASURES

The literature clearly shows that the cognitive abilities required of warfighters during CONOPS/SUSOPS, such as comprehension, perception, vigilance, attention, and concentration, are significantly degraded by sleep loss. In general, warfighters can maintain combat-effective cognitive performance: indefinitely when they receive six to eight hours of sleep each night; five to six days on three to four hours of sleep per night; and two to three days with little (less than three hours per night) to no sleep.

Of course, there are significant tactical, operational, and strategic risks when warfighters' cognitive performance falls below accepted militarily effective levels. In order for warfighters to remain combat effective, leaders should consider implementing as many of the known fatigue countermeasures as possible in their sleep logistics planning. The more common fatigue countermeasures are outlined in this section and listed in Table 1.

FATIGUE COUNTERMEASURES

- Unit organization and staffing
- Sleep personalities
- Training and preparation
- Work/rest schedules and sleep discipline plans
- Sleep environment
- Napping
- Stand-to procedures
- Caffeine
- Performance-enhancing medications and supplements
- Sleep-aid medications and supplements

Table 1. Commonly referenced Fatigue Countermeasures (After: Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987; McCallum et al., 2003; Folkard, 1990; Zarcone, 2000; De Valck & Cluydts, 2001; Dement & Vaughan, 1999; Babkoff & Krueger, 1992; Mitler & Aldrich, 2000; Ramsey & McGlohn, 1997; Roehrs & Roth, 2000; Moore-Ede & LeVert, 1998; Maas, 2001).

1. Unit Organization and Staffing Principles

One critical method to counter the problem of sleep lost is staffing units with sufficient personnel to provide redundancy and to allow warfighters to work in shifts. Units should increase staffing in areas known to have shortfalls for CONOPS. Reserve units should be allowed sufficient recovery from sleep loss and should only be used when absolutely required (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987).

It is incumbent upon unit leaders to: identify those positions in which personnel are most likely to suffer sleep deprivation during CONOPS/SUSOPS and adapt adequate manning doctrine, over-learning, and cross-training to reduce the impact of continuous battle upon these personnel; rotate cross-trained personnel can reduce performance deterioration by relieving some effects of fatigue, visual strain, and alertness; and further, mix rested and unrested warfighters may be useful during CONOPS in order to ensure accuracy and completeness of tasks by reducing the likelihood that two members of a unit will become sleepy or make the same mistake at exactly the same time (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987).

One of the most critical positions on the battlefield requiring maximum cognitive performance is the unit commander. It has been suggested that commanders have a moral obligation to ensure that the decisions they make are not degraded due to sleep loss (Shay, 1998). Commanders should consider appointing a Second-in-Command for SUSOPS so that the battle can be conducted without interruption while the commander gets rest (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987).

2. Sleep Personalities

Since individuals have different chronotypes of circadian profiles, consideration should be given to identifying and selecting personnel who prefer and are able to adapt to different shift work schedules and then honoring such preferences. For example, it makes intuitive sense to have “owls” work at night and “larks” work during the day (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987; McCallum et al., 2003; Folkard, 1990). Therefore, according to Folkard (1990, p. 551), during situations where safety is paramount, it seems reasonable that we might consider creating a “nocturnal sub-society that not only works at night but also remains on a nocturnal routine on rest days.” This nocturnal sub-society would then be well adapted for working during time periods that would normally be low points in the circadian rhythm.

3. Training and Preparation

Units should train as they plan to fight. That is, training should include CONOPS and SUSOPS conditions so all personnel will recognize the effects of sleep loss, their own responses to sleep loss, and the responses of others. In keeping with the motto “train as you fight,” commanders should also implement sleep logistics into their training programs to condition personnel to properly plan for and combat sleep-loss effects (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987).

The research suggests that performance deterioration is inevitable during sleep loss, but the degree of deterioration may be significantly less when tasks are over-learned and responses become almost automatic. Finally, personnel should be cross-trained to take over other crewmembers’ tasks in order to adequately rotate personnel for rest (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987).

4. Work/Rest Schedules and Sleep Discipline Plans

Sleep is the only sure way to mitigate the deterioration of performance effectiveness caused by sleep loss. Therefore, commanders and leaders at all levels should develop and distribute detailed work/rest schedules and sleep discipline plans. Commanders and leaders must supervise their units to ensure that the schedules and plans are being adhered to. Equally important, leaders must set the example and adhere to the schedules and plans themselves to ensure they maintain their performance effectiveness (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987).

Work/rest plans should recognize circadian factors by anticipating performance lulls from 0300-0600 (regardless of shift rotation schedules) and avoiding circadian desynchronization. When planning to work in shifts, commanders should be aware that rapidly rotating shifts could force an individual warfighter’s natural biological clock to desynchronize from the 24-hour day. The “12-hours on/12-hours off” shift rotation is the best shift for avoiding circadian desynchronization, but may be difficult to implement for some ground combat forces. Therefore, the “4-hours on/4-hours off” shift schedule should be considered the next best option since it can be well maintained in terms of performance decrement for periods greater than 2 weeks and up to 30 days (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987).

When SUSOPS conditions are expected, leaders should try to allow warfighters 12 hours of duty-free time immediately preceding SUSOPS for rest and sleep. While research suggests that sleep cannot be stored up, the onset of performance degradation can be delayed by ensuring that warfighters are starting SUSOPS at a maximal performance level (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987).

Ideally, warfighters should get 6-8 hours of continuous sleep per 24-hour period in order to sustain performance indefinitely. At a minimum, warfighters should get 4-5 hours of sleep per 24-hour period, preferably in a single, continuous period. While the warfighter's performance effectiveness will be significantly lower than that of a well-rested warfighter, research suggests that the performance degradation reaches equilibrium around 4.5 hours of sleep per 24-hour period (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987).

In order to help implement work/rest schedules on the battlefield, we will look at scheduling tools available to commanders later in this chapter and in chapter III.

5. Sleep Environment

A good sleeping environment is the foundation for restorative sleep. While warfighters will sleep in almost any environment and in almost any location, commanders and leaders should attempt to provide a good sleeping environment whenever possible. In order for a sleep environment to promote restorative sleep, it must be quiet, dark, and comfortable. The bottom line is that the sleep environment is for sleep, not for holding meetings, playing cards, listening to music, or other distracting activities.

Some common techniques employed to ensure a quiet sleep environment include: using earplugs; using a constant low-level noise source, or "white noise," such as a fan; and using name cards on cots to avoid unnecessary disruptions during sleep, such as being awakened to questions like, "Where is Private Jones?"

Sunlight and other sources of light can affect sleep by disrupting the secretion of melatonin in the body. We will discuss the role of melatonin in greater detail later in this section, but it is important to note that low levels of the melatonin hormone in the body trigger the individual to wake up. Therefore, ensuring a dark sleeping environment is a key component to restorative sleep. Some common techniques to ensure a dark sleep environment include: issuing eye shades; using black out shades over windows; using heavy dark fabric for curtains; and placing shutters over windows.

Finally, the last component to a good sleep environment is comfort. Comfort is affected by temperature and the quality of the individual's sleeping arrangement. While not always practical, commanders and leaders should try to provide warfighters with sleeping accommodations, such as tents or designated structures that have cots with mattresses or beds. Ideally, these sleeping accommodations should have air conditioners or heating units, depending on the situation (McCallum et al., 2003; Zarcone, 2000).

6. Napping

According to the literature, unit leaders should optimize the timing and duration of naps during CONOPS in order to make the most of sleep opportunities. Research suggests that even small amounts of sleep can substantially improve performance and mood. Therefore, warfighters should be encouraged to nap whenever practical regardless of the time of day. While sleep inertia may cause the warfighter to initially feel groggy immediately after waking up, naps can significantly improve warfighter performance, especially when taken during circadian lulls (0300-0600, 1300-1400). In order to reduce the impact of sleep inertia, the length of a nap should coincide with the natural sleep architecture. The bottom line is that we want to wake the individual up from a nap either before he or she enters deep sleep or after the sleep cycle has passed through deep sleep. Naps that last between 15-30 minutes, 2 hours, and 3-4 hours in length keep the warfighter from waking up during stages of deep sleep. However, since naps can significantly improve performance effectiveness regardless of length, naps should not be avoided simply to avoid sleep inertia (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987; McCallum et al., 2003).

7. Stand-To Procedures

Military units go to “stand-to,” or 100% alert, for approximately one hour around sunset and one hour around sunrise because enemy units historically attack at these time. However, depending on the situation, commanders may want to consider modified stand-to procedures to maximize the ability to recover from sleep loss while minimizing the risk to the force (Belenky et al., 1987; Evans et al., 1991; Naitoh et al., 1987).

8. Caffeine

One of the most commonly used fatigue countermeasures is caffeine. While caffeine is usually consumed by drinking coffee, tea, or soda, caffeine is available in tablet form, such as NoDoz and Vivarin, and in chewing gum form. Caffeine typically affects the nervous system within

15-20 minutes and the effects include rapid heart rate and increased alertness. The metabolic half-life[1] of caffeine ranges from 2.5 to 7 hours. Therefore, depending on the amount of caffeine consumed, the effects typically last 4-5 hours. Depending on the sensitivity of the individual, however, these effects may last up to 10 hours (Tharion et al., 2003; Lieberman et al., 2002).

Our bodies gradually build up tolerance to repeated consumption of high levels of caffeine, so it is important to use caffeine only as a short-term way to boost alertness. Due to the lasting effect of caffeine, it should not be consumed too close to when a warfighter wants to sleep (McCallum et al., 2003; De Valck & Cluydts, 2001; Dement & Vaughan, 1999).

9. Performance-Enhancing Medications and Supplements

Performance-enhancing stimulants may be used as a fatigue countermeasure during periods when sleep may not be possible for extended periods, such as CONOPS/SUSOPS. In general, there are two types of stimulants: controlled medications (such as modafinil and dextroamphetamine) and herbal stimulants (such as ephedra). Stimulants can increase attentiveness and alertness, but may not prevent the onset of sleep when an individual has the opportunity to sleep. Further, stimulants may reduce the need for sleep while maintaining normal alertness levels when sleep is limited. However, current research suggests that the benefits of these stimulants are limited because using them

[1] The metabolic half-life is the time it takes for half of the dosage to disintegrate. For example, if we consume 200 mg of caffeine and assume a metabolic half-life of 4 hrs, then 100 mg of caffeine remains in our system 4hrs after consumption.

can lead to rebound fatigue once use is discontinued. Finally, while these stimulants may restore alertness and motivation, they can impair judgment (McCallum et al., 2003; Babkoff & Krueger, 1992; Mitler & Aldrich, 2000).

Stimulant medications, such as modafinil[2] and dextroamphetamine[3], are controlled substances that reduce the effects of sleep loss by increasing alertness and enhancing performance in sleep-deprived individuals. Since these stimulants are controlled substances, they require a physician’s prescription and can have unwanted and dangerous side effects, including changes in blood pressure and pulse, headaches, irritability, insomnia, and nervousness. Stimulants have a high potential for addiction and abuse and should only be considered as a possible fatigue countermeasure with a physician’s supervision.

Herbal stimulants are becoming increasingly popular to counter sleep deprivation, but they are not regulated, and the effects of many of those supplements are not known because of insufficient evaluation. We do know that ephedra is associated with heart attack and stroke and should not be used by warfighters. As in the case of controlled stimulants, herbal stimulants should not be considered as a fatigue countermeasure without the approval of medical personnel.

[2] Commercial drug names for modafinial include Provigil, Alertec, Modiodal, and Vigicer.

[3] Commercial drug names for dextroamphetamine include Dexedrine, Desoxyn, Dextrostat, and Ferndex.

10. Sleep-Aid Medications and Supplements

Hypnotic medications such as temazepam[4], zaleplon[5], and zolpidem[6] promote sleep. These drugs reduce the amount of time required to fall asleep and can keep an individual asleep for 7-8 hours. Hypnotics may be useful fatigue countermeasures when warfighters experience difficulty sleeping because of things like shift changes, jet lag, or stress-related, short-term insomnia, but it is possible to develop a dependence on hypnotics if used for extended periods. Additionally, these drugs may cause users to feel sluggish the following day and warfighters may experience increased difficulty sleeping 1-2 days after discontinuing use. Therefore, hypnotics should only be used when prescribed by a physician, and for the shortest amount of time necessary to overcome sleeplessness. Current research is ongoing in the pursuit of hypnotics that can induce brief, restful sleep during short periods, or lulls, without the side effects of feeling groggy the following day (Ramsey & McGlohn, 1997; McCallum et al., 2003; Roehrs & Roth, 2000).

Another potential sleep aid is melatonin. Melatonin supplements, which are widely available without a prescription in capsule, tablet, or liquid form, may help to aid sleep and reset the body's biological clock after circadian desynchronization (e.g. jet lag). Melatonin is a natural hormone that is a key component to the sleep/wake cycle. The secretion of melatonin from the pineal gland, located in the brain, sets the stage for sleep. That is, as the body temperature falls, the level of melatonin

[4] The commercial drug name for temazepam is Restoril.

[5] The commercial drug name for zaleplon is Sonata.

[6] The commercial drug name for zolpidem is Ambien.

rises, and we begin to feel sleepy. Then, as the body temperature rises, melatonin levels fall, and we wake up. In humans, melatonin is almost exclusively released during periods of darkness. Typically, melatonin levels are at their lowest levels during the day, increase during the evening hours, and peak in the middle of the night. Therefore, melatonin supplements may help reset the body’s biological clock by triggering the sleep response in the brain at a different time than it would normally occur. Additionally, melatonin supplements may promote sleep by acting as an immediate sleep aid when taken prior to the time an individual wants to sleep. The current recommended dosage of melatonin is 1 mg, and the effects on individuals vary: some people find that melatonin helps them fall asleep and stay asleep; some experience no effect; others find that it makes them feel groggy the next day; and others have reported that melatonin causes them to feel agitated and anxious. A thorough exploration of melatonin’s potential long-term side effects has not yet been completed, so commanders should talk to medical personnel prior to using, or encouraging the use of, melatonin (Paul et al., 2004; Caldwell, 2000; Moore-Ede & LeVert, 1998; Maas, 2001; McCallum et al., 2003; Comperatore et al., 1996).

E. MODELING PERFORMANCE EFFECTIVENESS

From the studies previously mentioned, along with numerous others, it is well established that fatigue significantly degrades human performance. Since the first published experimental study of sleep deprivation and human cognitive performance (Patrick & Gilbert, 1896), researches have used many types of performance tests to measure the effects of sleep loss on cognitive functioning. One common testing approach is the “stimulus-response” (S-R) method (Dorrian et al., 2004). The S-R method requires a timely response from the experimental subject to the presentation of visual or auditory stimuli. Researchers then compare the timeliness of well-rested subjects with that of sleep-deprived subjects to study sustained attention vigilance performance. Current research uses psychomotor vigilance tasks (PVT) to provide an accurate and useful measure of performance during sleep loss. The PVT was developed to assess the cognitive processes used to sustain attention over the course of an individual’s circadian rhythm. Dorrian, Rogers, and Dinges (2004) explain that the PVT measures reaction time (in milliseconds) to a small, bright red light stimulus by pressing a response button as soon as the stimulus appears. Since the PVT is simple to perform, it has a minor learning curve, which makes it a preferred test to others that take several trials to learn. Due to the sensitivity of the test, the PVT is extremely useful for assessing the success of fatigue countermeasures, such as napping, different work-rest schedules, and performance-stimulating medications. The PVT provides objective, statistically reliable, and theoretically validated performance scores used to capture the effects of sleep loss on the cognitive processes (Dorrian et al., 2004).

Using the PVT, polysomnography, actual duration of nighttime sleep, sleep latency tests, and subjective alertness/sleepiness scales, researchers at Walter Reed Army Institute of Research conducted a sleep dose-response study to assess the patterns of performance degradation and restoration during sleep restriction and subsequent recovery (Belenky et al., 2003). Sixty-six volunteers spent either 3 (n = 18), 5 (n = 16), 7 (n = 16), or 9 hours (n = 16) in bed per day for 7 days (restriction/augmentation) followed by 3 days with 8 hours in bed per day (recovery). The purpose of the sleep dose-response study was to determine empirically the effects of several levels of restricted sleep (3, 5, or 7 hours) and one level of augmented sleep (9 hours) over 7 consecutive days on objective performance, and to determine the extent to which 3 days of subsequent recovery sleep restored performance and alertness to the baseline levels (Belenky et al., 2003). Figure 4 shows the experimental design of the study across 13 days.

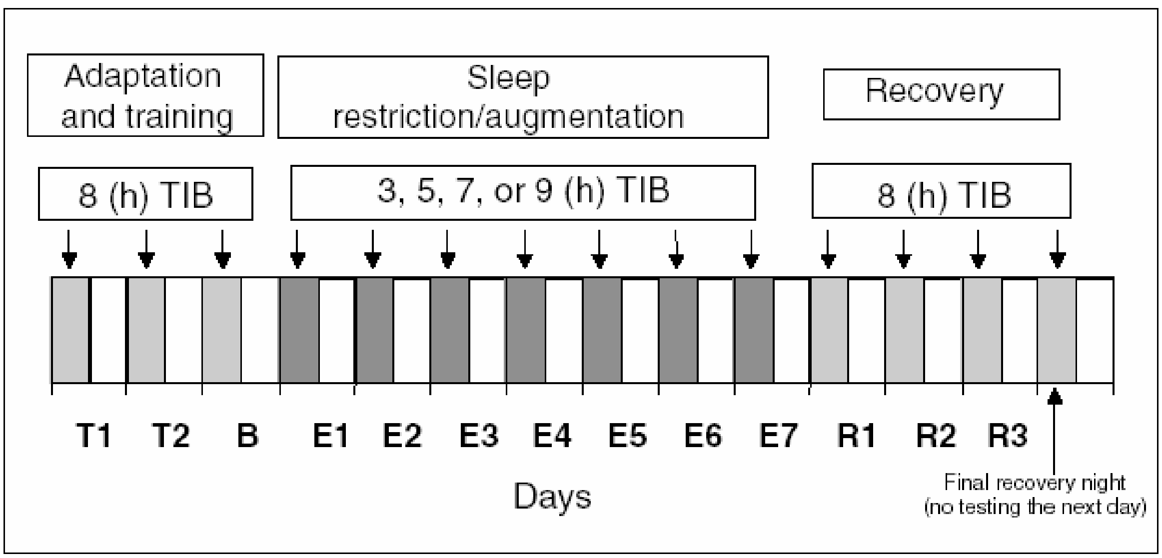

Figure 4. Experimental design (From: Belenky et al., 2003).

Figure 5 shows the mean psychomotor vigilance task speed (and standard error) across days as a function of time in bed. Belenky et al. (2003) observed that with mild to moderate sleep restriction (7- and 5-hours), performance initially declined and then appears to stabilize at a level significantly lower than the baseline. In contrast, performance declined continuously, with no apparent stabilization, for the group suffering from severe sleep restriction (3-hours).

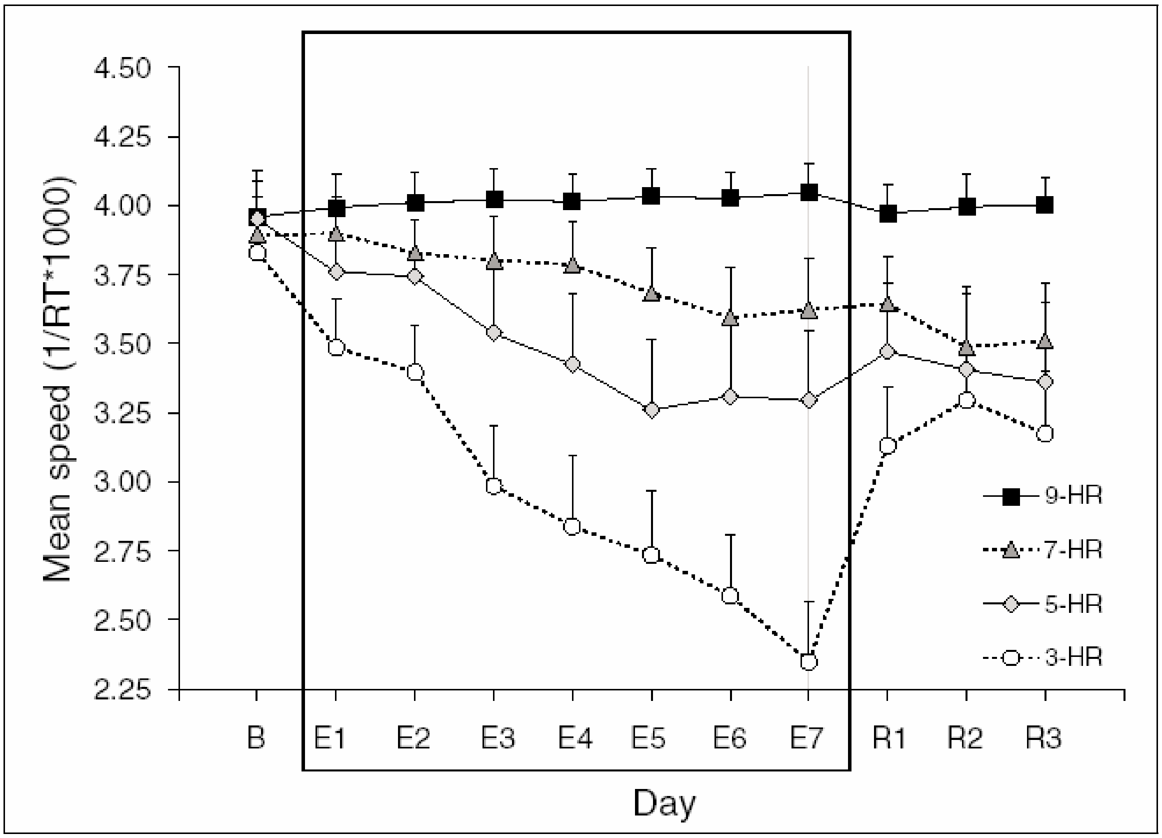

Figure 5. WRAIR study results (From: Belenky et al., 2003).

Based on the findings of this study, Belenky et al. concluded that the minimum amount of nightly sleep required to achieve a state of equilibrium in which daytime alertness and performance can be maintained at a stable, albeit reduced, level is approximately 4.5 hours per night.

Using the results of the WRAIR study, researchers have been able to formulate mathematical models to predict alertness and performance effectiveness from preceding sleep-wake history (Hursh, 2004; Dijk & Larkin, 2004). These models typically involve three parameters. The first parameter is *sleep homeostasis*. Sleep homeostasis is the physiological process in each of us that strives to obtain the amount of sleep needed to provide for a stable level of daytime alertness. Simply put, this parameter measures the how long we have been awake, since the longer we stay awake, the stronger the desire to go to sleep. The second parameter is our natural circadian rhythm, which adds a time-of-day effect to our performance model. Finally, the third parameter is sleep inertia. Sleep inertia is the feeling of grogginess when we are awakened from a deep sleep. Sleep inertia usually lasts about 30 minutes and may include feelings of paralysis in the arms and legs, blurred vision, and difficulty concentrating. This parameter allows us to capture the temporary degradation in performance immediately following a nap or after being awakened from a deep sleep.

Research teams at WRAIR, the Naval Health Research Center (NHRC), the Air Force Research Laboratory (AFRL), and the U.S. Army Aviation Research Laboratory (USAARL) continue to pursue an accurate model of fatigue related impairment of cognitive readiness. Currently, the most widely used model is the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) Model developed by Dr. Steve Hursh at Scientific Applications International Corp (SAIC) with support from WRAIR and AFRL. The SAFTE model, whose conceptual architecture is shown in Figure 6, evolved from the three-parameter models previously mentioned; it is a useful tool because it accurately models performance effectiveness as a function of the circadian process, sleep inertia, and the homeostatic process. Further, the SAFTE Model can be used to predict cognitive throughput and average psychomotor vigilance speed during restricted sleep duration over 7 days.

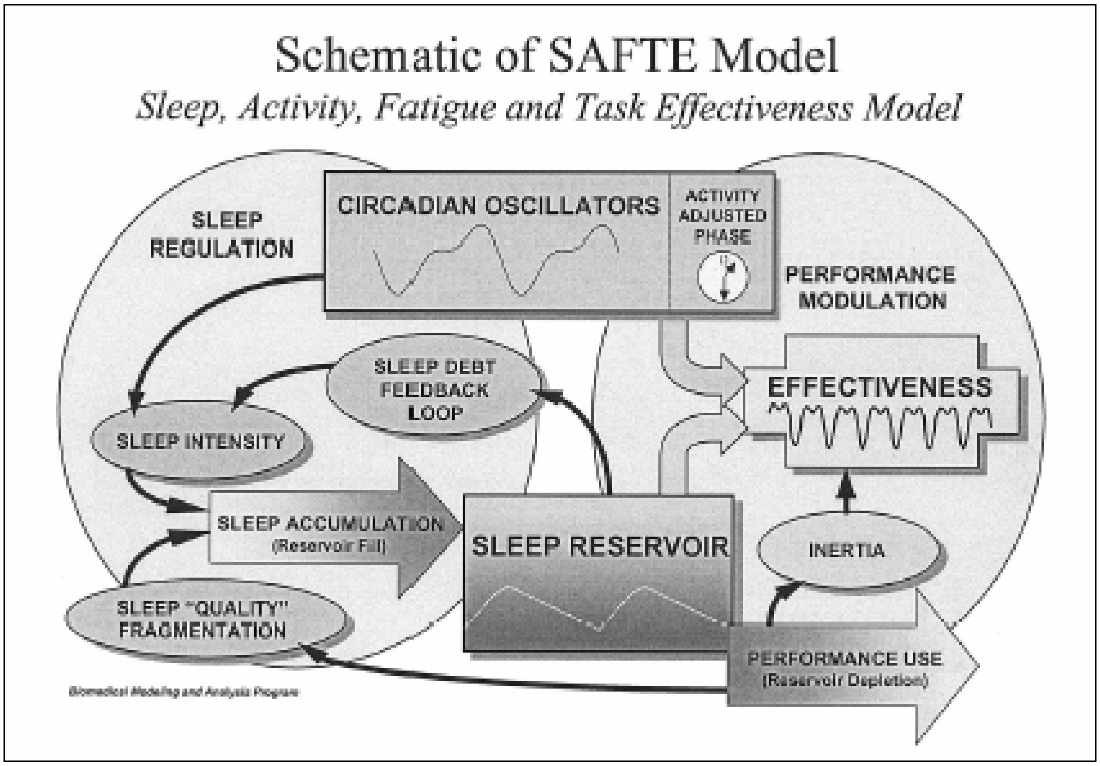

Figure 6. SAFTE Model (From: Hursh et al., 2004).

At the core of the SAFTE Model is a sleep reservoir used to represent sleep-dependent processes that govern the capacity to perform cognitive work. Under fully rested, optimal conditions, a person has a finite, maximal capacity to perform. While a person is awake, the sleep reservoir is depleted, which builds up a sleep debt. While a person is asleep, the sleep reservoir is replenished, which repays the sleep debt. The level of replenishment is dependent on factors such as the quality and intensity of sleep, the circadian process, and the current level of the sleep reservoir. Finally, the level of performance effectiveness is modeled as a function of the sleep reservoir and the circadian time-of-day effects (Hursh et al., 2004).

The SAFTE Model provides commanders with a valid and reliable means to predict individual and unit performance effectiveness. As an example of the validity of this model, Figure 7 compares the modified SAFTE Model PVT speed output with the PVT results of the WRAIR sleep dose-response study based on actual sleep durations. With R^2 = 0.94, we see that the SAFTE model fits the WRAIR data very well[7] (Hursh et al., 2004). Due to the reliability and validity of this model, the Army, Air Force, and Department of Transportation use an implementation of the SAFTE Model, known as the Fatigue Avoidance Scheduling Tool (FAST), to predict the performance effectiveness of personnel working specified schedules. We will discuss FAST, its contributions to this research, and its usefulness to planning CONOPS/SUSOPS in Chapter III.

[7] Recall that R^2 is the coefficient of determination that indicates the proportion of the variance explained by our model. The closer R^2 is to 1.0, the more accurately our model predicts the actual observed values.

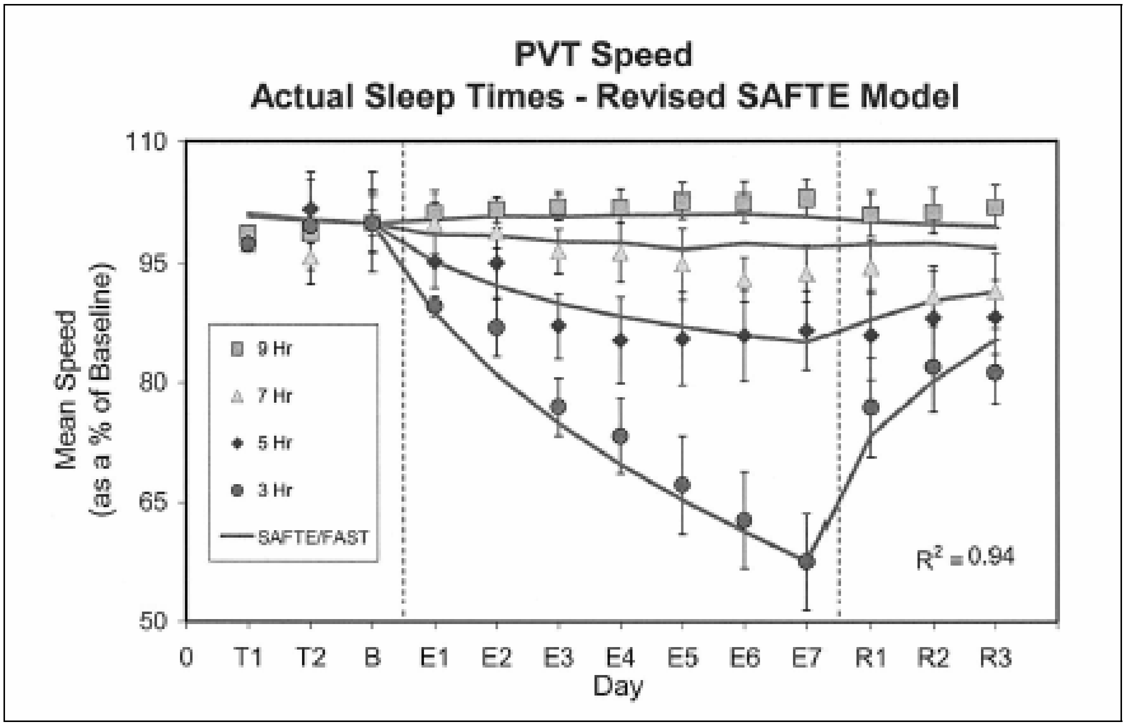

Figure 7. Fit of the modified SAFTE Model to PVT results of the WRAIR sleep dose-response study based on actual sleep (From: Hursh et al., 2004).

While the SAFTE Model is an extremely useful tool for predicting performance effectiveness of an average individual or group, its output is limited since it does not take into consideration individual differences. Specifically, the SAFTE Model does not currently take into consideration individual motivation, stress or arousal levels, environmental conditions, age, sleep personality type (lark, owl, or robin), flexibility to sleep patterns (rigid, regular, or flexible), or individual sleep requirements. However, despite these limitations, the SAFTE Model is one of the best and widely used models for predicting performance effectiveness and can be used by commanders to plan optimal CONOPS/SUSOPS sleep and rest schedules. While the SAFTE Model is not 100% accurate, it is extremely useful for predicting performance effectiveness as a function of sleep and circadian rhythm (Hursh et al., 2004; Dijk & Larkin, 2004; Belenky et al., 2003).

F. LITERATURE REVIEW SUMMARY

The literature reviewed for this thesis has directed our focus to understanding the importance of sleep, the significance of sleep loss on warfighter performance, the countermeasures available to commanders and planners to combat sleep loss, and the modeling tools to effectively develop sleep plans. During CONOPS/SUSOPS, warfighters have the added challenge of battling fatigue and sleep deprivation, and while there is no doubt that today’s military is superbly trained and ready to respond to any crisis, warfighters must also plan for the requirements of sleep in order to completely ensure success on the battlefield. Today’s military fights its battles under the constant watchful eye of the media, and as a result, one wrong decision by a warfighter on the frontlines of the battlefield can have strategic implications and life-and-death consequences. Finally, understanding and planning for the role fatigue plays on warfighter performance can significantly reduce sources of friction on the battlefield. The mathematical models and reliable fatigue countermeasures available to commanders and planners significantly enhance the planning process for sleep logistics today.

We have seen that an extensive amount of research has been done to assess the effects of fatigue on the performance of warfighters during CONOPS/SUSOPS. These studies thoroughly evaluate both the mental and physical fatigue of warfighters in order to quantify the performance effectiveness of an individual warfighter in a high-stress environment. Many of these studies have been collected, reviewed, and summarized by leading Department of Defense laboratories concerning fatigue in sustained and continuous military operations, such as Walter Reed Army Institute of Research, Air Force Research Laboratory, Naval Health Research Center, Office of Naval Research, U.S. Army Aviation Research Laboratory, and U.S. Army Research Institute. Many of the lessons learned from these studies and laboratories have been published by the U.S. military services in the forms of doctrinal procedures, reference publications, field manuals, and commander’s guidance. Therefore, since the warfighter is expected to train as he fights, it is incumbent on leaders and commanders at all levels to ensure battlefield success by maintaining a balanced focus between mission accomplishment and troop welfare, especially when the troop welfare issue of sleep loss directly affects mission accomplishment.

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III. METHODOLOGY

A. OVERVIEW

This study is observational in nature and relies primarily on anonymous and voluntary survey data collected from military personnel operating in Kuwait and Iraq from 25 August to 15 October 2003. For the purposes of this study, the survey data collected in Kuwait serve as a baseline for comparison with the survey data collected in Iraq. In order to test the reliability of the survey data collected in Southwest Asia, additional subjective survey data and objective actigraphy data were collected at the Naval Postgraduate School (NPS). We will discuss the usefulness of the NPS data later in the chapter.

B. PARTICIPANTS

Our target population for this study was military personnel currently deployed to SWA irrespective of Service Branch, component (regular, reserve, or guard), MOS, rank, age, or gender (a detailed summary of participant's demographics is presented in Chapter IV). While all military services were invited to participate in the study, logistical constraints made it difficult for the survey administrator to travel between designated areas of responsibility. Specifically, since the survey administrator traveled with soldiers throughout Iraq and Kuwait, the participants for this study were sampled by convenience within the U.S. Army's area of responsibility (AOR). Therefore, the survey administrator was unable to survey servicemembers from services other than the U.S. Army (we will discuss the details of the data collection phase in greater depth later in this chapter). While it would have been useful to compare the data obtained from U.S. Army personnel with data obtained from the U.S. Marine Corps' AOR, we believe that these participants provide insights that are useful for the general population of military forces deployed to SWA, regardless of the branch of service.

C. INSTRUMENTS

The primary instrument used for this observational study is a pilot survey designed by the author to capture sleep patterns and adherence to sleep/rest plans. A second instrument, known as a Wrist Actigraphy Monitor[8] (WAM), was used by a control group at NPS in order to test the reliability of subjective, self-reported survey data. While the WAM was not used in SWA, it did significantly contribute to this study.

1. Survey

On or about 20 July 2003, researchers at NPS were contacted by a U.S. Army Material Command research psychologist, Command Sergeant Major Steve Burnett, USA (ret), who was already deployed to the SWA region conducting separate research. Burnett advised NPS that senior U.S. Army officers in the SWA region were concerned about the effects of fatigue on performance and that the local commanders would support research that would provide additional insight regarding the potential problem. In order to minimize the research footprint and ensure that the research did not interfere with operational missions,

[8] Sometimes referred to as a Wrist Activity Monitor.

it was agreed that the study of warfighter sleep habits would be observational in nature and sample warfighters throughout Iraq and Kuwait by convenience on a strictly voluntary basis (personal communication, July 20, 2003).

The NPS researchers immediately began developing a survey that would provide insight regarding the primary research questions and would be appropriate for military personnel operating in a combat environment. In order to design a useful and relevant survey tool, we combined our knowledge of the military environment with proven questionnaire design techniques, such as those outlined by the U.S. Army Research Institute (Babbitt & Nystrom, 1989) and the U.S. General Accounting Office (1993), with known sleep-pattern surveys and indices found in the review of the literature, such as the Collegiate Sleep Habit Survey (Bradley Hospital/Brown University Sleep Research Laboratory, 1991), the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989), and Stanford Sleepiness Scale (Hoddes, et al., 1973). Upon completion of the initial draft survey, a working group consisting of 22 members was formed to evaluate its usefulness and relevance. The Survey Working Group (SWG) included 5 Army enlisted personnel, 6 Army officers, 3 Marine Corps officers, 6 Navy officers, and 2 NPS professors.

The resulting pilot survey (Appendix B), *SOUTHWEST ASIA SLEEP, FATIGUE, AND ENDURANCE STUDY*, is a 5-page, 96-question, document broken into 10 sections, including a 15-question demographics section, providing insight regarding: unit-level sleep plans and individual adherence to sleep plans; daily, weekly, and monthly sleep patterns; sleep quality; operational tempo levels; and lifestyle factors that may interfere with sleep. The pilot survey included fill-in-the-blank questions, yes-no questions, questions with "implied no" choices, questions with single-item choices, multiple-choice questions, rating questions, and intensity scale questions. On average, the pilot survey took each participant 40 minutes to complete.

2. The Wrist Actigraphy Monitor (WAM)

The secondary instrument used in this study was an Actiwatch WAM developed by Mini Mitter Co., Inc., (see Figure 8). According to the Actiwatch Actigraphy Systems brochure provided by Mini Mitter Co., Inc. (2003), "[a]ctigraphy is the use of instruments sensitive to movement, typically worn on the wrist, to record activity over time" (www.minimitter.com). The Actiwatch brand of WAMs feature digital integration, which accurately measures both movement and intensity. Movement is measured by a highly sensitive accelerometer and is digitally processed and recorded in the WAM's memory at designated user-selected time periods, or epochs[9]. Depending on the epoch size, data can be collected and stored 24 hours a day for up to a year. The data are downloaded from the WAM to a computer and may be expressed numerically and graphically, aiding in sleep/wake history analysis. The activity measurements recorded by WAMs have been shown to accurately identify periods of sleep and periods of wakefulness, as well as offer general indications of sleep quality (Pollak et al., 2001; The National Academy of Sciences, 2004).

[9] For example, if the user selects a 1-minute epoch length, then the WAM will record a digitally integrated measure of gross motor activity during each 1-minute epoch.

Figure 8. The Mini Mitter Co., Inc. Actiwatch™

Since Actiwatches are small, rugged, and reliable instruments for determining sleep/wake patterns, sleep quality, and evaluating circadian rhythms without disturbing the user, they are ideal for non-laboratory, military settings, such as SWA. Unfortunately, due to time, logistical, and administrative constraints, we were unable to use the Actiwatch WAM in SWA during the data collection phase of this study.

However, in order to test the reliability of the self-reported SWA sleep pattern data, we conducted a separate experiment using the Actiwatch WAM and the *SOUTHWEST ASIA SLEEP, FATIGUE, AND ENDURANCE STUDY* survey. Specifically, participants were asked to wear the Actiwatch WAM continuously for 7 days. On the final day, participants were asked to complete the *SOUTHWEST ASIA SLEEP, FATIGUE, AND ENDURANCE STUDY* survey, which asked for the participant to recall the times that he or she slept during the past 7 days. The objective Actiwatch data were then compared to the subjective, self-reported sleep/wake data in order to test the reliability of the self-reported data. We will discuss the results of this reliability test in Chapter IV.

D. DATA COLLECTION

The preferred method of data collection is by random sampling of a population. However, this sampling of the population was not possible given that the survey administrator, Command Sergeant Major (CSM) Burnett, was collecting data during Phase IV of Operation Iraqi Freedom and was solely dependent on local military units for transportation throughout the AOR. Specifically, all throughout the data collection phase, CSM Burnett requested transportation assistance from any military unit willing to give him a ride in the general direction that he was trying to go. For all practical purposes, CSM Burnett hitchhiked from Al Jahrah, Kuwait to Tikrit, Iraq and back for a round trip of over 1000 miles. While the transportation method is impressive in itself, we should not forget that military engagements, small-arms fire, mortar attacks, and roadside Improvised Explosive Devices (IED) were constant obstacles to the data collection process. Needless to say, the data were sampled by convenience. Despite this fact, the data are useful and provide us with insight into the larger general military population operating in the SWA region.

As CSM Burnett traveled throughout the region, he asked military units if they would be willing to participate in this study. He then provided the unit with a stack of surveys and consent forms with privacy notices, gave detailed instructions regarding the voluntary nature of the study, and then left each unit to administer the survey in a manner that best fit that unit's operational environment. Periodically, CSM Burnett would check in with the units that agreed to participate in the study and collect any completed surveys, as well as completed consent forms. Once substantial batches of surveys were collected, they were mailed back to NPS for data entry. Thanks to the dedicated and determined support of CSM Burnett, this observational study uses the survey data of 273 warfighters operating in Iraq and Kuwait from 25 August to 15 October 2003.

E. DATA ENTRY AND ANALYSIS TOOLS

Upon completion of the data collection phase, all of the surveys were sent back to NPS for data entry and analysis. In this section, we will briefly discuss specific tools used to accomplish these tasks, namely, Microsoft® Excel 2000, Fatigue Avoidance Scheduling Tool (FAST), and S-Plus 6.1.

1. Microsoft® Excel 2000

Once all of the surveys were returned to NPS, the data were manually entered by hand into an Excel spreadsheet. The data were stored such that each row corresponded to one participant's survey and each column corresponded to one question. Questions were scored and coded in order to maximize the use of statistical tools. Appendix D identifies the codes and scales used for each question. Some questions were broken up into corresponding sub-questions. For example, if a question asked a participant to "check all that apply," then that question would be broken up into binary sub-questions where a “1” corresponded to items that applied and a “0” corresponded to items that did not apply. Some questions were scored using a Likert scale and others with continuous numeric values corresponding to the amount of time a person had slept, napped, etc. Since there were 273 participants in our study, there are 273 rows in our data matrix. Because some of the original 96 questions were broken up into subcomponents, there are 127 columns in our data matrix: 111 corresponding to primary survey questions and 16 corresponding to demographic questions.

2. Fatigue Avoidance Scheduling Tool (FAST) Version Beta 0.9.61

The Fatigue Avoidance Scheduling Tool (FAST) is a Windows®-based decision aid for operational planning and is based on the SAFTE model of human sleep and performance, which was discussed in Chapter II. FAST was developed by Dr. Steve Hursh and his colleagues at NTI, Inc. and Science Applications International Corporation (SAIC) to provide the U.S. Air Force and U.S. Department of Transportation with a user-friendly tool to evaluate the benefits of various sleep/wake schedules. By doing so, planners are able to determine optimal schedules that maximize human performance effectiveness and minimize operational risk caused by fatigue-related performance degradation.

Data can be input in FAST (version Beta 0.9.61 or higher) by several methods: standard ASCII text files; actigraphy data pre-processed by actigraph analysis programs; or directly using a schedule grid. Figure 9 shows how easily sleep schedules can be entered into FAST.

Starting with a blank schedule grid, the user simply highlights a section of cells, designates those cells as sleep, and then selects the appropriate sleep quality for that time period. Sleep appears in the schedule grid in blue and designated periods of work appear in red.

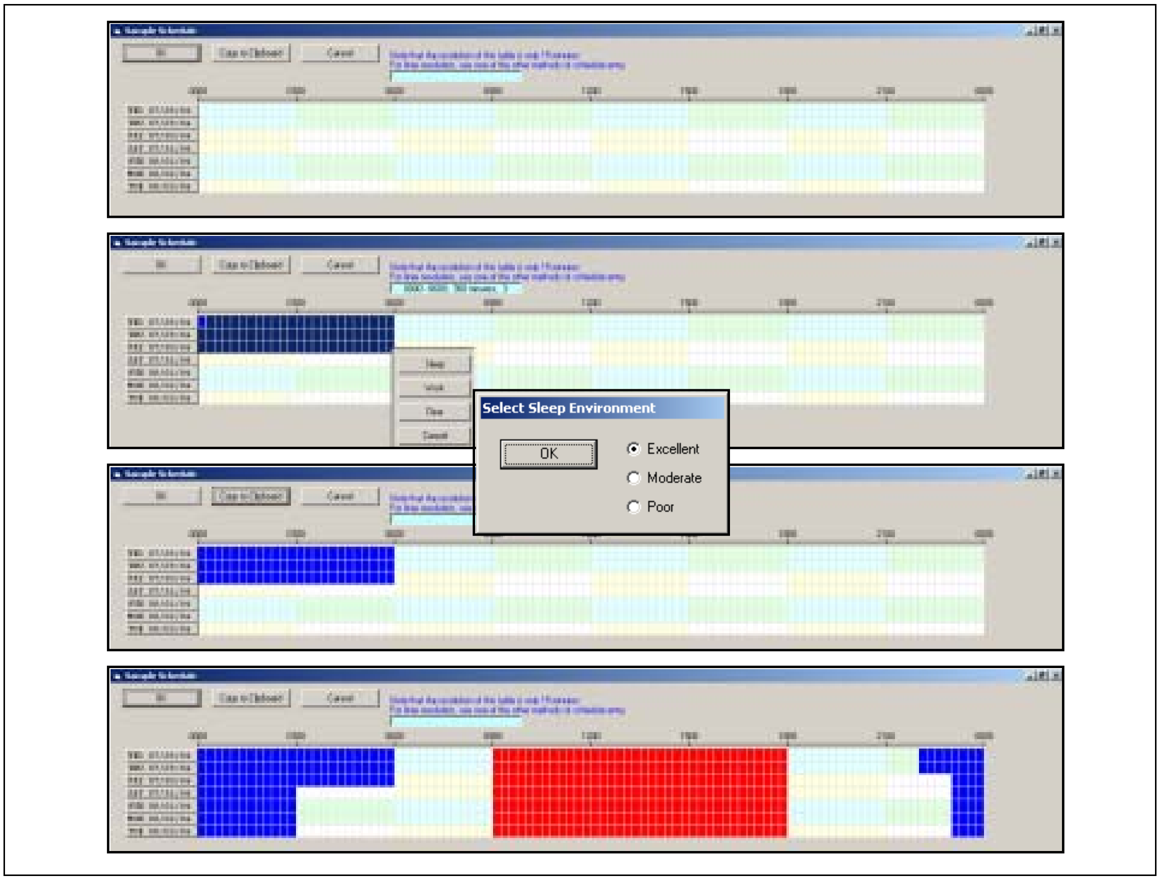


Figure 9. Entering sleep and work data into FAST using the schedule grid (From: FAST, 2003).

Once the user has indicated all of the critical sleep or work events, then the predicted mean performance effectiveness is displayed graphically. Figure 10 graphically represents the mean performance effectiveness associated with the sleep schedule created in Figure 9.

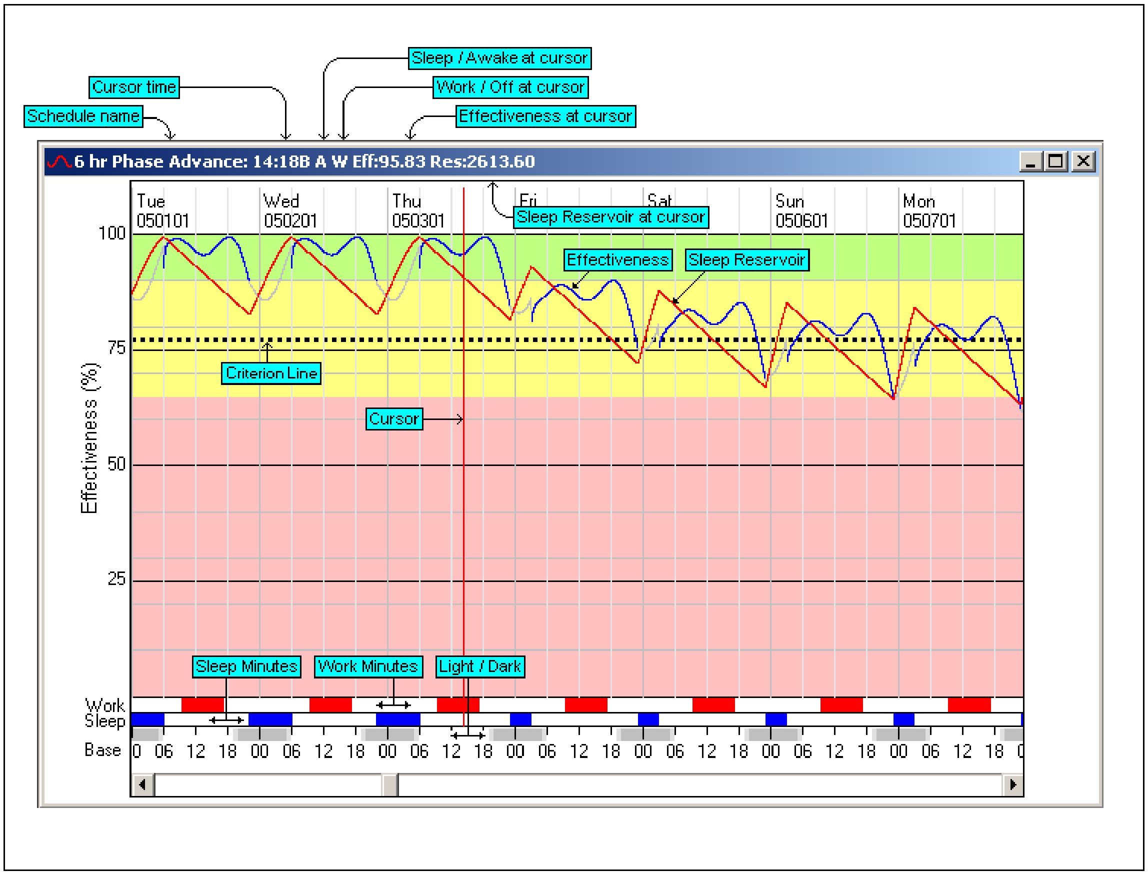


Figure 10. Sample graphical display from FAST with comments to explain main components (From: FAST, 2003)

The colored zones (green, yellow, and red) are based on detailed analysis of performance data obtained from several sleep deprivation studies conducted by the U.S. Army and U.S. Air Force. Further, NTI, Inc. and SAIC developed these color zones to meet the requirements specified by the military customers using FAST as a decision aid. The help feature in FAST describes the color zones as follows:

> **Green Zone:** The green zone on the graph is the range of performance during a normal duty day following an eight-hour period of excellent sleep.

Yellow Zone: The yellow zone is the range of performance during the 24-hour period after missing one night of sleep. While difficult to avoid dropping into this zone during the early morning hours (midnight to 0400), naps and other countermeasures are recommended to keep performance in the top half of the yellow zone, above the heavy dashed line. Performance in the yellow zone below the dashed [Criterion] line represents performance equivalent to a person during the day following the loss of an entire night's sleep.

Red Zone: The red zone indicates performance that is below the level that is deemed acceptable for military operations. Reaction time in the Red Zone is more than double normal. The red zone represents the range of effectiveness equivalent to a person following sleep deprivation of two full days and a night.

In addition to the graphical representation of the estimated mean performance effectiveness of a large population on cognitive tasks based on that sleep schedule, FAST also provides graphical representations of the increasing variation of the population as the sleep debt increases. Since some people are more sensitive to sleep loss than others, FAST takes into consideration an increase in standard deviation of a population to current sleep debt based on the sleep reservoir level. This feature allows researchers to evaluate the performance effectiveness for different percentiles of the general population. For example, Figure 11 uses the same sleep/wake schedule used in Figure 10; by selecting the lower 10^{th} percentile in FAST, we are able to gain greater insight into this particular sleep/wake schedule by evaluating the predicted performance effectiveness of individuals who are extremely sensitive to sleep loss.

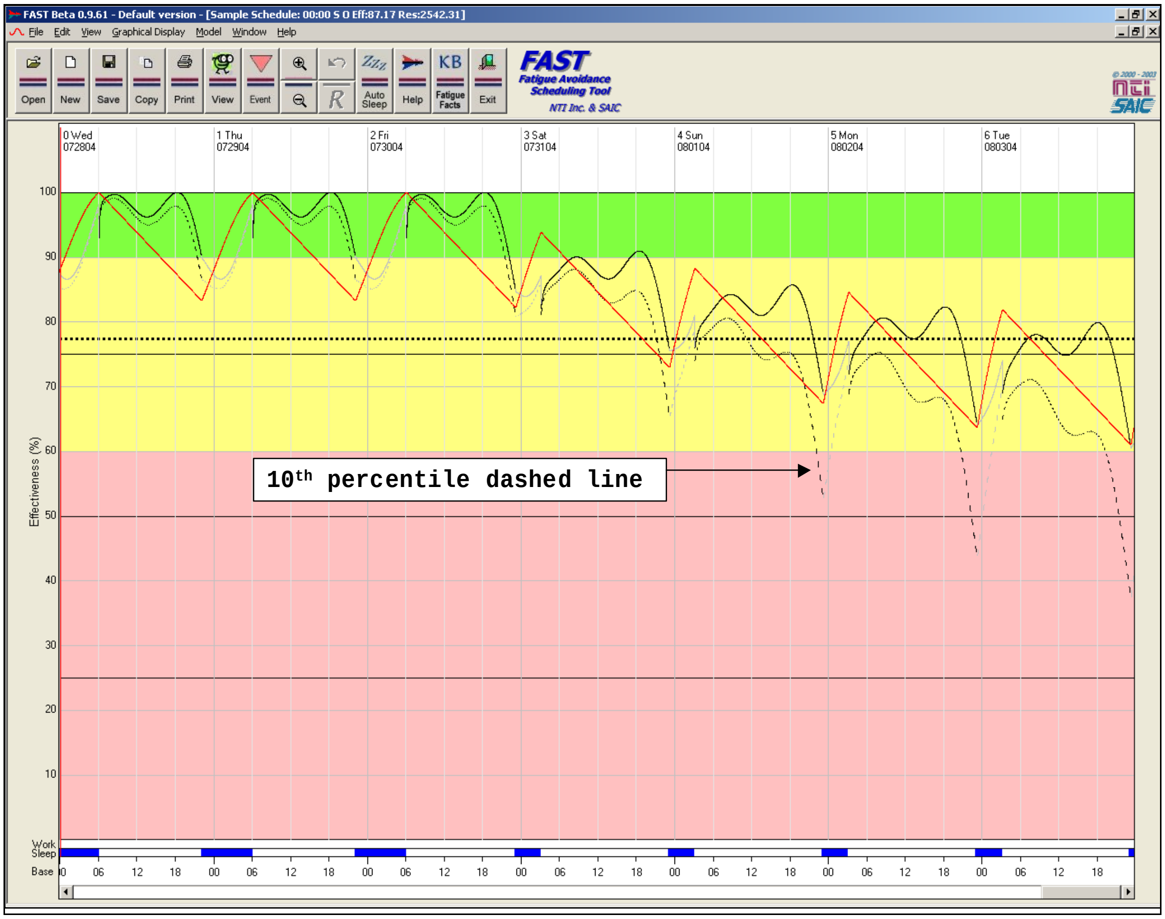
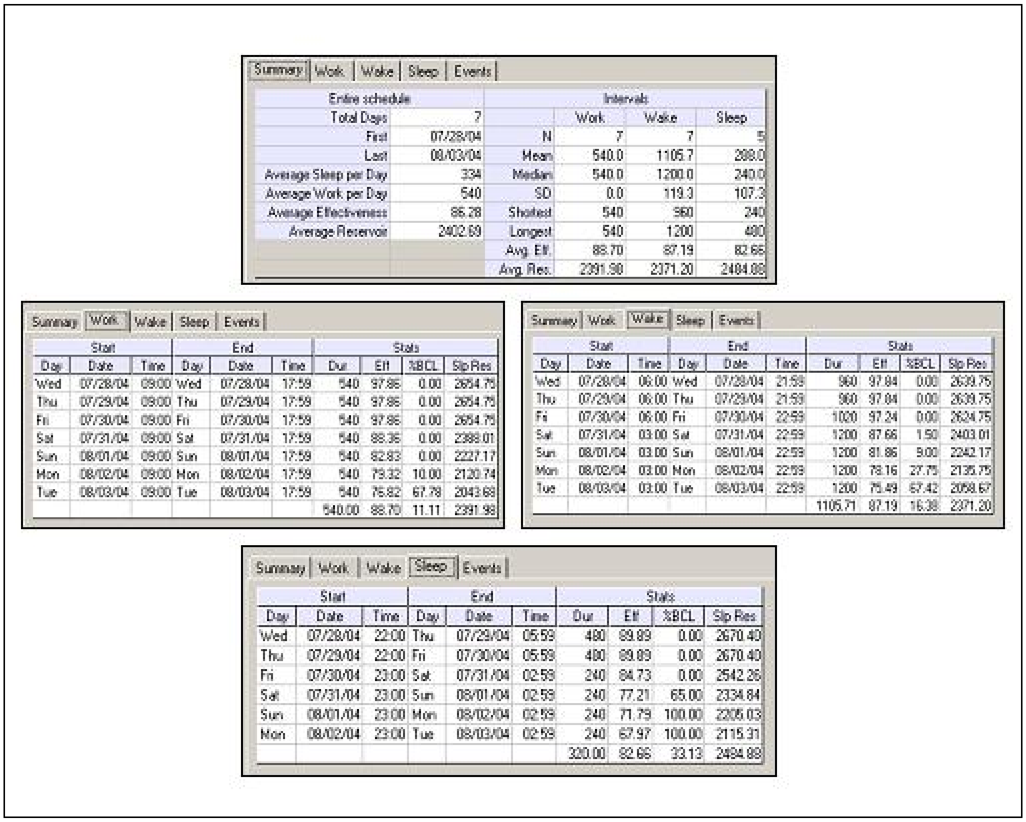


Figure 11. Sample graphical display from FAST with dashed line to represent the mean performance effectiveness of the lower 10 percent of the population, which is most sensitive to sleep loss (From: FAST, 2003).

In addition to the graphical displays shown in Figures 10 and 11, FAST also provides summary data tables, such as those shown in Figure 12. These data tables include useful summary statistics such as average predicted effectiveness over the entire time period, average predicted effectiveness by day, average sleep per day, and average estimated sleep reservoir levels.



Entire schedule	
Total Days	7
First	07/28/04
Last	08/03/04
Average Sleep per Day	334
Average Work per Day	540
Average Effectiveness	86.28
Average Reservoir	2402.69

Intervals	Work	Wake	Sleep
N	7	7	5
Mean	540.0	1105.7	288.0
Median	540.0	1200.0	240.0
SD	0.0	119.3	107.3
Shortest	540	960	240
Longest	540	1200	480
Avg. Eff.	88.70	87.19	82.66
Avg. Res.	2391.98	2371.20	2404.88

Work

Start			End			Stats			
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL	Slp Res
Wed	07/28/04	09:00	Wed	07/28/04	17:59	540	97.86	0.00	2654.75
Thu	07/29/04	09:00	Thu	07/29/04	17:59	540	97.86	0.00	2654.75
Fri	07/30/04	09:00	Fri	07/30/04	17:59	540	97.86	0.00	2654.75
Sat	07/31/04	09:00	Sat	07/31/04	17:59	540	88.36	0.00	2388.01
Sun	08/01/04	09:00	Sun	08/01/04	17:59	540	82.83	0.00	2227.17
Mon	08/02/04	09:00	Mon	08/02/04	17:59	540	79.32	10.00	2120.74
Tue	08/03/04	09:00	Tue	08/03/04	17:59	540	76.82	67.78	2043.68
						540.00	88.70	11.11	2391.98

Wake

Start			End			Stats			
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL	Slp Res
Wed	07/28/04	06:00	Wed	07/28/04	21:59	960	97.84	0.00	2639.75
Thu	07/29/04	06:00	Thu	07/29/04	21:59	960	97.84	0.00	2639.75
Fri	07/30/04	06:00	Fri	07/30/04	22:59	1020	97.24	0.00	2624.75
Sat	07/31/04	03:00	Sat	07/31/04	22:59	1200	87.66	1.50	2403.01
Sun	08/01/04	03:00	Sun	08/01/04	22:59	1200	81.86	9.00	2242.17
Mon	08/02/04	03:00	Mon	08/02/04	22:59	1200	78.16	27.75	2135.75
Tue	08/03/04	03:00	Tue	08/03/04	22:59	1200	75.49	67.42	2058.67
						1105.71	87.19	16.38	2371.20

Sleep

Start			End			Stats			
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL	Slp Res
Wed	07/28/04	22:00	Thu	07/29/04	05:59	480	89.89	0.00	2670.40
Thu	07/29/04	22:00	Fri	07/30/04	05:59	480	89.89	0.00	2670.40
Fri	07/30/04	23:00	Sat	07/31/04	02:59	240	84.73	0.00	2542.26
Sat	07/31/04	23:00	Sun	08/01/04	02:59	240	77.21	65.00	2334.84
Sun	08/01/04	23:00	Mon	08/02/04	02:59	240	71.79	100.00	2205.03
Mon	08/02/04	23:00	Tue	08/03/04	02:59	240	67.97	100.00	2115.31
						320.00	82.66	33.13	2404.88

Figure 12. Sample Summary Data Tables provided in FAST (From: FAST, 2003)

FAST was an integral component to our research because it helped to quantify the sleep/wake history reported in the survey by study participants. Specifically, each reported sleep/wake history was imported into FAST and converted into mean predicted performance effectiveness scores by the SAFTE model of human sleep and performance. For this measure of performance to be useful, we must assume that each participant answered the subjective questions honestly and as accurately as possible. Due to the observational nature of this study, it is safe to make this assumption and that this predicted performance measure provides us with insight into the research questions.

3. S-Plus 6.1

S-Plus 6.1 is distributed by Insightful Corporation (IC) and is based on the latest version of the object-oriented S language developed by Lucent Technologies. S-Plus 6.1 is a powerful statistics and analysis package that includes data visualization and exploration, statistical modeling, and programming (IC, 2001). S-Plus 6.1 proved to be a useful tool for implementing data analysis techniques required in this thesis.

IV. STATISTICAL RESULTS

A. OVERVIEW

In this chapter, we will analyze the survey data collected in SWA in order to answer the four primary research questions. Further, we will test the reliability of self-reported survey data, such as that reported in SWA, with objective actigraphy data.

While all branches of the military service were encouraged to participate in this study, our sample was made up entirely of U.S. Army personnel. Therefore, all Military Occupational Specialty (MOS) codes correspond to U.S. Army MOS's. For the purposes of this analysis, we will assume that missing values (NA responses) occur at random (Conover, 1999). As a check, we will compare the results obtained from participants with NA responses with those without NA responses when possible to ensure that they are not statistically different from each other. In general, most NA responses are the result of a participant not understanding the survey question, the question not applying to the participant, or the participant feeling that it was possible to have the survey traced back to him or her based on the response to a certain question. When appropriate, we will report summary statistics related to NA responses.

B. SUMMARY STATISTICS

Prior to addressing the primary research questions, we will consider the summary statistics for demographics and for the individual survey questions in order to provide insight into the sample and data. Table 2 shows the sample distribution of number of days deployed, age in years, height in inches, weight in pounds, and gender. COUNT is the number of participants who responded to the specific demographic question and NA corresponds to the number of participants who did not answer the specific question. From this table, we see that our average male participant was 29 years old, 69.7 inches tall, weighed 178 pounds, and had been deployed to the SWA region for 177 days. Our average female participant was 29 years old, 65.6 inches tall, weighed 143 pounds, and had been deployed to the SWA region for 143 days.

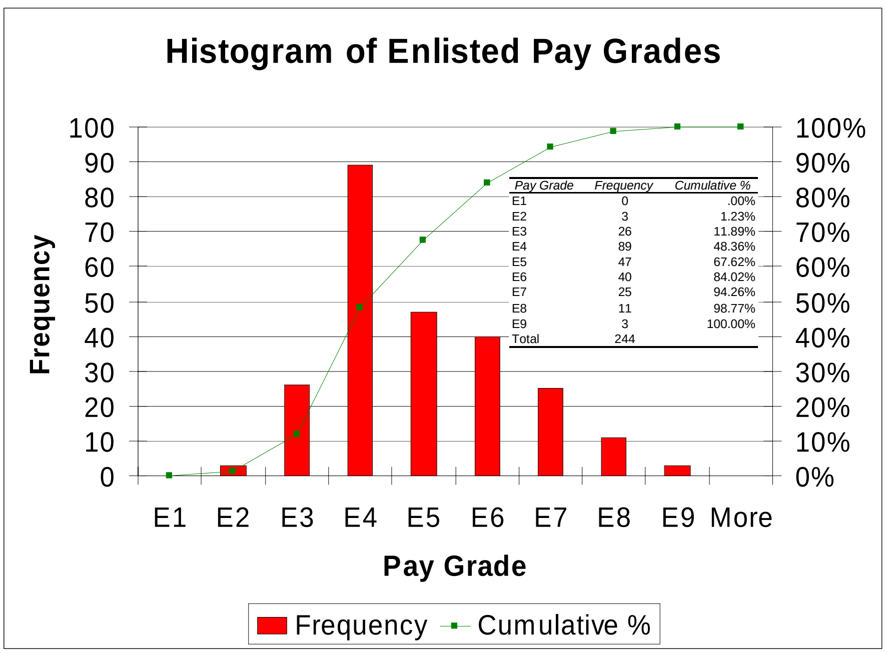
DEMOGRAPHIC SUMMARY

		DEPLOYED (days)	AGE (years)	HEIGHT (inches)	WEIGHT (pounds)
SAMPLE POPULATION	COUNT	261	265	265	264
	NA	12	8	8	9
	MIN	7.5	18	52	106
	MAX	315.5	57	77	270
	MEDIAN	174.5	27	70	170
	MEAN	178.00	29.79	69.35	175.64
	STD DEV	68.32	8.96	3.22	26.07
		DEPLOYED (days)	AGE (years)	HEIGHT (inches)	WEIGHT (pounds)
MALE	COUNT	237	242	242	240
	MIN	7.5	18	52	106
	MAX	315.5	57	77	270
	MEDIAN	172.5	27	70	174
	MEAN	177.22	29.85	69.70	178.84
	STD DEV	69.06	8.96	3.02	24.51
		DEPLOYED (days)	AGE (years)	HEIGHT (inches)	WEIGHT (pounds)
FEMALE	COUNT	24	23	23	24
	MIN	68.5	19	60	110
	MAX	260.5	50	72	174
	MEDIAN	198	26	66	142.5
	MEAN	185.71	29.22	65.61	143.63
	STD DEV	61.34	9.15	2.90	18.73

Table 2. Summary of demographic information for the sample including number of days deployed (days), age (years), height (inches), and weight (pounds). COUNT is the number of participants who answered the demographic question and NA corresponds to the number of non-responses.

1. Demographic Summary of Rank/Grade

Figure 13 shows the distribution of the enlisted participants across the pay scale. We see from this figure that nearly 12% of our enlisted participants are junior enlisted (E-1 to E-3), over 36% are Specialists and Corporals (E-4), and over 51% are E-5's or above. These statistics provide insight regarding the reliability of our data since we can generally assume that Non-Commissioned Officers (NCOs) are charged with being responsible to their commanding officer for the morale, welfare, and training of the members of that unit. Since 87% of our enlisted participants are E-4's or above, it seems reasonable to suggest that the majority of our enlisted participants have some sort of leadership responsibilities and that they have a fairly clear picture of what is or is not happening in their unit.



Pay Grade	Frequency	Cumulative %
E1	0	.00%
E2	3	1.23%
E3	26	11.89%
E4	89	48.36%
E5	47	67.62%
E6	40	84.02%
E7	25	94.26%
E8	11	98.77%
E9	3	100.00%
Total	244	

Figure 13. Summary of demographics for enlisted pay grades (n = 244).

Figure 14 shows the distribution of the officer participants across the officer pay grades. We see from this figure that 77% of our officer participants are company grade officers and that 23% are field grade officers. While not every officer is a unit commander, every officer is responsible to lead and care for the men and women under his or her charge. Therefore, it seems reasonable to suggest that these officers, especially the company grade officers who work closest with the junior enlisted, should be aware of what is or is not happening in their units. This understanding provides additional insight regarding the reliability of these data.

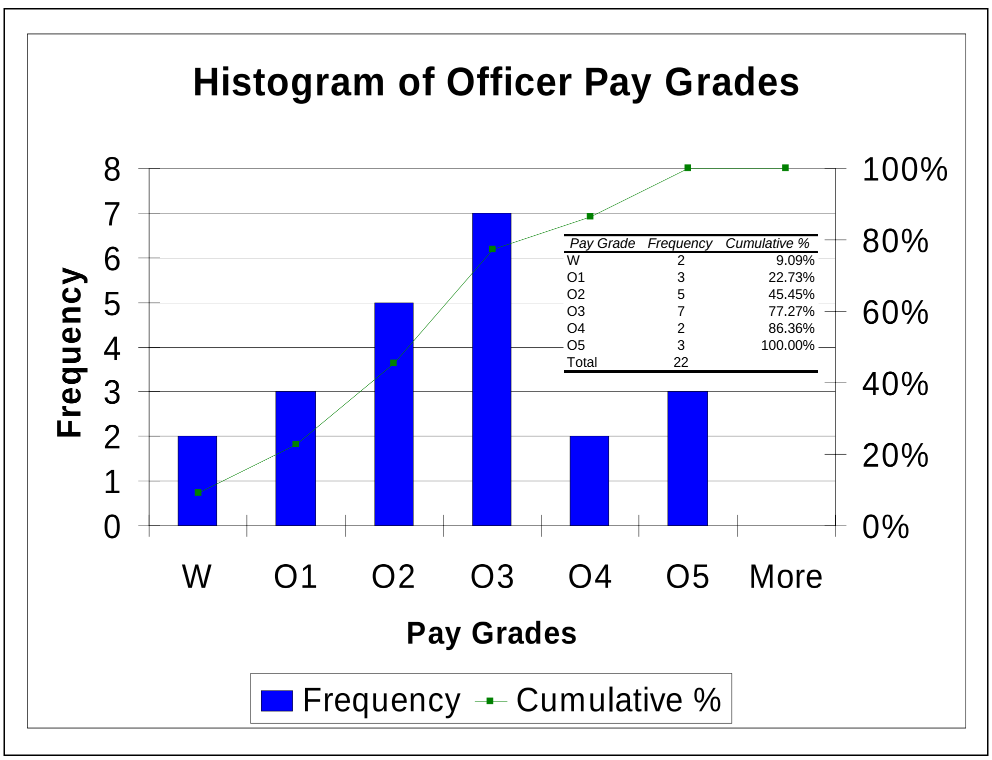


Figure 14. Summary of demographics for officer pay grades (n = 22).

2. Grouping by Military Occupational Specialty

When asked to specify Military Occupational Specialty (MOS), some participants gave the primary MOS category, such as "11" for the infantry MOS, "13" for the field artillery MOS, or "31" for the communications MOS. Other participants responded with a 3-digit MOS designation, such as "11A," "11B," or "11C" for different duty areas within the infantry MOS. Still others responded with a 4- or 5-digit MOS designation, which provides greater detail regarding the exact duties and rank associated with an MOS. While this high resolution accurately identifies the MOS, the 2-digit MOS code provides enough information for the purposes of this research. To this end, Appendix E provides the distribution of the participants (n = 273) by their reported 2- or 3-digit MOS code.

Further, since the purpose of this study is to provide general insight regarding the larger population, we chose to group participants according to MOS category rather than specific MOS's. The main reason for this decision is several MOS's had very small representation, e.g. fewer than five participants. Therefore, if the MOS indicated by the participant was a Combat MOS or a Combat Support MOS, then the participant was placed in Group 1, and if the MOS indicated by the participant was a Combat Service Support MOS, then the participant was placed in Group 2. Table 3 shows the classification of the participants by group.

GROUPING BY MOS (2 GROUPS)

GROUP 1: COMBAT & COMBAT SUPPORT MOSs
GROUP 2: COMBAT SERVICE SUPPORT MOSs

REPORTED MOS COMPONENT	MOS CATEGORY	ASSIGNED TO GROUP 1	ASSIGNED TO GROUP 2	NA RESPONSE	TOTAL
00Z (ENGR BN)	COMBAT SUPPORT	1	0	0	1
00Z (TRANS BN)	COMBAT SERVICE SUPPORT	0	1	0	1
11	COMBAT	65	0	0	65
13	COMBAT SUPPORT	48	0	0	48
15	COMBAT SUPPORT	3	0	0	3
21	COMBAT SUPPORT	3	0	0	3
25	COMBAT SERVICE SUPPORT	0	2	0	2
27	COMBAT SERVICE SUPPORT	0	1	0	1
31	COMBAT SERVICE SUPPORT	0	12	0	12
35	COMBAT SERVICE SUPPORT	0	6	0	6
42	COMBAT SERVICE SUPPORT	0	1	0	1
54	COMBAT SERVICE SUPPORT	0	2	0	2
55	COMBAT SERVICE SUPPORT	0	3	0	3
62	COMBAT SERVICE SUPPORT	0	3	0	3
63	COMBAT SERVICE SUPPORT	0	9	0	9
67	COMBAT SERVICE SUPPORT	0	7	0	7
68	COMBAT SERVICE SUPPORT	0	12	0	12
71	COMBAT SERVICE SUPPORT	0	5	0	5
74	COMBAT SERVICE SUPPORT	0	3	0	3
75	COMBAT SERVICE SUPPORT	0	3	0	3
77	COMBAT SERVICE SUPPORT	0	11	0	11
88	COMBAT SERVICE SUPPORT	0	13	0	13
90	COMBAT SERVICE SUPPORT	0	1	0	1
91	COMBAT SERVICE SUPPORT	0	8	0	8
92	COMBAT SERVICE SUPPORT	0	28	0	28
95	COMBAT SERVICE SUPPORT	0	13	0	13
96	COMBAT SERVICE SUPPORT	0	2	0	2
NA	NO RESPONSE	0	0	7	7
	TOTAL	**120**	**146**	**7**	**273**

Table 3. Grouping of participants by MOS into two groups: Group 1 contains Combat and Combat Support MOS’s; and Group 2 contains Combat Service Support MOS’s.

Participants are also classified into three groups: Group A containing Combat and Combat Support MOS’s (excluding aviation MOS’s); Group B containing Combat Service Support MOS’s (excluding aviation MOS’s); and Group C containing only aviation-specific MOS’s. Letters are used for these groups instead of numbers to avoid confusion with the previous two groups. Table 4 shows the distribution of the participants (n = 273) into these three groups.

GROUPING BY MOS (3 GROUPS)

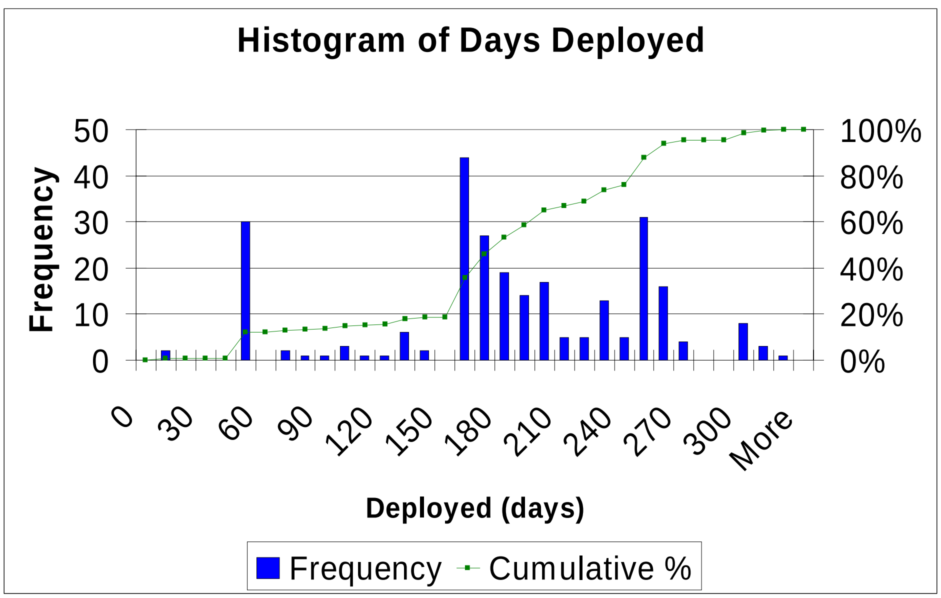
GROUP A: COMBAT & COMBAT SUPPORT MOSs (NON-AVIATION)
GROUP B: COMBAT SERVICE SUPPORT MOSs (NON-AVIATION)
GROUP C: AVIATION-SPECIFIC MOSs

REPORTED MOS COMPONENT	MOS CATEGORY	ASSIGNED TO GROUP A	ASSIGNED TO GROUP B	ASSIGNED TO GROUP C	NA RESPONSE	TOTAL
00Z (ENGR BN)	COMBAT SUPPORT	1	0	0	0	1
00Z (TRANS BN)	COMBAT SERVICE SUPPORT	0	1	0	0	1
11	COMBAT	65	0	0	0	65
13	COMBAT SUPPORT	48	0	0	0	48
15	COMBAT SUPPORT	0	0	3	0	3
21	COMBAT SUPPORT	3	0	0	0	3
25	COMBAT SERVICE SUPPORT	0	2	0	0	2
27	COMBAT SERVICE SUPPORT	0	1	0	0	1
31	COMBAT SERVICE SUPPORT	0	12	0	0	12
35	COMBAT SERVICE SUPPORT	0	6	0	0	6
42	COMBAT SERVICE SUPPORT	0	1	0	0	1
54	COMBAT SERVICE SUPPORT	0	2	0	0	2
55	COMBAT SERVICE SUPPORT	0	3	0	0	3
62	COMBAT SERVICE SUPPORT	0	3	0	0	3
63	COMBAT SERVICE SUPPORT	0	9	0	0	9
67	COMBAT SERVICE SUPPORT	0	0	7	0	7
68	COMBAT SERVICE SUPPORT	0	0	12	0	12
71	COMBAT SERVICE SUPPORT	0	5	0	0	5
74	COMBAT SERVICE SUPPORT	0	0	3	0	3
75	COMBAT SERVICE SUPPORT	0	3	0	0	3
77	COMBAT SERVICE SUPPORT	0	11	0	0	11
88	COMBAT SERVICE SUPPORT	0	13	0	0	13
90	COMBAT SERVICE SUPPORT	0	1	0	0	1
91	COMBAT SERVICE SUPPORT	0	8	0	0	8
92	COMBAT SERVICE SUPPORT	0	28	0	0	28
95	COMBAT SERVICE SUPPORT	0	13	0	0	13
96	COMBAT SERVICE SUPPORT	0	2	0	0	2
NA	NA	0	0	0	7	7
	TOTAL	**117**	**124**	**25**	**7**	**273**

Table 4. Grouping of participants by MOS into three groups: Group A contains Combat and Combat Support MOS's (excluding aviation MOS's); Group B contains Combat Service Support MOS's (excluding aviation MOS's); and Group C contains aviation-specific MOS's.

3. Demographic Summary of Days Deployed

Figure 15 classifies the sample by number of days they had been deployed at the time they took the survey. This number was calculated by asking the participant to provide the date that he or she deployed from their home base. Once obtained, the number of days from that date to 18 Sep 2003 were counted, the median date of the data collection phase (15 Aug to 15 Oct 2003). While the exact number of days the participant was deployed is not known, this approximate date provides sufficient insight regarding the sample. Further, the clear majority of these participants had been deployed for more than 180 days, or prior to 18 March 2003, so we can assume that the majority of this sample participated in or directly supported the major combat phase of Operation Iraqi Freedom as well as Phase IV operations. Given this information, these participants should have had sufficient time to implement workable sleep/rest plans in support of continuous operations. Therefore, the information from this study may represent a steady state regarding sleep patterns. We do see from the spike at 60 days, however, that at least one of the military units that were sampled had arrived in theater after the major combat phase of OIF.



COUNT	NA	MIN	MAX	MEDIAN	MEAN	STD DEV
261	12	7.5	315.5	174.5	178.00	68.32

Figure 15. Summary of demographics for number of days deployed. NA corresponds to non-responses to the demographic question. MIN, MAX, MEDIAN, MEAN, and STD DEV are reported in days.

4. Other Demographic Information

Additional information is provided on these demographic topics in Appendix F. In tabulating the summary statistics, we find that of the 273 participants making up our sample, 242 were male (88.64%), 24 were female (8.79%), and 7 did not answer the question (2.56%). While we would like to have had a larger sample size from our female population, these demographic statistics will not detract greatly from our findings and conclusions.

5. Summary Statistics of Survey Questions

In this section, we will briefly consider the summary statistics for each of the survey questions, including count, the proportion of participants who did not respond to a specific question (NA response rate), the minimum, maximum, median, and mean values for each question based on the scaling and coding indicated in Appendix D, the standard deviation[10] associated with the mean, and the 95% confidence interval associated with the mean. When appropriate, we will provide histograms for responses to specific questions in order to gain additional insight. However, due to the large number of questions associated with this survey, we will limit our focus to significant findings. Prior to reviewing these summaries, the reader is encouraged to review Appendix D in order to better understand how a particular question was numbered, what the question asked, and how the question was coded and/or scaled.

[10] Standard deviations are sample standard deviations and should not be confused with standard errors for the sample mean or sample proportion for numeric and binary variables respectively.

a. Summary Statistics for Survey Section 1

Table 5 shows the summary statistics for Section 1 of the SOUTHWEST ASIA SLEEP, FATIGUE, AND ENDURANCE STUDY survey (SWA survey). Questions S1Q1A and S1Q2A are follow-on questions and therefore had lower response rates than the other questions in our survey. We see from this table that only 38% of our sample reported that they were briefed on a sleep plan (S1Q1). Considering that the majority of our sample includes E-4's and above, this suggests that units may not have considered the importance of implementing sleep/rest plans since it would be the responsibility of the E-4's and above to supervise the implementation of a sleep/rest plan.

	MIN	MAX	MEDIAN	MEAN	LOWER 95% CI	UPPER 95% CI	STD DEV	COUNT	NA	RESPONSE RATE
S1Q1	0	1	0	0.38	0.32	0.44	0.49	269	4	98.53%
S1Q1A	0	1	1	0.77	0.72	0.82	0.42	95	178	34.80%
S1Q2(Y)	0	1	0	0.14	0.10	0.18	0.35	250	23	91.58%
S1Q2(N)	0	1	0	0.43	0.37	0.49	0.50	250	23	91.58%
S1Q2(IDK)	0	1	0	0.43	0.37	0.49	0.50	250	23	91.58%
S1Q2A	1	9	4	3.76	3.54	3.98	1.82	54	219	19.78%
S1Q3	1	7	4	4.39	4.20	4.58	1.59	192	81	70.33%
S1Q4	0	1	1	0.62	0.57	0.68	0.49	244	29	89.38%

Table 5. Section 1 Summary Statistics.

The fact that only 38% of the sample reported being briefed on a sleep plan, however, could be the result of the participant not fully understanding what a sleep plan is. For example, 62% of the sample reported that their unit worked in shifts, which we could assume is a sleep plan in support of continuous operations.

In either case, of those commenting on the effectiveness of their unit's sleep plan, the majority reported that that their unit's sleep plan either made no difference or did not work well (S1Q3). Figure 16 shows the detailed distribution of question S1Q3 and explains the numeric code associated with the question.

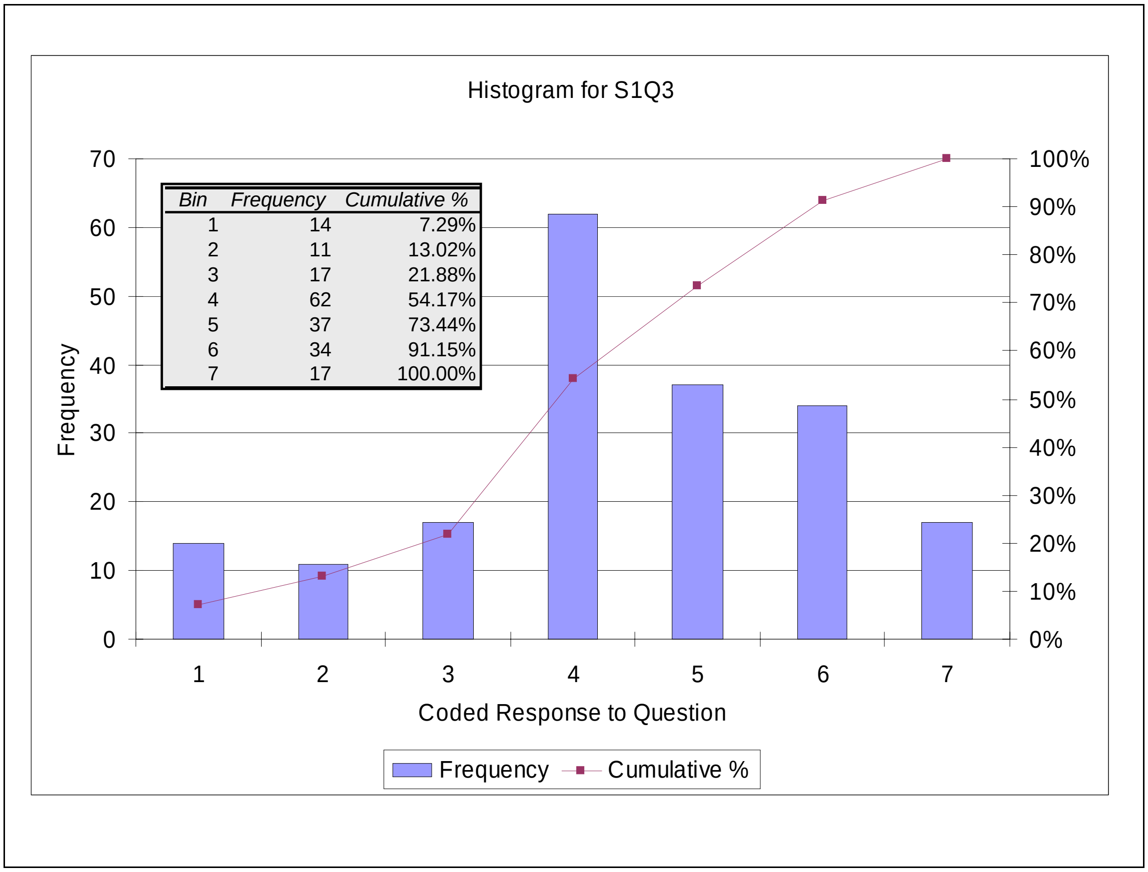


Figure 16. Histogram of responses to question S1Q3, which asks participants to evaluate their unit’s sleep plan where: 1 = Never works; 2 = Almost never works; 3 = Sometimes doesn’t work; 4 = Doesn’t make much of a difference; 5 = Sometimes works well; 6 = Almost always works well; and 7 = Always works well.

b. Summary Statistics for Survey Section 2

Table 6 shows the summary statistics for Section 2 of the SWA survey. In this section, participants were asked questions regarding their sleep patterns over the past 24 hours. Questions in this section included shading in the time intervals when the participant was allowed to sleep (S2Q1) and when the participant actually slept

(S2Q2), the total number of hours slept (S2Q3), the number of naps taken (S2Q4), how long it took to fall asleep (S2Q6), where the participant slept (S2Q7), the types of activities the participant performed (S2Q8), problems that the participant may have experienced (S2Q9), dreaming habits (S2Q10 & 11), and reasons why the participant may have had difficulty sleeping (S2Q12). The complete question and related scales/codes are provided in Appendix D.

	MIN	MAX	MEDIAN	MEAN	LOWER 95% CI	UPPER 95% CI	STD DEV	COUNT	NA	RESPONSE RATE
S2Q1	80.92	110.00	98.27	97.32	96.63	98.00	5.72	272	1	99.63%
S2Q2	80.92	104.74	96.65	95.60	95.08	96.12	4.36	272	1	99.63%
S2Q3	1	18	7	7.30	7.03	7.56	2.23	271	2	99.27%
S2Q4	0	8	0	0.63	0.51	0.74	0.93	272	1	99.63%
S2Q5	0	9	0	0.87	0.70	1.03	1.37	271	2	99.27%
S2Q6	1	7	4	3.74	3.56	3.92	1.53	271	2	99.27%
S2Q7(COT)	0	1	1	0.73	0.68	0.79	0.44	273	0	100.00%
S2Q7(BED)	0	1	0	0.22	0.17	0.27	0.42	273	0	100.00%
S2Q7(ONV)	0	1	0	0.02	0.00	0.03	0.13	273	0	100.00%
S2Q7(INV)	0	1	0	0.01	0.00	0.02	0.10	273	0	100.00%
S2Q7(GND)	0	1	0	0.01	0.00	0.02	0.09	273	0	100.00%
S2Q7(OTH)	0	1	0	0.00	0.00	0.01	0.06	273	0	100.00%
S2Q8(P)	0	1	0	0.10	0.06	0.13	0.29	273	0	100.00%
S2Q8(GDL4)	0	1	0	0.09	0.06	0.13	0.29	273	0	100.00%
S2Q8(GDM4)	0	1	0	0.18	0.13	0.22	0.38	273	0	100.00%
S2Q8(RW)	0	1	0	0.13	0.09	0.17	0.33	273	0	100.00%
S2Q8(DD)	0	1	0	0.11	0.07	0.15	0.31	273	0	100.00%
S2Q8(SD)	0	1	0	0.06	0.03	0.09	0.24	273	0	100.00%
S2Q8(DO)	0	1	0	0.03	0.01	0.05	0.18	273	0	100.00%
S2Q8(OM)	0	1	0	0.40	0.34	0.46	0.49	273	0	100.00%
S2Q8(OTHER)	0	1	0	0.25	0.20	0.30	0.44	273	0	100.00%
S2Q9(FALLING ASLEEP)	0	1	0	0.40	0.34	0.45	0.49	273	0	100.00%
S2Q9(WAKING UP)	0	1	0	0.26	0.20	0.31	0.44	273	0	100.00%
S2Q9(STAY ASLEEP)	0	1	0	0.38	0.32	0.44	0.49	273	0	100.00%
S2Q9(STAY AWAKE)	0	1	0	0.16	0.12	0.21	0.37	273	0	100.00%
S2Q10	0	1	0	0.48	0.42	0.54	0.50	271	2	99.27%
S2Q11	0	1	0	0.17	0.12	0.21	0.37	269	4	98.53%
S2Q12(NOISE)	0	1	0	0.37	0.31	0.42	0.48	273	0	100.00%
S2Q12(TEMP)	0	1	0	0.29	0.24	0.35	0.46	273	0	100.00%
S2Q12(LIGHT)	0	1	0	0.22	0.17	0.27	0.42	273	0	100.00%
S2Q12(PHYS DISCOMF)	0	1	0	0.30	0.25	0.36	0.46	273	0	100.00%
S2Q12(STRESS)	0	1	0	0.37	0.31	0.42	0.48	273	0	100.00%
S2Q12(OTHER)	0	1	0	0.10	0.06	0.13	0.30	273	0	100.00%

Table 6. Section 2 Summary Statistics.

The values reported here for questions S2Q1 and S2Q2 are the average predicted performance effectiveness scores for all non-sleep periods as determined by FAST using the sleep/wake histories reported in these questions. The process of computing these performance effectiveness scores was described in Chapter III.

From these summary statistics, we see that 73% of our sample reported sleeping on a cot for approximately 7.3 hours during the 24 hours preceding the survey. Some of the duties that were performed during the past 24 hours included unspecified operational missions (40%), guard duty last more than 4 hours (18%), radio watch (13%), duty driver (11%), and patrolling (10%). Our sample reported having trouble falling asleep (40%), staying asleep (38%), waking up (26%), and staying awake (16%). The major factors making it difficult for our sample to sleep include stress (37%), noise (37%), physical discomfort (30%), temperature (29%), and light (22%).

c. Summary Statistics for Survey Section 3

Table 7 shows the summary statistics for Section 3 of the SWA survey. In this section, participants were asked questions regarding their sleep patterns over the previous 7-day period. The questions asked in Section 3 of the survey were similar in nature to the questions asked in Section 2 and simply covered a longer time interval.

	MIN	MAX	MEDIAN	MEAN	LOWER 95% CI	UPPER 95% CI	STD DEV	COUNT	NA	RESPONSE RATE
S3Q1A(OverallAvg)	50.05	110.00	97.89	94.90	93.92	95.87	8.18	272	1	99.63%
S3Q1A(Last24Avg)	33.83	110.00	98.27	95.34	94.13	96.55	10.16	272	1	99.63%
S3Q1B(OverallAvg)	50.05	104.62	94.21	90.92	89.82	92.02	9.22	272	1	99.63%
S3Q1B(Last24Avg)	34.46	110.00	94.02	89.42	87.95	90.89	12.36	272	1	99.63%
S3Q2A	0	35	0	0.23	0.00	0.50	2.28	257	16	94.14%
S3Q2B	0	28	0	0.39	0.14	0.64	2.09	257	16	94.14%
S3Q2C	0	20	0	0.34	0.08	0.60	2.17	257	16	94.14%
S3Q2D	0	15	0	0.64	0.40	0.89	2.07	259	14	94.87%
S3Q2E	0	98	0	12.09	9.41	14.77	22.49	257	16	94.14%
S3Q2F	0	98	38	31.31	28.91	33.71	20.11	261	12	95.60%
S3Q3	2.5	14	6.5	6.67	6.49	6.86	1.55	272	1	99.63%
S3Q4	0	11	6	5.52	5.26	5.79	2.22	270	3	98.90%
S3Q5	0	9	1	1.60	1.37	1.83	1.93	271	2	99.27%
S3Q6	0	7	0	0.68	0.57	0.79	0.92	272	1	99.63%
S3Q7	0	9	0	0.77	0.62	0.92	1.28	261	12	95.60%
S3Q8A	0	7	3	3.14	2.82	3.46	2.70	272	1	99.63%
S3Q8B	0	7	0	0.66	0.46	0.86	1.67	270	3	98.90%
S3Q8C	0	7	1	2.34	2.02	2.67	2.73	269	4	98.53%
S3Q8D	0	7	0	0.54	0.37	0.70	1.40	270	3	98.90%
S3Q8E	0	7	3	2.85	2.53	3.18	2.70	272	1	99.63%
S3Q8F	0	7	0	1.45	1.21	1.69	2.02	268	5	98.17%
S3Q9A	0	7	2	2.53	2.25	2.81	2.37	271	2	99.27%
S3Q9B	0	7	0	0.94	0.75	1.14	1.65	264	9	96.70%
S3Q10A	0	7	2	2.48	2.20	2.77	2.39	272	1	99.63%
S3Q10B	0	7	0	0.21	0.10	0.31	0.90	270	3	98.90%
S3Q10C	0	7	0	0.67	0.50	0.84	1.44	269	4	98.53%
S3Q10D	0	7	0	0.61	0.44	0.79	1.47	270	3	98.90%
S3Q10E	0	7	1	1.95	1.68	2.22	2.25	271	2	99.27%
S3Q10F	0	7	0	1.11	0.87	1.36	2.06	270	3	98.90%
S3Q10G	0	7	0	1.26	1.01	1.51	2.07	270	3	98.90%
S3Q10H	0	7	0	0.66	0.47	0.84	1.52	270	3	98.90%
S3Q10I	0	7	0	0.23	0.12	0.34	0.91	267	6	97.80%
S3Q10J	0	7	0	0.39	0.24	0.54	1.25	270	3	98.90%
S3Q10K	0	7	0	1.05	0.80	1.30	2.08	267	6	97.80%
S3Q11	0	7	0	0.87	0.69	1.05	1.50	267	6	97.80%

Table 7. Section 3 Summary Statistics.

The values reported for S3Q1A(OverallAvg), S3Q1A(Last24Avg), S3Q1B(OverallAvg), and S3Q1B(Last24Avg) were computed in the same manner as S2Q1 and S2Q2. These values are the average predicted performance effectiveness scores during the specified non-sleep periods corresponding to the sleep/wake histories reported in questions S3Q1A and S3Q1B. These scores were calculated using the Fatigue Avoidance Scheduling Tool (FAST). As we can see in the summary statistics, there was a wide range in predicted performance effectiveness in our sample. We will look at the response values to these questions in greater depth when we answer our primary research questions.

The average participant in our sample reported getting 6.67 hours of sleep per day (S3Q3), most of which was on a cot (S3Q2F). The average participant reported taking a nap approximately every other day (S3Q6) for around 45 minutes (S3Q7) and 34% of our sample reported falling asleep at least once when they were supposed to be awake (S3Q12). Figure 17 shows the histogram for the approximate number of hours of sleep reported for the average day.

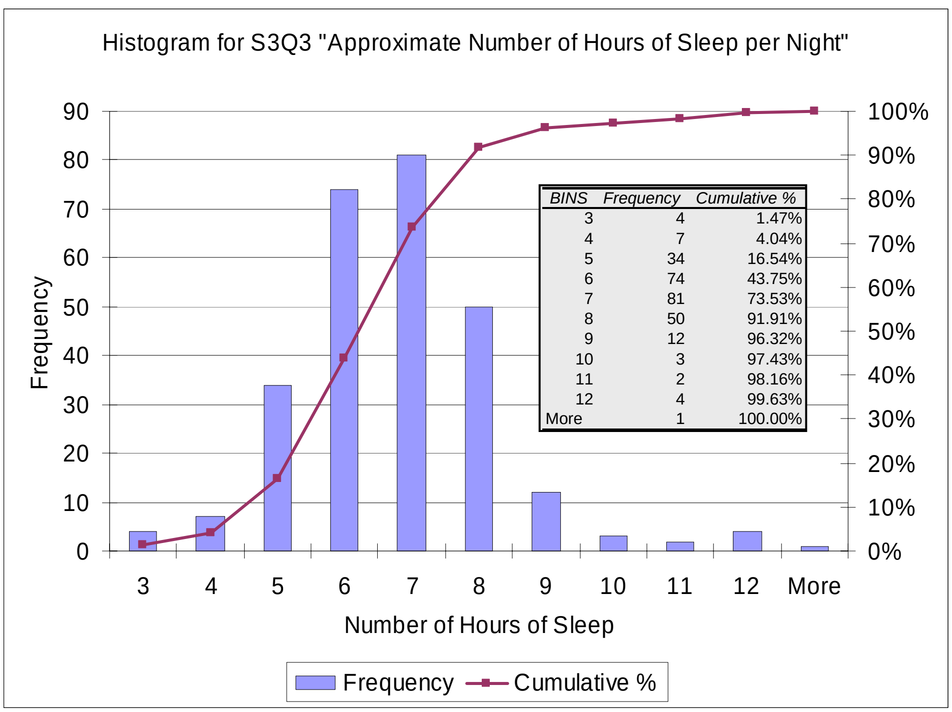


Figure 17. Histogram of responses to question S3Q3, which asks participants how many hours of sleep did they get every day (including naps).

Further, our sample indicated having trouble falling asleep in general (S3Q8A), staying asleep (S3Q8E), and waking up under normal conditions (S3Q8C). The histograms for S3Q8C, and S3Q8E look very similar to the histogram of S3Q8A, shown in Figure 18. That is, around 35% of the sample reports no trouble (response = 0) and around 20% report trouble seven days a week (response = 7).

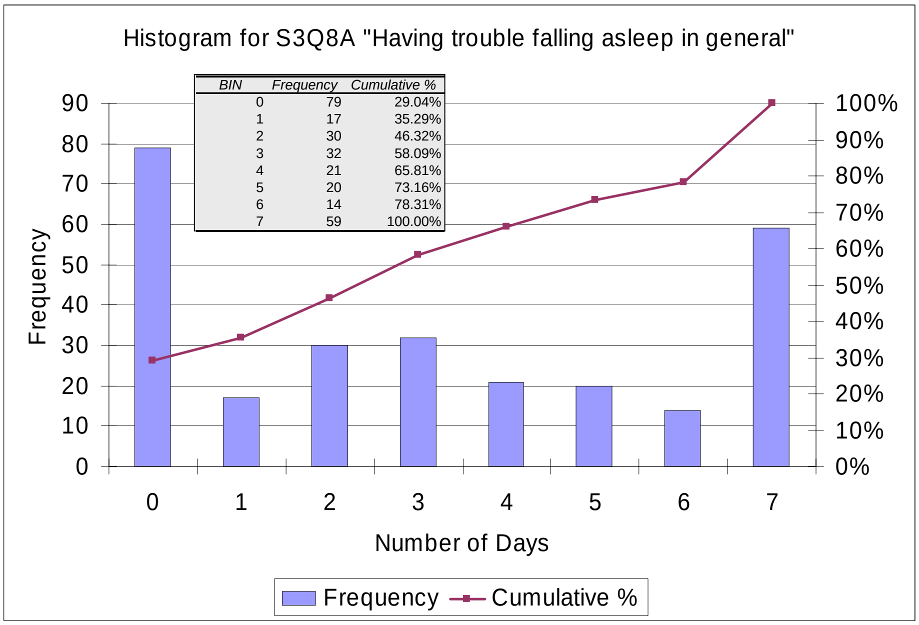


Figure 18. Histogram of responses to question S3Q8A, which asks participants how many times in the past week they had trouble falling asleep in general.

The most common reasons for having trouble sleeping or for waking up after falling asleep included having to go to the bathroom (S3Q10A) and not in a comfortable sleeping position (S3Q10E), shown in Figure 19.

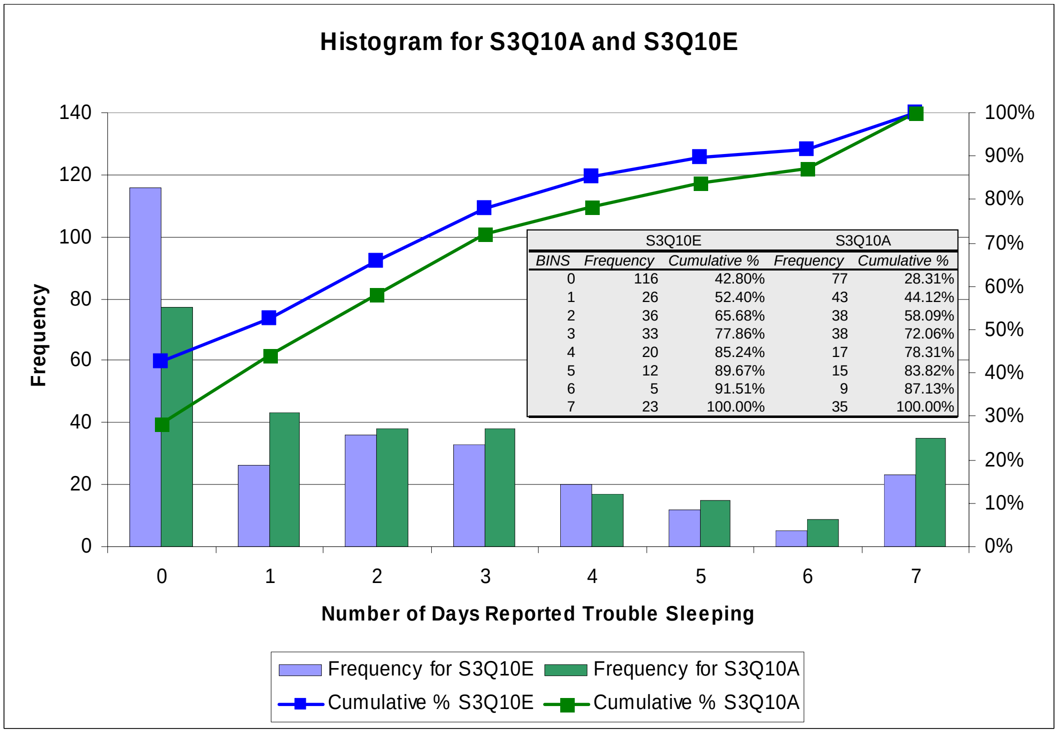


Figure 19. Histogram of responses to questions S3Q10A and S3Q10E, which asks participants how many times in the past week they had trouble sleeping or staying asleep because of the need to go to the bathroom or not being in a comfortable sleeping position.

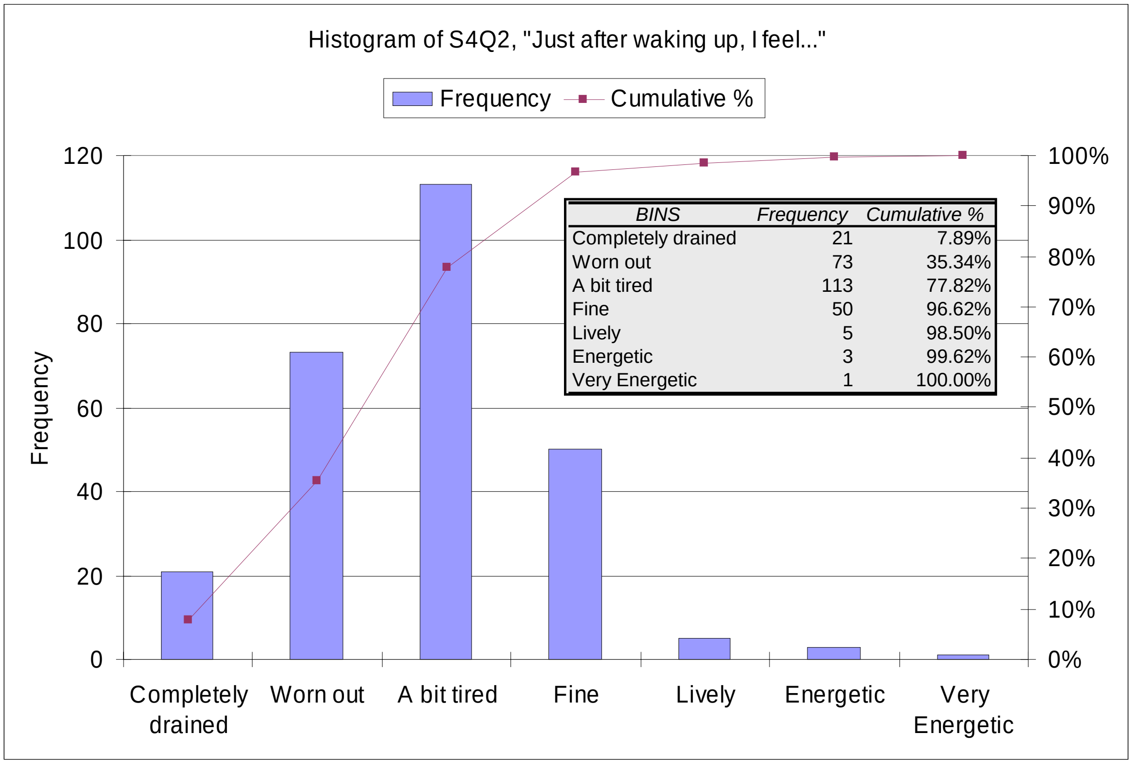
d. Summary Statistics for Survey Section 4

Table 8 shows the summary statistics for Section 4 of the SWA survey. This section asked participants additional questions regarding their recent sleep patterns that might indicate symptoms of sleep deprivation and sleep latency, such as difficulty concentrating, difficulty staying awake, experiencing noticeable mood changes, and how tired the participant felt just before going to bed and just after waking up.

	MIN	MAX	MEDIAN	MEAN	LOWER 95% CI	UPPER 95% CI	STD DEV	COUNT	NA	RESPONSE RATE
S4Q1	1	7	4	3.99	3.86	4.12	1.11	268	5	98.17%
S4Q2	1	7	3	2.84	2.72	2.96	1.00	266	7	97.44%
S4Q3	1	7	3	3.34	3.18	3.49	1.30	267	6	97.80%
S4Q4A	1	5	2	2.11	2.00	2.22	0.94	269	4	98.53%
S4Q4B	1	5	2	2.16	2.05	2.27	0.92	269	4	98.53%
S4Q4C	1	5	3	2.60	2.46	2.74	1.15	268	5	98.17%
S4Q4D	1	5	3	3.07	2.95	3.20	1.05	268	5	98.17%
S4Q4E	0	5	2	2.41	2.27	2.55	1.15	267	6	97.80%
S4Q4F	1	5	3	2.66	2.51	2.80	1.23	267	6	97.80%
S4Q4G	1	5	2	1.97	1.84	2.10	1.13	269	4	98.53%
S4Q4H	1	5	1	1.64	1.53	1.76	0.96	268	5	98.17%
S4Q4I	1	5	1	1.59	1.48	1.69	0.91	268	5	98.17%
S4Q4J	1	4	1	1.27	1.20	1.35	0.63	268	5	98.17%

Table 8. Section 4 Summary Statistics.

One indication of sleep deprivation is how a person feels shortly after waking up. Figure 20 shows the histogram associated with question S4Q2, which asks this very question. We see from the histogram that 77.82% of the sample indicated that they felt tired, worn-out, or drained shortly after waking up. While we will take a closer look at possible sleep deprivation in our sample shortly, this histogram indicates that sleep deprivation may be evident.



BINS	Frequency	Cumulative %
Completely drained	21	7.89%
Worn out	73	35.34%
A bit tired	113	77.82%
Fine	50	96.62%
Lively	5	98.50%
Energetic	3	99.62%
Very Energetic	1	100.00%

Figure 20. Histogram of responses to questions S4Q2, which asks participants how they feel shortly after waking up.

Other questions that may provide insight regarding sleep deprivation include S4Q4A through F. These questions ask the participant to report how often it is true that they feel so tired that they cannot concentrate (S4Q4A), how often they have difficulty staying awake (S4Q4B), how often they experience noticeable mood changes in themselves (S4Q4C) or others (S4Q4D), how often they have difficulty waking up or getting out of bed (S4Q4E), and how often they still feel tired 30 minutes after waking up (S4Q4F). While very few participants reported that these situations never occurred, S4Q4D had the most noticeably skewed distribution to the right. The histogram for this question is provided in Figure 21.

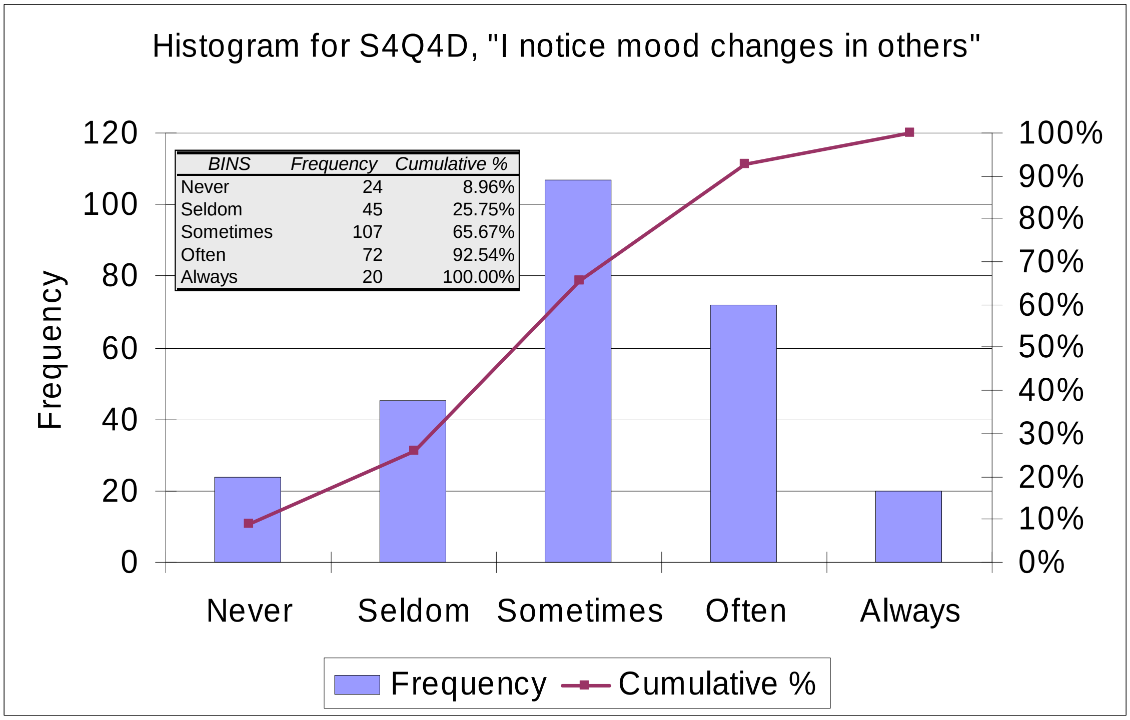


Figure 21. Histogram of responses to questions S4Q4D, which asks participants how often they notice mood changes in others.

e. Summary Statistics for Survey Section 5

Table 9 shows the summary statistics for Section 5 of the SWA survey. This section asked participants about their physical fitness level, which is an important lifestyle factor that may help or hinder restorative sleep.

	MIN	MAX	MEDIAN	MEAN	LOWER 95% CI	UPPER 95% CI	STD DEV	COUNT	NA	RESPONSE RATE
S5Q1	0	36	6	7.70	6.93	8.47	6.48	257	16	94.14%
S5Q2	1	7	4	4.12	3.92	4.32	1.66	269	4	98.53%
S5Q3	0	1	0	0.47	0.41	0.53	0.50	255	18	93.41%

Table 9. Section 5 Summary Statistics.

The average participant in our sample reported 7.7 hours of physical fitness per week and indicated that their fitness level remained about the same when compared with their fitness level prior to deployment. Approximately 47% of our sample indicated that they were pleased with their current fitness level.

f. Summary Statistics for Survey Section 6

Table 10 shows the summary statistics for Section 6 of the SWA survey. This section asked participants questions about their personal use of nicotine products. Nicotine use is another lifestyle factor that research suggests may help or hinder restorative sleep.

	MIN	MAX	MEDIAN	MEAN	LOWER 95% CI	UPPER 95% CI	STD DEV	COUNT	NA	RESPONSE RATE
S6Q1	0	1	1	0.56	0.50	0.62	0.50	269	4	98.53%
S6Q2	1	8	3	3.56	3.25	3.87	2.57	268	5	98.17%
S6Q2(DNU)	0	1	0	0.42	0.36	0.48	0.49	268	5	98.17%
S6Q2(USE)	1	7	4	4.40	4.18	4.61	1.81	156	117	57.14%
S6Q3	0	21	2	6.91	5.96	7.86	8.00	266	7	97.44%

Table 10. Section 6 Summary Statistics.

While entering the data, we noticed several participants indicate that they had used nicotine products in the previous week (yes response to S6Q1), but then indicate that they did not use nicotine products in question S6Q2. It appears that this question was misunderstood because of the wording used in S6Q2. Overall, the data seem fairly consistent with 56% of the sample indicating that they did use nicotine products during the past week (S6Q1) and 42% of the sample indicating that they did not use nicotine products (S6Q2(DNU)). For those participants who did use nicotine products, the average use was 6 to 7 times a day, which was reported to be about the same level of usage before deployment.

g. Summary Statistics for Survey Section 7

Table 11 shows the summary statistics for Section 7 of the SWA survey. This section asked participants about their use of caffeine. Caffeine is a widely used and effective fatigue countermeasure and may help to increase performance when used in moderation. However, when used too close to bedtime, caffeine can hinder one's ability to sleep.

	MIN	MAX	MEDIAN	MEAN	LOWER 95% CI	UPPER 95% CI	STD DEV	COUNT	NA	RESPONSE RATE
S7Q1	1	8	3	3.69	3.45	3.92	1.97	270	3	98.90%
S7Q1(DNU)	0	1	0	0.13	0.09	0.17	0.34	270	3	98.90%
S7Q1(USE)	1	7	3	3.11	2.89	3.32	1.78	234	39	85.71%
S7Q2	0	21	2	2.96	2.57	3.34	3.25	269	4	98.53%
S7Q3	0	1	0	0.05	0.02	0.07	0.21	265	8	97.07%
S7Q4	0	1	0	0.08	0.04	0.11	0.27	264	9	96.70%

Table 11. Section 7 Summary Statistics.

The summary statistics for this section indicate that 13% of the sample did not use caffeine products of any kind. Of those who did use caffeine products, the average participant indicated that he or she consumed 2 to 3 caffeinated beverages per day, which was a little less than the amount consumed prior to deployment. Further, a very small number in the sample reported using products to help enhance their performance, such as Ripped Fuel or Metabolife (8%), and fewer reported using products that helped them stay awake, such as NoDOZ or Vivarin (5%).

h. Summary Statistics for Survey Section 8

Table 12 shows the summary statistics for Section 8 of the SWA survey. This section asked participants questions regarding their use of prescribed and/or over-the-counter medications. As with nicotine, caffeine, and performance enhancing products, medications are important lifestyle factors that should be taken into consideration when assessing sleep patterns and/or problems related to sleep.

	MIN	MAX	MEDIAN	MEAN	LOWER 95% CI	UPPER 95% CI	STD DEV	COUNT	NA	RESPONSE RATE
S8Q1(MALARIA)	0	1	1	0.56	0.50	0.62	0.50	273	0	100.00%
S8Q1(PAIN)	0	1	0	0.22	0.17	0.27	0.41	273	0	100.00%
S8Q1(SLEEP AID)	0	1	0	0.04	0.02	0.07	0.21	273	0	100.00%
S8Q1(NO DOSE)	0	1	0	0.01	0.00	0.03	0.12	273	0	100.00%
S8Q1(OTHER)	0	2	0	0.20	0.15	0.25	0.41	273	0	100.00%
S8Q2	0	3	0	0.02	0.00	0.05	0.21	273	0	100.00%
S8Q3	0	3	0	0.18	0.13	0.23	0.43	273	0	100.00%

Table 12. Section 8 Summary Statistics.

While all servicemembers deployed to the SWA region were required to take the malaria pill, only 56% reported doing so. Initially, this figure was thought to have been a mistake, but upon further investigation, it was confirmed by personnel with first hand experience that many of the servicemembers deployed to the SWA region stopped taking the malaria pill due to perceived or actual side effects. Some participants reported to the survey administrator that they believe the malaria pill was hindering their ability to sleep and causing them to have bad dreams (Burnett, personal communication 16 Jan 2004).

i. Summary Statistics for Survey Section 9

Table 13 shows the summary statistics for Section 9 of the SWA survey. This section was originally designed to capture the possibility that a servicemember's sleep may be hindered if they were required to perform extra duties as a result of punishment. In hindsight, these questions should not have been included in this study because the expected population is very small.

	MIN	MAX	MEDIAN	MEAN	LOWER 95% CI	UPPER 95% CI	STD DEV	COUNT	NA	RESPONSE RATE
S9Q1	0	1	0	0.00	0.00	0.01	0.06	267	6	97.80%
S9Q2	0	1	0	0.01	0.00	0.02	0.11	267	6	97.80%
S9Q3	0	1	0	0.03	0.01	0.06	0.18	267	6	97.80%

Table 13. Section 9 Summary Statistics.

Now that we have a good understanding of what questions were asked and what the responses to those questions were for this sample, we are ready to address the four primary research questions.

C. RESULTS FOR RESEARCH QUESTION #1

Is sleep deprivation a significant problem for forces currently deployed to the SWA region?

In order to answer this question, we will first look at the reported sleep habits of our participants. From the summary statistics, we find several key pieces of information that help address this question, such as the sample mean for the number of hours of sleep per day, the number of naps per day, and the duration of naps. Based on the reported times when our sample slept, we are able to plot the proportion of the sample that was awake during a given time period, shown in Figure 22.

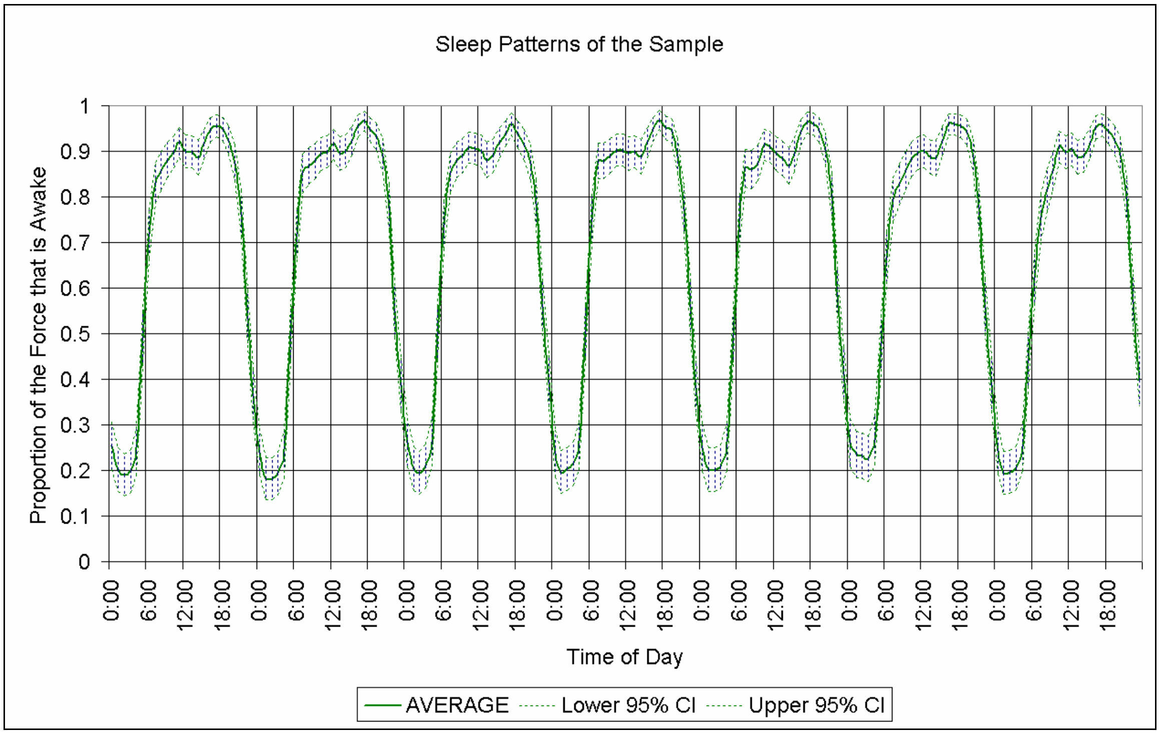


Figure 22. Sleep patterns of the sample based on the sleep/wake histories reported over a 7-day period (S3Q1B).

If we were to assume that our sample was required to operate around the clock in support of continuous operations, we might expect that the proportion of the population that was asleep at any given time would be no higher than 75% and no lower than 25%. While subjective, it could be argued that a substantial force, say 25% of the total force structure, is required to maintain a credible force to support continuous operations during any given time. The data shown in Figure 22, however, indicate that the sample consisted primarily of diurnal participants sleeping from 2200 to 0530. On average, less than 20% of the force was awake from 2400 to 0400 and less than 15% of the force was asleep from 0800 to 2000.

Another interesting observation drawn from Figure 22 is that the plot resembles that of the natural circadian rhythm, shown again in Figure 23 and discussed in Chapter II. Notice that the sleep patterns of our sample are almost identical to the alertness plot of the natural circadian rhythm with a peak around 1100, followed by a mid-afternoon dip around 1300, a second peek around 1800, and a deep trough around 0400. The similarity in Figures 22 and 23 may suggest that this sample has not deviated from their natural biological rhythm. That is, circadian desynchronization has not occurred as might be expected if the population were required to conduct military operations around the clock.

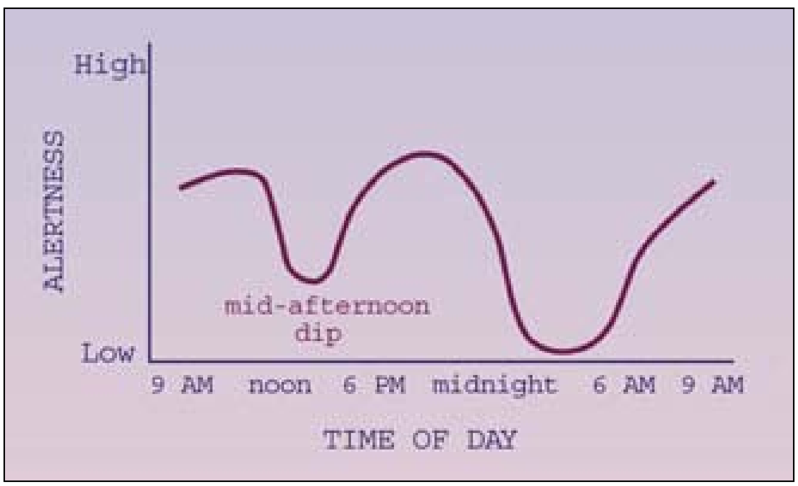


Figure 23. The Circadian Rhythm (From: NSF, 2003).

We know that a significant number of our sample were required to support flight operations, convoy operations, raids, and patrols during Phase IV operations of OIF and throughout the data collection phase. Therefore, in order to evaluate the impact of these around-the-clock requirements on our sample, we will consider the predicted performance effectiveness scores for the 50^{th}, 25^{th}, and 10^{th}

percentiles of our sample based on the sleep/wake schedules reported in question S3Q1B.

The first example represents the median sleep/wake schedule: 50% of the sleep/wake histories reported by our sample had lower average predicted performance effectiveness scores than the average score for the participant (P010) whose sleep/wake schedule and corresponding performance effectiveness is shown in Figure 24.

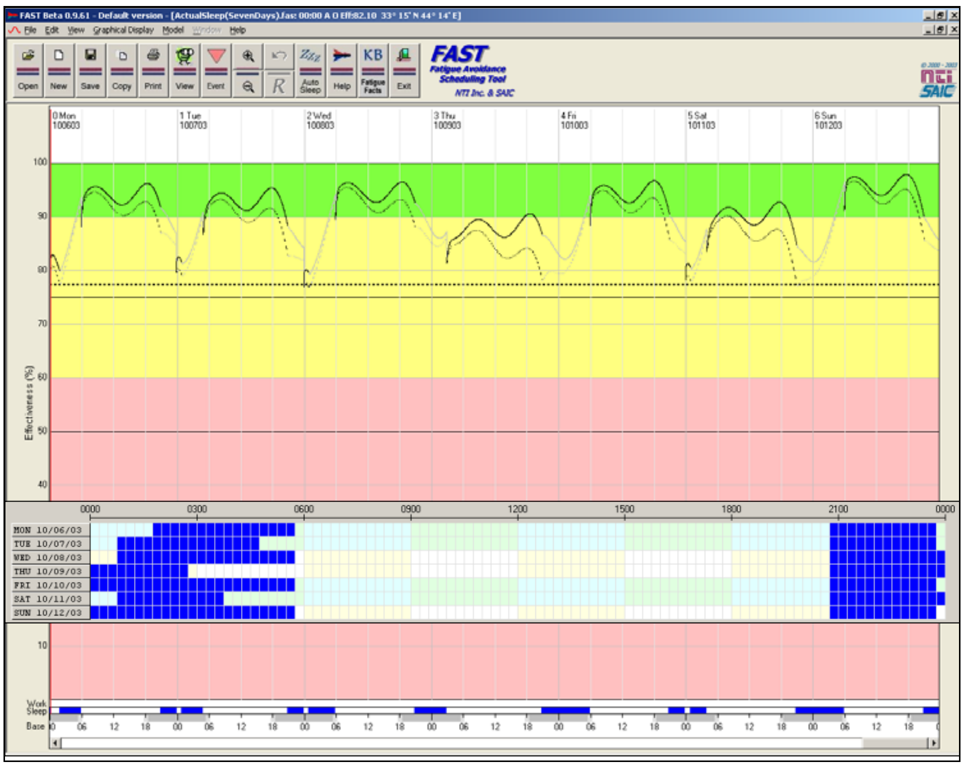


Figure 24. Graphical view of the predicted performance effectiveness for a large population based on the sleep/wake schedule reported by participant P010 on question S3Q1B.

The predicted effectiveness plot for participant P010, shown in Figure 24, has an average score of 94% during all waking periods for a typical person. If, however, the person working this schedule is sensitive to changes in sleep patterns, we see (from the dashed lines in the plot) that the majority of the performance effectiveness remains in the cautionary (yellow) zone for effectiveness.

The second example represents the 25th percentile: 25% of the sleep/wake histories reported by our sample had lower average effectiveness scores than the participant (P154) whose sleep/wake schedule and corresponding performance effectiveness is shown in Figure 25.

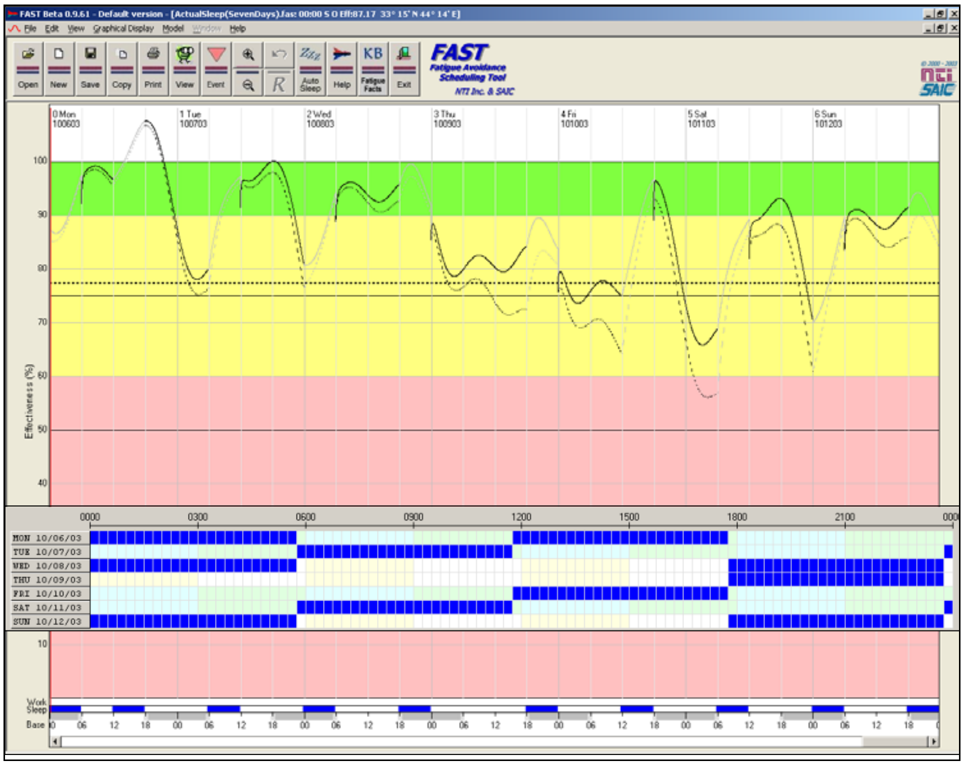


Figure 25. Graphical view of the predicted performance effectiveness for a large population based on the sleep/wake schedule reported by participant P154 on question S3Q1B.

The predicted performance effectiveness plot for participant P154, shown in Figure 25, has an average performance effectiveness score of 87% during all waking periods for a typical person and regularly dips below our criterion line of 77.5%. If however, the person working this schedule is sensitive to changes in sleep patterns, we see (from the dashed lines in the plot) that the majority of the performance effectiveness remains in the cautionary (yellow) zone for effectiveness and even dips below 50% effective (red zone). Remembering that a performance effectiveness score of 77.5% is equivalent to the performance of a person with a 0.08 BAC level, and that a performance effectiveness score of 50% is equivalent to the performance of a person with a 0.15 BAC level, these performance scores are clearly unsatisfactory for military operations.

The third example represents the 10th percentile: 10% of the sleep/wake histories reported by our sample had lower average effectiveness scores than the participant (P054) whose sleep/wake schedule and corresponding performance effectiveness is shown in Figure 26.

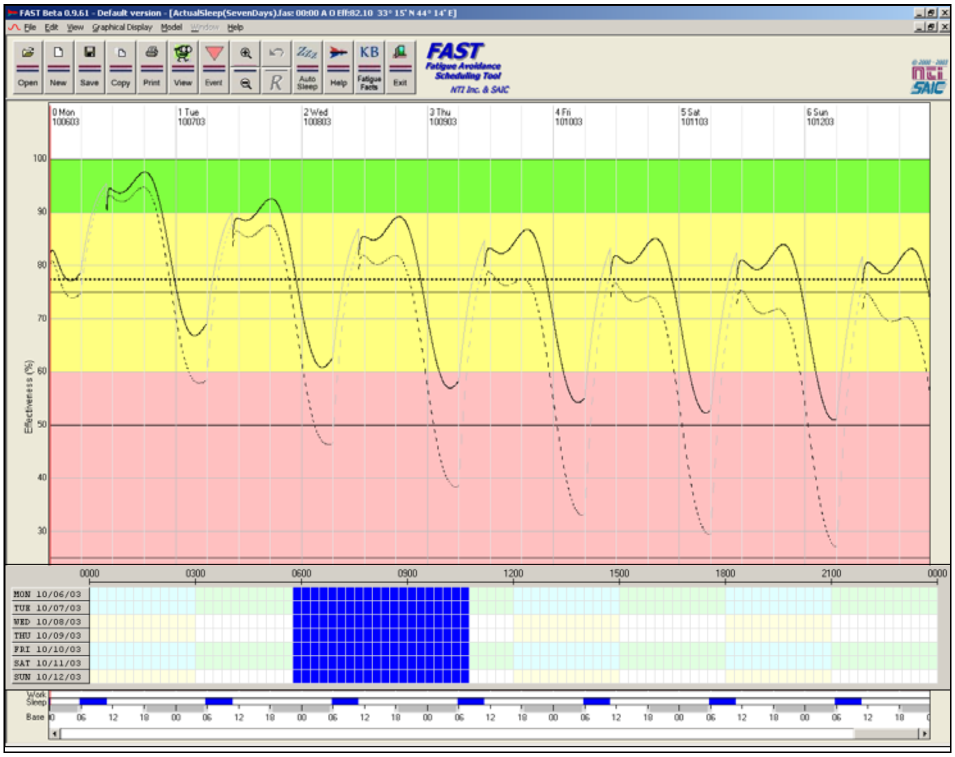


Figure 26. Graphical view of the predicted performance effectiveness for a large population based on the sleep/wake schedule reported by participant P054 on question S3Q1B.

The predicted effectiveness plot for participant P054, shown in Figure 26, has an average score of 77% during all waking periods for a typical person, which is below our criterion of 77.5%. If the person working this schedule is sensitive to changes in sleep patterns, we see (from the dashed lines in the plot) that a significant amount of time this person is awake is spent below the 50% effectiveness threshold. When considering the equivalent BAC levels for the performance effectiveness of this schedule, it is evident that this schedule and the 10% that are worse than this schedule are clearly unsatisfactory for military operations.

Now that we have established that there is evidence of sleep deprivation among the sample, we will analytically test the scope of the problem by using a factor score for symptoms of sleep deprivation.

1. Factor Scores for Sleep Deprivation

In order to test whether or not sleep deprivation is a significant problem for the sample, we need a way to designate a participant as "demonstrating significant symptoms of sleep deprivation" or "not demonstrating significant symptoms of sleep deprivation." We will do this using the results of factor analysis (Hand et al., 2001; Hamilton, 1992; IC, 2001). Specifically, we will use the underlying factor in the data that measures sleep deprivation symptoms. We will explain factor analysis and principal components analysis in greater detail when we answer the fourth research question. For now, however, we will assume that the data may be successfully summarized as a linear combination of the known variables as a factor that measures sleep deprivation (Hand et al., 2001; Hamilton, 1992; IC, 2001).

After constructing a factor analysis model using 50 factors, we found that our second factor satisfactorily measures sleep deprivation. Specifically, this factor is heavily loaded on the observed values for questions S4Q2, S4Q3, S4Q4A, S4Q4B, S4Q4C, S4Q4D, S4Q4E, and S4Q4F, which refer to clear symptoms of sleep deprivation as discussed during our review of the literature in Chapter II, and which were summarized earlier in this chapter. After constructing the factor from the linear combination of the known variables, the resulting factor score is derived from the responses or values of the original variables. This factor score then provides us with a single measure of sleep deprivation.

Table 14 shows the factor loadings used in the linear combination of the original variables to compute the factor of sleep deprivation. Notice that this factor is heavily loaded on the questions previously mentioned that indicate symptoms of sleep deprivation.

SLEEP DEPRIVATION FACTOR

ORIGINAL OBSERVED VARIABLE	FACTOR LOADINGS	ORIGINAL OBSERVED VARIABLE	FACTOR LOADINGS	ORIGINAL OBSERVED VARIABLE	FACTOR LOADINGS
S1Q1	-0.0665	S3Q1A(OverallAvg)	-0.0282	**S4Q3**	-0.6605
S2Q1	0.0527	S3Q1A(Last24Avg)	-0.0256	**S4Q4A**	0.6350
S2Q2	-0.0495	S3Q1B(OverallAvg)	-0.1492	**S4Q4B**	0.4405
S2Q3	-0.1021	S3Q1B(Last24Avg)	-0.1234	**S4Q4C**	0.5923
S2Q4	-0.0433	S3Q2F	-0.0220	**S4Q4D**	0.4918
S2Q5	0.0098	S3Q3	-0.1939	**S4Q4E**	0.5588
S2Q6	0.1010	S3Q4	-0.2164	**S4Q4F**	0.7662
S2Q7(COT)	0.0670	S3Q5	0.0943	S4Q4G	0.2967
S2Q7(BED)	-0.0528	S3Q6	-0.0525	S4Q4H	0.1421
S2Q7(INV)	-0.0140	S3Q7	-0.0377	S4Q4I	0.1798
S2Q7(GND)	-0.0189	S3Q8A	0.1876	S4Q4J	0.1113
S2Q8(P)	-0.0007	S3Q8B	-0.0391	S5Q2	-0.0757
S2Q8(GDL4)	0.0167	S3Q8C	0.0695	S6Q1	0.0586
S2Q8(GDM4)	0.0197	S3Q8D	0.1085	S6Q2	-0.0258
S2Q8(RW)	-0.0580	S3Q8E	0.2038	S6Q2(DNU)	0.0105
S2Q8(DD)	0.0105	S3Q8F	0.1839	S6Q3	0.0457
S2Q8(SD)	0.0332	S3Q9A	-0.0944	S7Q1	0.0515
S2Q8(DO)	0.0282	S3Q9B	0.1236	S7Q1(DNU)	-0.0205
S2Q8(OM)	-0.0050	S3Q10A	0.0865	S7Q2	0.1181
S2Q8(OTHER)	-0.0093	S3Q10B	0.0894	S7Q3	0.0118
S2Q9(FALLING ASLEEP)	0.0657	S3Q10C	0.0740	S7Q4	0.0140
S2Q9(WAKING UP)	0.2486	S3Q10D	0.0056	S8Q1(MALARIA)	0.0466
S2Q9(STAY ASLEEP)	0.0807	S3Q10E	0.2103	S8Q1(PAIN)	0.1125
S2Q9(STAY AWAKE)	0.2084	S3Q10F	0.3678	S8Q1(SLEEP AID)	0.0414
S2Q10	-0.0862	S3Q10G	0.1486	S8Q1(NO DOSE)	-0.0687
S2Q11	0.1699	S3Q10H	0.0587	S8Q1(OTHER)	0.0602
S2Q12(NOISE)	0.0690	S3Q10I	-0.0737	S8Q2	0.1251
S2Q12(TEMP)	-0.0335	S3Q10J	0.0863	S8Q3	0.0312
S2Q12(LIGHT)	0.0652	S3Q10K	0.3379	S9Q2	0.0212
S2Q12(PHYS DISCOMF)	0.1034	S3Q11	0.1379	S9Q3	-0.0876
S2Q12(STRESS)	0.2432	S4Q1	-0.0790		
S2Q12(OTHER)	0.0843	**S4Q2**	-0.7126		

Table 14. Factor loadings used to linearly combine the original variables into the underlying factor of sleep deprivation. This factor is heavily loaded on the questions pertaining to symptoms of sleep deprivation.

Factor scores are computed for each participant by multiplying the factor loadings for the original variables by the normalized values for the original observed variables. That is, if x_i is the vector of observed values for participant i, then z_i is the vector of normalized values for the observed values for participant i, where the elements of z_i are normalized by subtracting the corresponding sample mean and dividing by the corresponding sample standard deviation. Letting l be the vector of loadings shown in Table 14, then the factor score for participant i is given as, $s_i = z_i^T * l$. Figure 27 is the resultant histogram of the factor scores for this sleep deprivation factor for the sample.

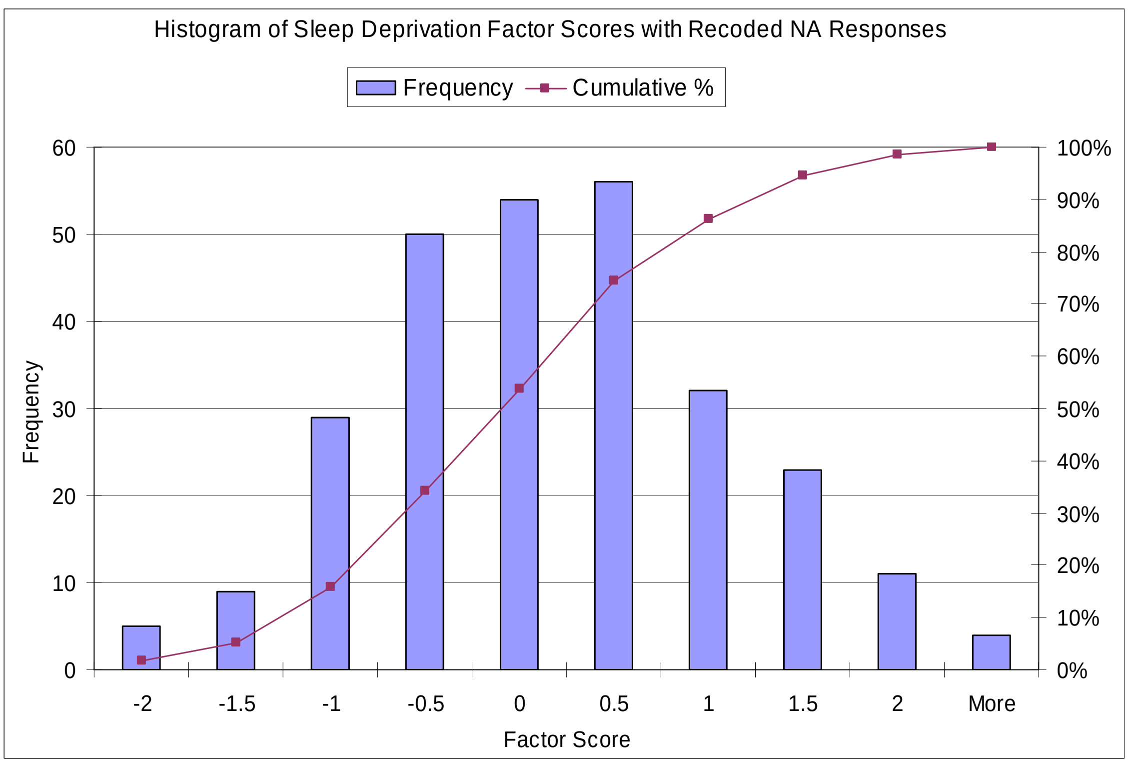


Figure 27. Histogram of sleep deprivation factor scores for the entire sample (n = 273) with NA responses recoded as zeros.

When computing the factor scores, NA responses are not allowed. Therefore, we recode the NA responses as zeros in order to provide insight regarding the overall indication of sleep deprivation. This substitution of zeros for NA responses will simply exclude the loading on a particular observed variable rather than discard the entire participant's factor score as NA. Table 15 lists the summary statistics related to Figure 27.

Summary Statistics for Sleep Deprivation Factor Scores with Recoded NA Responses

Summary Statistics	
Total Count	273
Minimum Score	-4.6317
Maximum Score	2.4411
Median Score	-0.0949
Mean Score	-0.0810
Lower 95% CI	-0.1967
Upper 95% CI	0.0347
Variance	0.9430
Std Dev	0.9711

Factor Score	*Frequency*	*Cumulative %*
-2	5	1.83%
-1.5	9	5.13%
-1	29	15.75%
-0.5	50	34.07%
0	54	53.85%
0.5	56	74.36%
1	32	86.08%
1.5	23	94.51%
2	11	98.53%
More	4	100.00%

Table 15. Summary statistics for sleep deprivation factor scores with recorded NA responses.

However, since recoding NA responses as zeros may have the tendency to drive the entire factor score to zero and thus falsely indicate moderate symptoms of sleep deprivation, we will want to compare the results of the recoded NA responses with the results excluding participants with NA responses to ensure that our results hold. Therefore, rather than recoding NA responses as zeros, we will simply exclude participants who did not answer all of the survey questions. Figure 28 is the histogram of the factor scores for our sleep deprivation factor for the subset of the sample not containing NA responses, and the resultant summary statistics are provided in Table 16. Notice that the subset of the sample excluding NA responses is similar to the sample with NA responses coded as zeros. This suggests that those who did not answer all of the survey questions are reasonably the same as those who did answer all of the questions as far as sleep deprivation scores are concerned.

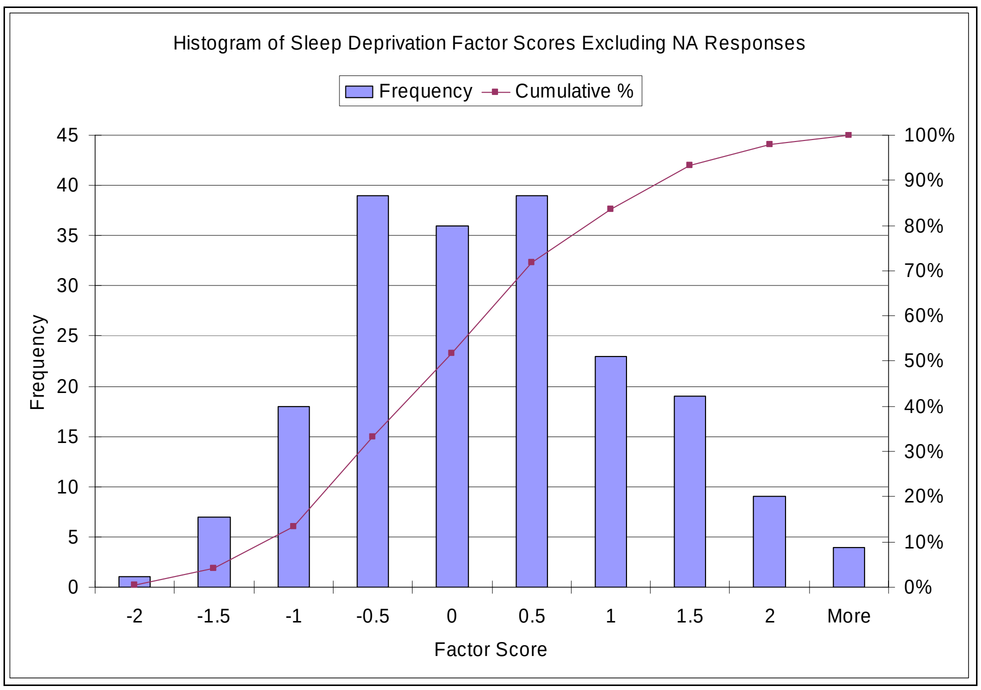


Figure 28. Histogram of sleep deprivation factor scores for the entire sample (n = 195) with NA responses recoded as zeros.

Summary Statistics for Sleep Deprivation Factor Scores excluding NA Responses

Summary Statistics	
Total Count	195
Minimum Score	-2.1785
Maximum Score	2.4411
Median Score	-0.0754
Mean Score	0.0000
Lower 95% CI	-0.1344
Upper 95% CI	0.1344
Variance	0.9060
Std Dev	0.9518

Factor Score	*Frequency*	*Cumulative %*
-2	1	.51%
-1.5	7	4.10%
-1	18	13.33%
-0.5	39	33.33%
0	36	51.79%
0.5	39	71.79%
1	23	83.59%
1.5	19	93.33%
2	9	97.95%
More	4	100.00%

Table 16. Summary statistics for sleep deprivation factor scores excluding participants with NA responses.

Based on our analysis of the sleep deprivation factor scores, we estimate that an individual who shows very few or no symptoms of sleep deprivation has a score of –0.8 or smaller, a person who shows some or moderate signs of sleep deprivation has a score between –0.8 and 0.8, and a person who shows significant signs of sleep deprivation has a score of 0.8 or greater. These values were subjectively chosen after using our factor analysis model to predict factor scores for survey responses that indicated varying degrees of sleep deprivation symptoms. Based on this assessment, Figure 29 shows the distribution of the sample into these three levels of sleep deprivation.

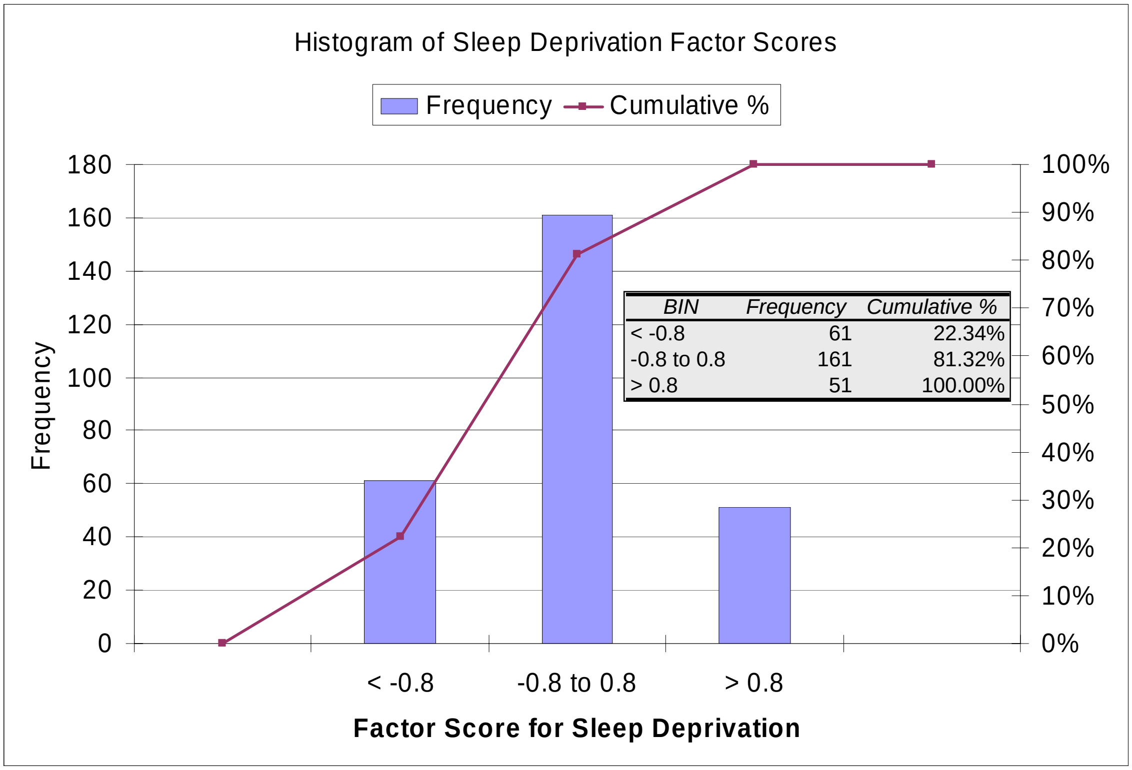


Figure 29. Histogram of sleep deprivation factor scores for the sample where scores < -0.8 indicate few or no signs of sleep deprivation, scores between –0.8 and 0.8 indicate some to moderate signs of sleep deprivation, and scores > 0.8 indicate significant signs of sleep deprivation. NA responses are coded as zeros.

From Figure 29, we see that over 77% of the sample show signs of sleep deprivation, ranging from some to significant, with a 95% confidence interval from 72.7% to 82.6% (n = 273, std dev = 0.025). Further, we see that over 18% of the sample shows significant signs of sleep deprivation with a 95% confidence interval from 14.0% to 23.3% (n = 273, std dev = 0.024). While it is ultimately up to the decision maker as to whether this is a satisfactory or unsatisfactory level of sleep deprivation, the data clearly show that sleep deprivation is a significant problem facing the sample in the SWA region.

The next logical question to ask is if there is a significant difference between warfighters conducting operations in Iraq and warfighters in Kuwait. We will address the broader issue of comparing sleep patterns of warfighters in Iraq with the sleep patterns of warfighters in Kuwait later in this chapter, but it seems appropriate to compare the problem of sleep deprivation in these two locations here.

To this end, we will again use the factor scores as an indication of sleep deprivation and classify each participant as showing symptoms of sleep deprivation or not showing symptoms of sleep deprivation. As we did previously, we will assume that a participant with a factor score greater than –0.8 is showing symptoms of sleep deprivation. Using this threshold value, we test the hypothesis that the probability of a participant in Iraq showing symptoms of sleep deprivation is greater than the probability of a participant in Kuwait showing symptoms of sleep deprivation. Recall that we computed our factor scores for sleep deprivation two ways: coding NA responses as zeros; and omitting participants with NA responses altogether. The observed values for our sample with NA responses coded as zeros are shown in Table 17 and the observed values for our sample omitting NA responses are shown in Table 18.

	Class 1: Factor Score suggests no symptoms of sleep deprivation	**Class 2:** Factor Score suggests sleep deprivation	
Sample 1: Iraq	O_{11} =35	O_{12} =154	n_1 =189
Sample 2: Kuwait	O_{21} =24	O_{22} =53	n_2 =77
	C_1 =59	C_2 =207	N =266

Table 17. The 2 X 2 contingency table of observed values for factor scores indicating sleep deprivation with NA responses coded as zeros. N = 266 because 7 participants in our sample (P041, P268, P269, P270, P271, P272, and P273) did not respond to the question asking if they were located in either Iraq or Kuwait (After: Conover, 1999).

Since we have a large sample and it is reasonable to assume that the survey responses for Iraq are independent of those from Kuwait, we will use a large-sample test procedure concerning the differences between proportions Devore, 2000) with the variables shown in Tables 17 and 18 defined as follows:

O_{ij} = Observed value corresponding to row i, column j.

C_1 = Total count of participants not showing symptoms of sleep deprivation as indicated by factor score.

C_2 = Total count of participants showing symptoms of sleep deprivation as indicated by factor score.

n_1 = Total number of participants sampled in Iraq.

n_2 = Total number of participants sampled in Kuwait.

N = Total number of participants sampled.

Letting $p_1 = \Pr\{\text{symptoms of sleep deprivation, Iraq}\}$, and $p_2 = \Pr\{\text{symptoms of sleep deprivation, Kuwait}\}$, the hypothesis we wish to test is (Devore, 2000):

$$H_0: p_1 - p_2 \le 0$$
$$H_A: p_1 - p_2 > 0$$

The test statistic for the large-sample test of difference between proportions is (Devore, 2000):

$$z = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{\hat{p}\hat{q}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \text{ where } \hat{p}_1 = \frac{O_{11}}{n_1}, \hat{p}_2 = \frac{O_{21}}{n_2}, \hat{p} = \frac{C_1}{N}, \text{ and } \hat{q} = \frac{C_2}{N}$$

Using the observed values shown in Table 17, z = 2.252 with a p-value of 0.0122, which shows that the probability of sleep deprivation in Iraq is statistically higher than the probability of sleep deprivation in Kuwait.

Since recoding NA responses as zeros may have the tendency to drive the factor score to zero, we must also test to see if our results hold if we consider the factor scores that exclude NA responses. The observed values for our two samples are shown in Table 18.

	Class 1: Factor Score suggests no symptoms of sleep deprivation	Class 2: Factor Score suggests sleep deprivation	
Sample 1: Iraq	$O_{11}=20$	$O_{12}=108$	$n_1=128$
Sample 2: Kuwait	$O_{21}=18$	$O_{22}=44$	$n_2=62$
	$C_1=38$	$C_2=152$	$N=190$

Table 18. The 2 X 2 contingency table of observed values for factor scores indicating sleep deprivation with NA responses omitted. N = 190 because 83 participants had at least one unanswered (NA) response that could not be used to compute the factor score (After: Conover, 1999).

Using the observed values shown in Table 18, $z=2.166$ with a p-value of 0.0151, which again shows that the probability of sleep deprivation in Iraq is statistically higher than the probability of sleep deprivation in Kuwait regardless of how we handle NA responses. Thus, this analysis offers additional evidence that sleep deprivation is a significant problem throughout the SWA region and especially in Iraq.

D. RESULTS FOR RESEARCH QUESTION #2

Do current sleep patterns of forces operating in SWA support a unit’s ability to accomplish assigned missions?

From question S3Q1B, we are able to obtain predicted performance effectiveness scores for the reported sleep/wake schedule by using the Fatigue Avoidance Scheduling Tool (FAST). Using these data, we test the hypothesis that the proportion of sleep patterns supporting mission accomplishment is greater than 75%. The Binomial Test for Proportions (Conover, 1999) is appropriate because the sample consists of the outcomes of $n = 273$ independent trials, where each outcome is in either "class 1" or "class 2," but not both. Here, we will define class 1 to be individuals whose predicted performance effectiveness score remains above 77.5% effective during waking hours, and class 2 to be individuals whose predicted performance effectiveness score drops below 77.5% effective during waking hours. While we are free to use any criteria we wish, the criterion of 77.5% effective is based on the requirements established by the military customers involved in the development of FAST; it also corresponds to the performance effectiveness level after missing one full night of sleep or after being awake for over 24 hours. Since the performance effectiveness of an individual who has been awake for 24 hours is equivalent to the performance effectiveness of a person with a 0.08 BAC level (Dawson & Reid, 1997), this criterion of 77.5% effective seems like a reasonable lower limit for satisfactory performance. Using this criterion, we will let the number in class 1 be O_1 and the number in class 2 be $O_2 = n - O_1$.

We will assume that the n trials are mutually independent and that each trial has probability p of resulting in the outcome "class 1," where p is the same for all n trials. For this situation, it seems reasonable to assume that the sleep patterns of SWA warfighters support the accomplishment of assigned missions if greater than 75% of all forces are able to maintain predicted performance effectiveness scores greater than 77.5%. In general, a unit is considered mission capable when 75% of its personnel and equipment are fully ready for duty. Therefore, it seems reasonable to assume that if less than 75% of the total force is maintaining a satisfactory performance effectiveness level, the force is hindered in accomplishing assigned missions.

For values of p greater than 0.75, we can assume that the sleep patterns of SWA warfighters supports mission accomplishment. Therefore, we are interested in conducting a lower-tailed test to see if the probability of sleep patterns supporting mission accomplishment is less than 75% ($p*$ = 0.75):

$$H_o : p \geq p*$$
$$H_A : p < p*$$

For our sample of $n = 273$ sleep patterns, only 140 sleep patterns successfully maintain predicted performance effectiveness scores higher than 77.5 during all waking periods. Using the Normal approximation for the Binomial Test of the sample proportion (Devore, 2000; Conover, 1999), z=-9.050 with a p-value of 0.000. Therefore, under these assumptions, the data clearly suggest that the sleep patterns of the sample throughout SWA do not support mission accomplishment. In fact, only 51% of our sample reported a sleep/wake pattern that would maintain a performance effectiveness score of greater than 77.5 for all non-sleep periods[11].

E. RESULTS FOR RESEARCH QUESTION #3

Do statistically significant differences in sleep patterns and predicted performance effectiveness exist between subset populations, such as units with clear sleep/rest plans, by location, by MOS, by rank, or by gender?

To properly answer all components of this research question, our data are best analyzed using either the Chi-squared Test for Independence or the Fisher's Exact Test (Conover, 1999). While the Chi-squared Test for Independence is appropriate for these questions due to the large sample size, we will regularly use the Fisher's Exact Test because it provides us with the ability to conduct one-sided tests of our hypotheses. We will now consider each of the subset populations individually in this section.

1. Subset by Units with Clear Sleep/Rest Plans

Using primary questions related to unit-level sleep plans (S1Q1 & S1Q4), our $N = 273$ observations in the data can be summarized best using a 2 X 2 contingency table, where the sample is classified into one of two subsets. For the purposes of this problem, sample 1 will be the subset of the sample that indicates having a unit-level sleep/rest plan and sample 2 will be the subset of the sample that indicates not having a unit-level sleep/rest plan. We will

[11] The 95% confidence interval for maintaining a satisfactory performance effectiveness scores is (0.453, 0.572) with a standard deviation of 0.030.

define a participant as being in sample 1 if the participant indicated either that they were briefed on a sleep plan (yes response to S1Q1) or they indicated that their unit worked in shifts (yes response to S1Q4). Otherwise, the participant will be in sample 2.

Additionally, if we use the sleep/wake histories reported in question S3Q1B to determine predicted performance effectiveness levels, our sample will fall into one of two classes. Either a participant maintains satisfactory predicted performance effectiveness levels based on reported sleep/wake history (class 1) or does not maintain satisfactory predicted performance effectiveness levels (class 2). We will classify a participant into category 1 in the same manner used previously; if a participant's reported sleep/wake history (response to S3Q1B) suggests that his or her predicted performance effectiveness remains above 77.5% for all non-sleep periods, then the participant is grouped in class 1. Otherwise, the participant is grouped in class 2 because the participant's reported sleep/wake history suggests that his or her predicted performance effectiveness level fell below the minimum level considered to be satisfactory at least once while the participant was awake and assumed to be performing military duties.

Now that we have defined the samples and the classes, we are ready to test the outcomes using the Fisher's Exact Test. We use the Fisher's Exact Test since it does not assume random or mutually independent samples, and it provides us with the ability to conduct a one-sided test of our hypothesis, which we will address shortly. Following the guidance of Conover (1999), we will populate our 2 X 2 contingency table in the manner shown in Table 19.

	Class 1: Maintains Satisfactory Performance Effectiveness	**Class 2:** Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: Indicates Clear Sleep/Rest Plan	x	$r-x$	r
Sample 2: Does Not Indicate Clear Sleep/Rest Plan.	$c-x$	$N-r-c+x$	$N-r$
	c	$N-c$	N

Table 19. The Fisher's Exact Test, 2 X 2 Contingency Table (After: Conover, 1999).

The variables for Table 19 are defined as follows:

N is the total sample.

c is the total number in the sample who fall into category A.

r is the total number in the sample who fall into category 1.

x is the number in the sample who fall into category A and category 1.

We will assume that each observation is classified into exactly one cell. Further, the Fisher's Exact Test assumes the row and column totals are fixed. However, the test is valid for contingency tables with random row and/or column totals, as in this case, with some sacrifice to the test's power (Conover, 1999).

The test statistic, T_3, is the total number of observations that indicate clear sleep/rest plans (sample 1) and indicate maintaining satisfactory performance effectiveness during all non-sleep periods (class 1). The test statistic T_3 is determined by the responses to questions S1Q1, S1Q4, and FAST evaluation of the sleep/wake history reported in question S3Q1B.

When the null hypothesis is true, the distribution of the test statistic T_3 is the hypergeometric distribution with parameters N, c, r, and x as defined above. That is, the probability that the test statistic is equal to x, $P(T_3 = x)$, is as follows:

$$P(T_3 = x) = \frac{\binom{r}{x}\binom{N-r}{c-x}}{\binom{N}{c}} \text{ for } x = 0,1,\ldots,\min(r,c)$$

$$= 0 \text{ for all other values of } x$$

Let $p_1 = \Pr\{\text{class 1} \mid \text{population 1}\}$. This is the probability of an observation being classified as maintaining satisfactory performance levels during all non-sleep periods given that the observation falls into the sample of those indicating a clear sleep/rest plan. Let $p_2 = \Pr\{\text{class 1} \mid \text{population 2}\}$. This is the probability of an observation being classified as maintaining satisfactory performance levels during all waking periods given that the observation falls into the sample of those not indicating a clear sleep/rest plan. Then, the hypothesis we wish to test is that maintaining satisfactory performance is independent of having a sleep plan versus the alternative hypothesis that the satisfactory performance rate is higher for those with sleep plans. Our upper-tailed hypothesis test takes the form:

$$H_o : p_1 \leq p_2$$
$$H_A : p_1 > p_2$$

From our data, we populate our 2 X 2 contingency table as shown in Table 20.

	Class 1: Maintains Satisfactory Performance Effectiveness	**Class 2:** Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: Indicates Clear Sleep/Rest Plan	x =103	$r-x$ =97	r =200
Sample 2: Does Not Indicate Clear Sleep/Rest Plan.	$c-x$ =37	$N-r-c+x$ =36	$N-r$ =73
	c =140	$N-c$ =133	N =273

Table 20. Observed values from our sample using the Fisher’s Exact Test, 2 X 2 Contingency Table (After: Conover, 1999).

Here, small observed values, t_{obs}, suggest that the null hypothesis, H_o, is false. Testing at the $\alpha = 0.05$ level, we will reject H_o if $P(T_3 \geq t_{\text{obs}}) \leq \alpha$, where T_3 is a hypergeometric random variable with parameters N, c, r, and x as previously defined. We find that $P(T_3 \geq t_{\text{obs}}) \leq \alpha$ when t_{obs}=109, which yields an attained α of 0.0483. Thus, we will fail to reject H_o for $T_3 \leq 108$. For our problem, we find that our observed value, t_{obs}=103 $\leq T_3$ (p-value = 0.399). Therefore, under these assumptions, we fail to reject H_o. That is, these data do not support that the $\Pr\{\text{Sat Performance} \mid \text{Sleep Plan}\}$ > $\Pr\{\text{Sat Performance} \mid \text{No Sleep Plan}\}$.

These findings initially seem counterintuitive since it seems fairly reasonable to suggest that having a sleep plan should help with maintaining individual and unit performance effectiveness. The key factor, however, is not simply to have a sleep plan, but to have an effective sleep plan. Rather than simply considering the subset of the sample that indicated that they had a sleep plan, we will restrict our subset to those who indicate that their unit's sleep plan is effective. Using question S1Q3, we will define a response ≥5 as a positive indication that the unit has an effective sleep plan and a response <5 as a neutral or negative indication regarding the existence and effectiveness of a unit's sleep plan.

For this new problem, classes 1 and 2 remain the same, but samples 1 and 2 change. Sample 1 is the subset consisting of individuals who responded that they felt their unit's sleep plan either sometimes worked well, almost always worked well, or always worked well, which are the response choices to question S1Q3 coded as 5, 6, and 7 respectively. Sample 2 is the subset consisting of individuals who responded that they felt their unit’s sleep plan either never worked, almost never worked, sometimes did not work, made no difference, or did not respond at all, which are the remaining response choices to question S1Q3 coded as 1, 2, 3, 4, and NA respectively.

Our assumptions, test statistic, and null distribution remain the same as previously stated. Our hypothesis changes in that we are now interested in testing to see if individuals with effective sleep plans are more likely to have satisfactory performance effectiveness levels during waking hours. That is, $p_1 = \Pr\{\text{Sat Performance} \mid \text{An Effective Sleep Plan}\}$ and $p_2 = \Pr\{\text{Sat Performance} \mid \text{No Effective Sleep Plan}\}$. Then, the hypothesis we wish to test is that maintaining satisfactory performance is independent of having an effective sleep plan versus the alternative hypothesis that the satisfactory performance rate is higher for those with effective sleep plans. As before, our upper-tailed hypothesis test takes the form:

$$H_o : p_1 \le p_2$$
$$H_A : p_1 > p_2$$

From our data, we populate our 2 X 2 contingency table as shown in Table 21.

	Class 1: Maintains Satisfactory Performance Effectiveness	Class 2: Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: Indicates Effective Sleep/Rest Plan	$x = 55$	$r - x = 33$	$r = 88$
Sample 2: Does Not Indicate Effective Sleep/Rest Plan.	$c - x = 85$	$N - r - c + x = 100$	$N - r = 185$
	$c = 140$	$N - c = 133$	$N = 273$

Table 21. Observed values from our sample using the Fisher's Exact Test, 2 X 2 Contingency Table (After: Conover, 1999).

For this situation, $P(T_3 \geq t_{obs}) \leq \alpha$ when t_{obs} = 51, which yields an attained α of 0.0492. Thus, we will fail to reject H_o for $T_3 \leq 51$. We find that $t_{obs} = 55 > T_3$ and has a p-value = 0.0035. Therefore, under these assumptions, the data suggest that those with effective sleep plans are more likely to maintain satisfactory performance levels than those with non-effective sleep plans.

2. Subset by Location

Next, we wish to see if a unit's location has an impact on predicted performance effectiveness. That is, we wish to test the hypothesis that the probability of maintaining satisfactory performance effectiveness levels in Kuwait is higher than the probability of maintaining satisfactory performance effectiveness levels in Iraq. We have already seen from the results of the large-sample test for differences in proportions conducted earlier that the probability of showing moderate to significant symptoms of sleep deprivation appears to be higher in Iraq than in Kuwait. Now we will conduct the Fisher's Exact Test to test this new hypothesis.

For this situation, classes 1 and 2 remain the same as previously defined. Sample 1 becomes the subset that indicates they were located in Kuwait and sample 2 becomes the subset that indicates they were located in Iraq. Seven participants did not respond to the demographic question for location, so $N = 266$ for this problem rather than 273.

Let, $p_1 = \Pr\{\text{Sat Performance} \mid \text{Located in Kuwait}\}$ and $p_2 = \Pr\{\text{Sat Performance} \mid \text{Located in Iraq}\}$. Then, the hypothesis we wish to test is that maintaining satisfactory performance is independent of location versus the alternative hypothesis that the satisfactory performance rate is higher for those located in Kuwait. As before, our upper-tailed hypothesis test takes the form:

$$H_o : p_1 \le p_2$$
$$H_A : p_1 > p_2$$

Table 22 shows the observed values after populating our 2 X 2 contingency table in the same manner as we did previously.

	Class 1: Maintains Satisfactory Performance Effectiveness	**Class 2:** Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: Located in Kuwait	$x=49$	$r-x=28$	$r=77$
Sample 2: Located in Iraq	$c-x=87$	$N-r-c+x=102$	$N-r=189$
	$c=136$	$N-c=130$	$N=266$

Table 22. Observed values from our sample using the Fisher's Exact Test, 2 X 2 Contingency Table (After: Conover, 1999).

For this situation, $P(T_3 \geq t_{\text{obs}}) \leq \alpha$ when t_{obs} = 45, which yields an attained α of 0.0484. Thus, we will fail to reject H_o for $T_3 \leq 45$. For our problem, we find the $t_{\text{obs}}=49$ $>T_3$ (p-value = 0.0029). Therefore, under these assumptions, we reject H_o in favor of the alternative hypothesis that those located in Kuwait are more likely to maintain satisfactory performance levels than those located in Iraq.

3. Subset by Gender

Next, we wish to see if predicted performance effectiveness is dependent on gender. That is, we wish to test the hypothesis that the probability of maintaining satisfactory performance effectiveness levels for females is different than the probability of maintaining satisfactory performance effectiveness levels for males. We will conduct a two-sided hypothesis test using the Fisher's Exact Test for this new hypothesis.

For this situation, classes 1 and 2 remain the same as previously defined. Sample 1 becomes the subset of the sample who are female and sample 2 becomes the subset of the sample who are male. Seven participants did not respond to the demographic question for gender, so $N = 266$ for this problem rather than 273.

Let, p_1 = $\Pr\{\text{Sat Performance} \mid \text{Female}\}$ and p_2 = $\Pr\{\text{Sat Performance} \mid \text{Male}\}$. Then, the hypothesis we wish to test is that maintaining satisfactory performance is independent of gender versus the alternative hypothesis that the satisfactory performance rates are different for males and females. Our two-tailed hypothesis test takes the form:

$$H_o : p_1 = p_2$$
$$H_A : p_1 \neq p_2$$

Table 23 shows the observed values after populating our 2 X 2 contingency table in the same manner as we did previously.

	Class 1: Maintains Satisfactory Performance Effectiveness	Class 2: Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: Female	$x = 13$	$r - x = 10$	$r = 23$
Sample 2: Male	$c - x = 123$	$N - r - c + x = 119$	$N - r = 243$
	$c = 136$	$N - c = 130$	$N = 265$

Table 23. Observed values from our sample using the Fisher's Exact Test, 2 X 2 Contingency Table (After: Conover, 1999).

For this situation, we will reject H_o at the level of significance α if the p-value is $\leq \alpha$. Here the p-value is twice the smaller of $P(T_3 \leq t_{\text{obs}})$ or $P(T_3 \geq t_{\text{obs}})$. From our obtained data, we compute a p-value of 0.4484, which suggests that we fail to reject H_o. That is, the data do not suggest that the probabilities for maintaining satisfactory performance effectiveness levels are dependent on gender. It seems that both samples may have the same level of difficult in the area of sleep deprivation.

4. Subset by MOS

Next, we wish to see if predicted performance effectiveness is dependent on MOS. To address this problem, we will use the MOS categories outlined earlier in this chapter. Since there will be times that we are interested at looking at more than two MOS categories, we will use the Chi-squared Test for Independence using an r X c contingency table with r rows and c columns. Following the guidance of Conover (1999), we construct our contingency table as shown Table 24.

	Class 1	⋯	**Class c**	
Sample 1	O_{11}	⋯	O_{1c}	n_1
⋮	⋮	⋱	⋮	⋮
Sample r	O_{r1}	⋯	O_{rc}	n_r
	C_1	⋯	C_c	N

Table 24. The Chi-squared Test for Independence, r X c Contingency Table (From: Conover, 1999).

The variables shown in Table 24 are defined as follows:

r = The number of different subset samples.

c = The number of different classes.

O_{ij} = The number of observations from the ith sample that fall into the jth category.

$n_i = O_{i1} + O_{i2} + \cdots + O_{ic}$ for all i

$C_j = O_{1j} + O_{2j} + \cdots + O_{rj}$ for all j

N = The total number of observations from all samples.

We will assume that each sample is a random sample and that the outcomes of the various samples are all mutually independent. Further, each observation may be categorized into exactly one of the c classes.

Our test statistic for this test, T_4, is given as follows:

$$T_4 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}}, \text{ where } E_{ij} = \frac{n_i C_j}{N}$$

Here, E_{ij} represents the expected number of observations for cell (i, j) assuming that the null hypothesis is true and, as stated earlier, O_{ij} represents the observed values in cell (i, j). Then the null distribution of T_4 is approximately given by the Chi-squared distribution with $(r-1)(c-1)$ degrees of freedom.

Let p_{ij} be the probability of a randomly selected value from the ith sample be classified in the jth class. Then we will test the null hypothesis, which states that the event “an observation is in row i” is independent of the event “that same observation is in column j,” for all i and j (Conover, 1999, pp. 204-205). By the definition of independence of events, we can state the hypothesis test as follows:

$$H_o : P(\text{row } i,\ \text{column } j) = P(\text{row } i) \cdot P(\text{column } j),\ \text{for all } i, j$$
$$H_A : P(\text{row } i,\ \text{column } j) \neq P(\text{row } i) \cdot P(\text{column } j),\ \text{for some } i, j$$

Since T_4 is approximately distributed by the Chi-squared distribution, we will reject the null hypothesis, H_o, when $T_4 > \chi^2_{1-\alpha,(r-1)(c-1)}$, where α is our test significance level. Otherwise, we fail to reject H_o.

Now that we have a clear understanding of the Chi-squared Test for Independence, we are ready to specify our parameters. We will first consider the grouping of our participants into two MOS groups, and then we will consider the grouping of our participants into three MOS groups.

a. Chi-squared Test for Independence Between Two MOS Groups

First, we will let classes 1 and 2 be defined as they were previously. Next, let sample 1 be the participants with a Combat or Combat Support MOS, and let sample 2 be the participants with a Combat Service Support MOS. We will test the hypothesis that the probability of maintaining satisfactory performance effectiveness levels is the same regardless of MOS category. Then, based on these assumptions, we find the observed values in Table 25 and the expected values in Table 26.

	Class 1: Maintains Satisfactory Performance Effectiveness	**Class 2:** Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: MOS Group 1	O_{11} =56	O_{12} =64	n_1 =120
Sample 2: MOS Group 2	O_{21} =80	O_{22} =66	n_2 =146
	C_1 =136	C_2 =130	N =266

Table 25. Observed values from our sample using the Chi-squared Test for Independence, r X c Contingency Table (After: Conover, 1999).

	Class 1: Maintains Satisfactory Performance Effectiveness	**Class 2:** Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: MOS Group 1	E_{11}=61.35	E_{12}=58.65	n_1=120
Sample 2: MOS Group 2	E_{21}=74.65	E_{22}=71.35	n_2=146
	C_1=136	C_2=130	N=266

Table 26. Expected values from our sample using the Chi-squared Test for Independence, r X c Contingency Table (After: Conover, 1999).

From these data, we find that our test statistic T_4=1.74. When we compare T_4 with the appropriate Chi-squared statistic, $\chi^2_{1-\alpha,(r-1)(c-1)}$, where α = 0.05, r=2, and c=2, we find that the probability of $T_4 > \chi^2_{0.95,1}$ = 0.1870. Therefore, we fail to reject the null hypothesis. That is, these data suggest that maintaining satisfactory performance effectiveness levels is independent of MOS.

b. Chi-squared Test for Independence Between Three MOS Groups

Leaving class 1 and class 2 as previously defined, we will now let sample 1 be the participants with a Combat or Combat Support MOS (excluding aviation-specific MOS's), sample 2 be the participants with a Combat Service Support MOS (excluding aviation-specific MOS's), and sample 3 be all of the participants with aviation-specific MOS's. We will test the hypothesis that the probability of maintaining satisfactory performance effectiveness levels is the same regardless of MOS category. Then, based on these assumptions, we find the observed values in Table 27 and the expected values in Table 28.

	Class 1: Maintains Satisfactory Performance Effectiveness	**Class 2:** Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: MOS Group A	O_{11}=55	O_{12}=62	n_1=117
Sample 2: MOS Group B	O_{21}=12	O_{22}=10	n_2=22
Sample 3: MOS Group C	O_{31}=69	O_{32}=58	n_3=127
	C_1=136	C_2=130	N=266

Table 27. Observed values from our sample using the Chi-squared Test for Independence, r X c Contingency Table (After: Conover, 1999).

	Class 1: Maintains Satisfactory Performance Effectiveness	**Class 2:** Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: MOS Group A	E_{11}=59.82	E_{12}=57.18	n_1=117
Sample 2: MOS Group B	E_{21}=11.25	E_{22}=10.75	n_2=22
Sample 3: MOS Group C	E_{31}=64.93	E_{32}=62.07	n_3=127
	C_1=136	C_2=130	N=266

Table 28. Expected values from our sample using the Chi-squared Test for Independence, r X c Contingency Table (After: Conover, 1999).

From these data, we find that our test statistic T_4=0.897. When we compare T_4 with the appropriate Chi-squared statistic, $\chi^2_{1-\alpha,(r-1)(c-1)}$, where α = 0.05, r=3, and c=2, we find that the probability of $T_4 > \chi^2_{0.95,2}$ = 0.6385. Therefore, we fail to reject the null hypothesis. That is, these data suggest that maintaining satisfactory performance effectiveness levels is independent of MOS.

5. Subset by Rank

Here, we will continue testing our data using the Chi-squared Test for Differences in Probabilities with Class 1 and 2 as previously defined. For this test, we will divide our data into subset samples based on military pay grades. We will let sample 1 be the subset that is junior enlisted (E-1 to E-3), sample 2 be enlisted E-4's and E-5's, sample 3 be senior enlisted (E-6 to E-9), and sample 4 be all officers. Originally we wanted to consider company grade officers separately from field grade officers, but due to the small number of field grade officers in our sample, we chose to combine all of the officers together. Then our sample has the observed values shown in Table 29 and is expected to have the values shown in Table 30.

	Class 1: Maintains Satisfactory Performance Effectiveness	**Class 2:** Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: E-1 to E-3	O_{11} =11	O_{12} =18	n_1 =29
Sample 2: E-4 to E-5	O_{21} =77	O_{22} =59	n_2 =136
Sample 3: E-6 to E-9	O_{31} =38	O_{32} =41	n_3 =79
Sample 4: Officer	O_{41} =10	O_{42} =12	n_4 =22
	C_1 =136	C_2 =130	N =266

Table 29. Observed values from our sample using the Chi-squared Test for Independence, r X c Contingency Table (After: Conover, 1999).

	Class 1: Maintains Satisfactory Performance Effectiveness	**Class 2:** Does Not Maintain Satisfactory Performance Effectiveness	
Sample 1: E-1 to E-3	E_{11}=14.83	E_{12}=14.17	n_1=29
Sample 2: E-4 to E-5	E_{21}=69.53	E_{22}=66.47	n_2=136
Sample 3: E-6 to E-9	E_{31}=40.39	E_{32}=38.61	n_3=79
Sample 4: Officers	E_{41}=11.25	E_{42}=10.75	n_4=22
	C_1=136	C_2=130	N=266

Table 30. Expected values from our sample using the Chi-squared Test for Independence, r X c Contingency Table (After: Conover, 1999).

From these data, we find that our test statistic T_4=4.235. When we compare T_4 with the appropriate Chi-squared statistic, $\chi^2_{1-\alpha,(r-1)(c-1)}$, where α = 0.05, r=4, and c=2, we find that the probability of $T_4 > \chi^2_{0.95,3}$ = 0.2372. Therefore, we fail to reject the null hypothesis. That is, maintaining a satisfactory performance effectiveness level is independent of rank and it seems reasonable that the probability of maintaining a satisfactory performance effectiveness level is about the same for all ranks.

F. RESEARCH QUESTION #4

Does the current survey method support the research objectives?

As we have seen from answering the first three research questions, this survey method does provide us with valuable insight into the research questions. However, this research tool can be improved. For example, this survey was very long and, at times, asked questions in indirect manners. Some of the questions were difficult to understand.

In order to improve our survey, we will consider the results from data reduction techniques known as principal components analysis and factor analysis. Both of these methods are easily implemented in S-Plus (IC, 2001). In addition to principal components analysis and factor analysis, we also considered agglomerative hierarchical clustering, divisive hierarchical clustering, clustering around mediods, and Hartigan's K-means clustering, but the results were uninteresting for this data primarily due to the large number of variables. Principal components analysis and factor analysis provide us with valuable analysis regarding the improvement of our survey tool, as well as measurable quantities for hypothesis testing of the data obtained from our surveys. We will describe principal components analysis and factor analysis and their corresponding S-Plus functions shortly. First, however, we must discuss the process used to clean the data that we will use with these analysis techniques.

1. Data Cleaning

In order to implement principal component analysis and factor analysis methods in S-Plus, we must clean our original data matrix (273 rows by 113 columns) by removing missing values (NA responses), singularities caused by linear combinations of the observed variables, and zero-variance variables that cause “division by zero” errors.

Table 31 shows which variables were removed from the original matrix and the reason for the removal.

VARIABLE REDUCTION

VARIABLE/QUESTION	REASON FOR REMOVAL
S1Q1A	1
S1Q2(Y)	1
S1Q2(N)	1
S1Q2(IDK)	1
S1Q2A	1
S1Q3	1
S1Q4	1
S2Q7(OTHER)	2
S3Q2A	1
S3Q2B	1
S3Q2C	1
S3Q2D	1
S3Q2E	1
S5Q1	1
S5Q3	1
S6Q2(USE)	1, 2
S7Q1(USE)	1, 2
S2Q7(ONV)	3*
S9Q1	3*

CODE	REASON
1	RESPONSE RATE < 95%
2	LINEAR COMBINATION OF OTHER QUESTIONS
3*	ZERO VARIANCE IN SUBSET OF SAMPLE

Table 31. Variables removed from the original data for the purposes of implementing principal components analysis and factor analysis.

Even after removing the variables shown in Table 31, we still had individual surveys with one or more NA values. These participants needed to be removed from the data matrix in order to implement our analysis techniques. Table 32 shows which participants were removed from the data for this reason.

PARTICIPANTS STILL CONTAINING MISSING VALUES AFTER VARIABLE REDUCTION

REMOVED PARTICIPANTS (n = 78)			
P001	P039	P112	P191
P003	P040	P113	P192
P004	P042	P114	P193
P006	P043	P116	P197
P007	P048	P122	P199
P010	P051	P131	P207
P011	P053	P132	P222
P016	P054	P136	P224
P020	P058	P137	P239
P021	P061	P139	P240
P022	P069	P145	P242
P023	P071	P148	P246
P024	P072	P152	P248
P025	P075	P153	P250
P026	P076	P160	P254
P029	P077	P168	P262
P030	P089	P173	P269
P032	P099	P175	P270
P033	P106	P183	
P035	P110	P184	

Table 32. Participants removed from the original data due to NA responses. Missing values are not allowed when implementing principal component analysis or factor analysis methods in S-Plus.

After removing the variables and participants shown in Tables 31 and 32, our matrix of data, X, contains 195 participants (rows) and 94 question variables (columns). The last thing required before implementing our analysis techniques is to conduct a two-sample t test between the subset sample with missing values and the subset sample without missing values. The two-sample t test shows us whether or not the two samples are statistically different from each other based on the two sample means. The complete results of the two-sample t test are provided in Appendix G. Of the 94 question variables, only 4 of the variables have statistically different sample means. The four variables are S2Q8(DD), S3Q2F, S4Q2, and S4Q3. While it is important to note that these differences exist, they should not interfere with the results of our principal components analysis or factor analysis.

2. Principal Components Analysis

Now that we have a clean matrix containing a representative subset of the sample, we are ready to implement principal components analysis. Principal component analysis is a variable reduction technique that is often very useful for simplifying the analysis of data sets with a large number of variables by considering a smaller number of linear combinations of the original variables. Principal components analysis transforms the original variables into a set of standardized linear combinations, called principle components. The principal components are orthogonal and, when combined, explain all of the variance of the original data (Hand et al., 2001; Hamilton, 1992; IC, 2001).

Principal components analysis is easily implemented in S-Plus (IC, 2001), using the command princomp(X, cor = T), where X is the data frame containing our variables in the columns and observations in the rows, and cor = T implies that the variables are scaled to have unit variance by basing the principal components on the correlation matrix rather than the covariance matrix. The first step after constructing our principal components using the S-Plus function, is to analyze the eigenvalues. In principal components analysis, the eigenvalues associated with the components represent the variance of the original data explained by that component. The first principal component has the highest eigenvalue or variance, the second component has the second highest eigenvalue, and so on. The sum of the eigenvalues equals the number of variables. Therefore, we can easily determine the proportion of the total variance explained by each eigenvalue by dividing by the number of variables. In general, components are considered significant when their eigenvalues are greater than 1 or when their cumulative proportion of variance explains greater than 90% of the total variance (Hand et al., 2001; Hamilton, 1992; IC, 2001).

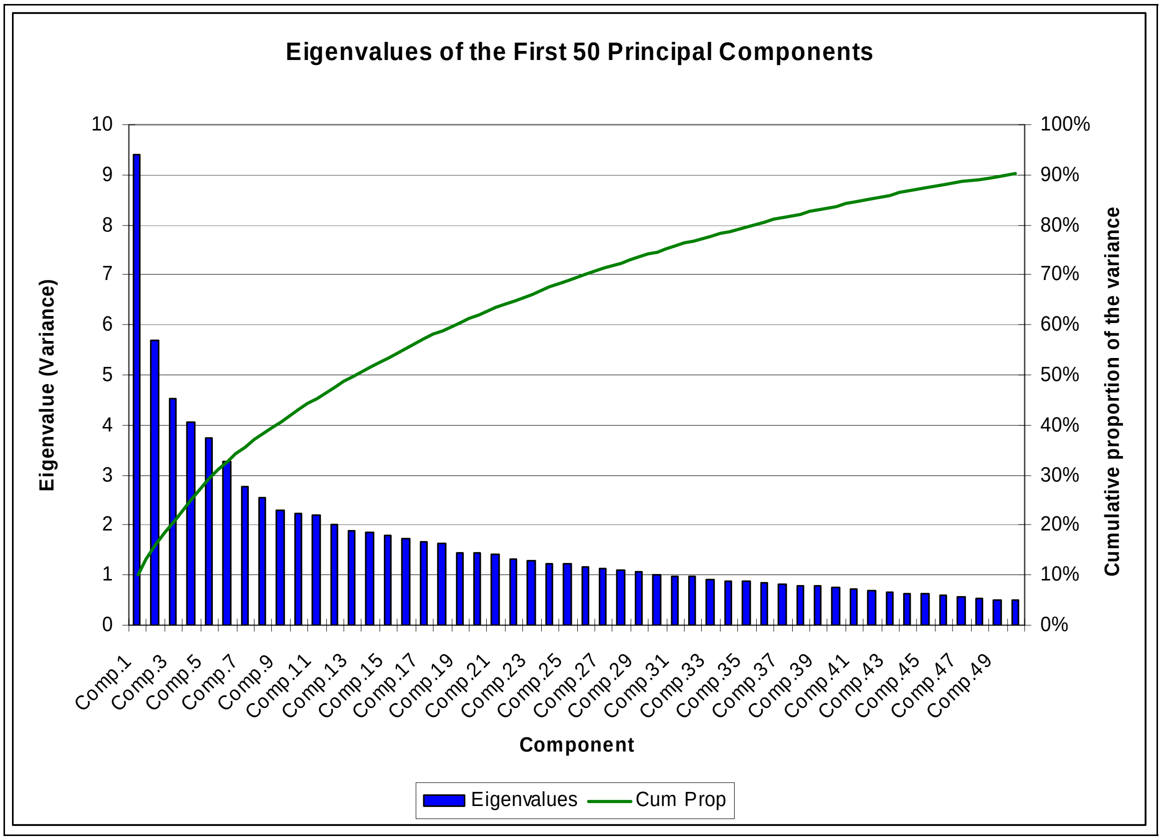


Figure 30. Eigenvalues of the first 50 principal components with corresponding cumulative proportion of the total variance explained by the eigenvalues.

Upon investigating the results of the principal components method, Figure 30 shows that there are 30 components with eigenvalues greater than 1, and it takes 50 components to explain 90% of the variability in the data. This suggests that we can simplify the 94-variable data to between 30 to 50 variables.

The next step required in analyzing the principal components is to interpret the loadings of each component. The principal component loadings are the coefficients of the principal components transformation. The loadings provide a convenient summary, and possible interpretation, of how the principal components are influenced by the original variables (Hand et al., 2001; Hamilton, 1992; IC, 2001).

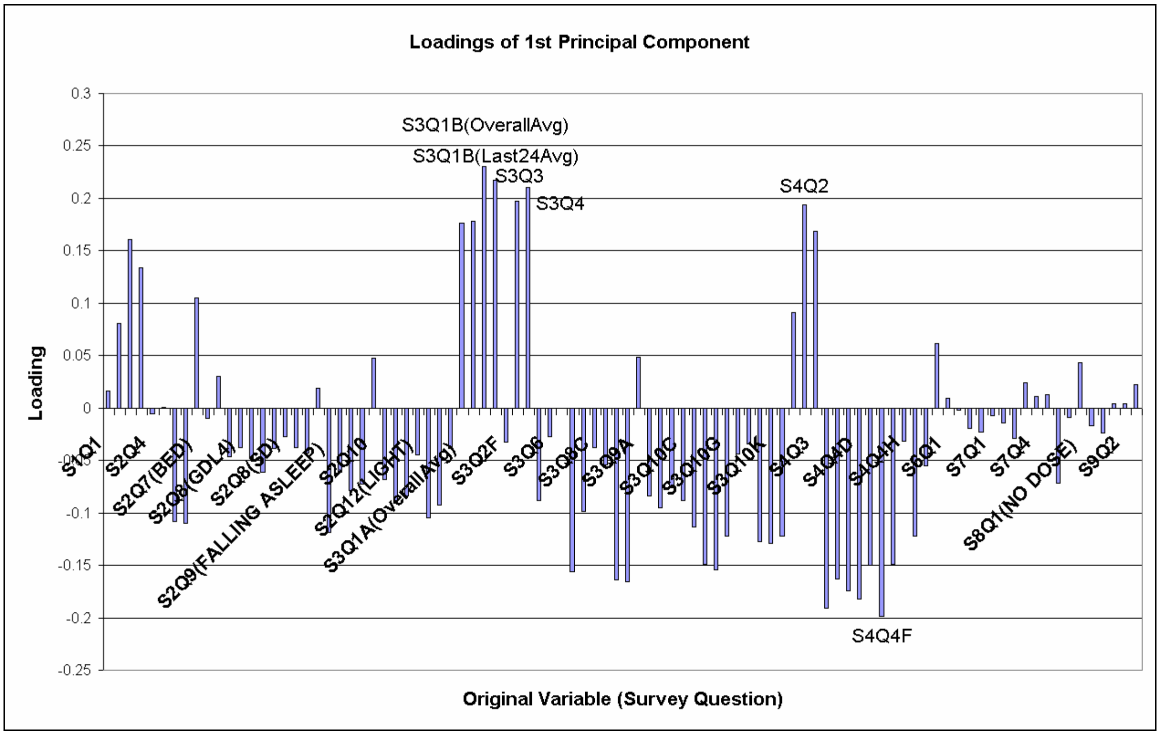


Figure 31. Loadings of the first principal component.

The first principal component makes up 10% of the total variance in the original data. This component seems to capture the overall fatigue level and sleep latency of the participant based on the amount of sleep the participant is getting (S3Q1B(OverallAvg), S3Q1B(Last24Avg), S3Q3) and how tired the participant still feels shortly after waking up (S4Q2, S4Q4F). The loadings for this component are graphically depicted in Figure 31.

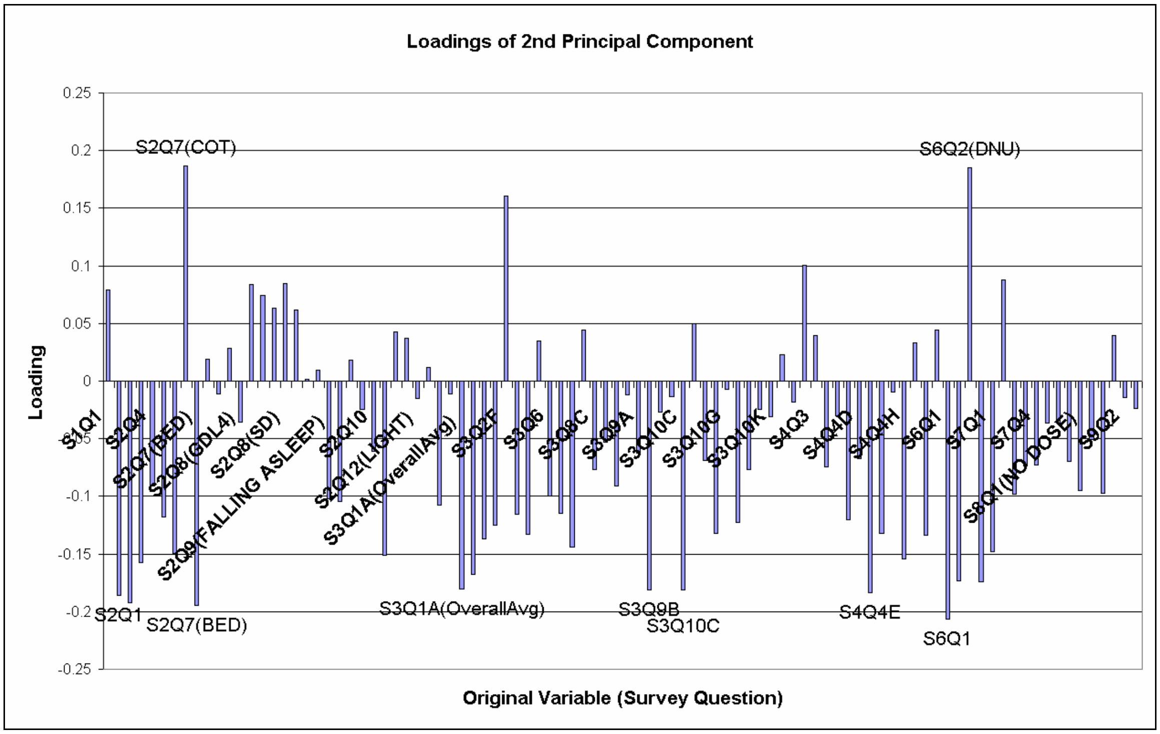


Figure 32. Loadings of the second principal component.

The second principal component, whose loadings are shown in Figure 32, is loaded on five different topics: nicotine use (S6Q1, S6Q2(DNU)); where a participant sleeps (S2Q7(BED), S2Q7(COT)); how long a participant is allowed to sleep (S3Q1A(OverallAvg)); how difficult it is for a participant to wake up (S4Q4E); and having bad dreams (S39B, S3Q10C). While the exact relationship and interpretation is not clear, the combination of this component with the first component captures 16% of the total variance in the data.

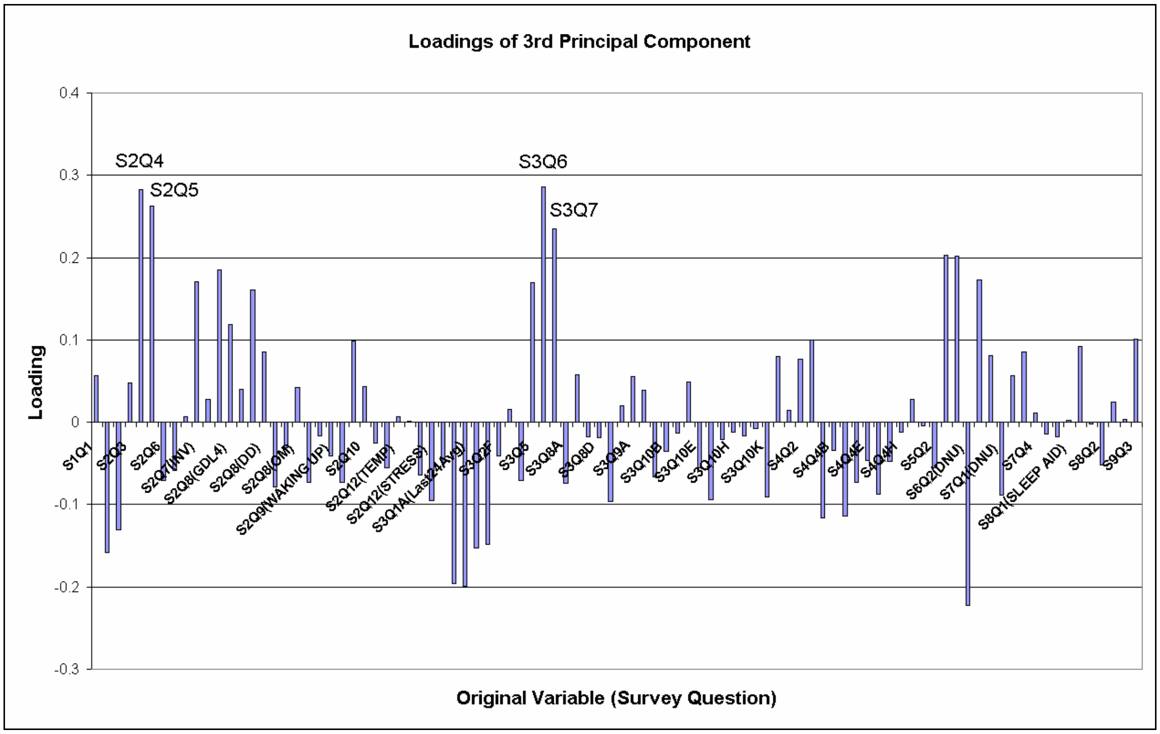


Figure 33. Loadings of the third principal component.

The third principal component, whose loadings are shown in Figure 33, clearly captures nap patterns. The four original variables with the highest loadings, all of which are greater than 0.23, all ask questions about naps (S2Q4, S2Q5, S3Q6, and S3Q7). Combined, the first three components capture over 20% of the total variance in the original data.

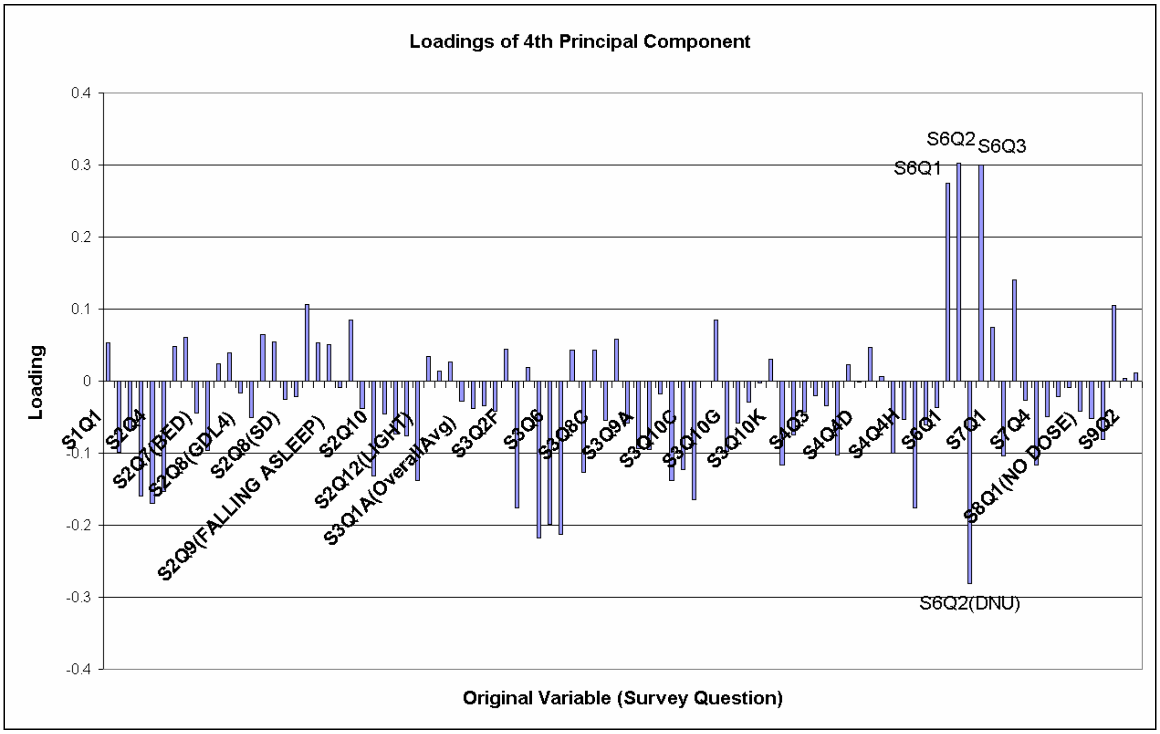


Figure 34. Loadings of the fourth principal component.

The fourth principal component, whose loadings are shown in Figure 34, clearly captures nicotine use. The four original variables with the highest loadings, all of which are greater than 0.27, ask questions related to the participant’s use of nicotine products. This component explains 4% of the total variance of the original data, bringing the cumulative total to 25%.

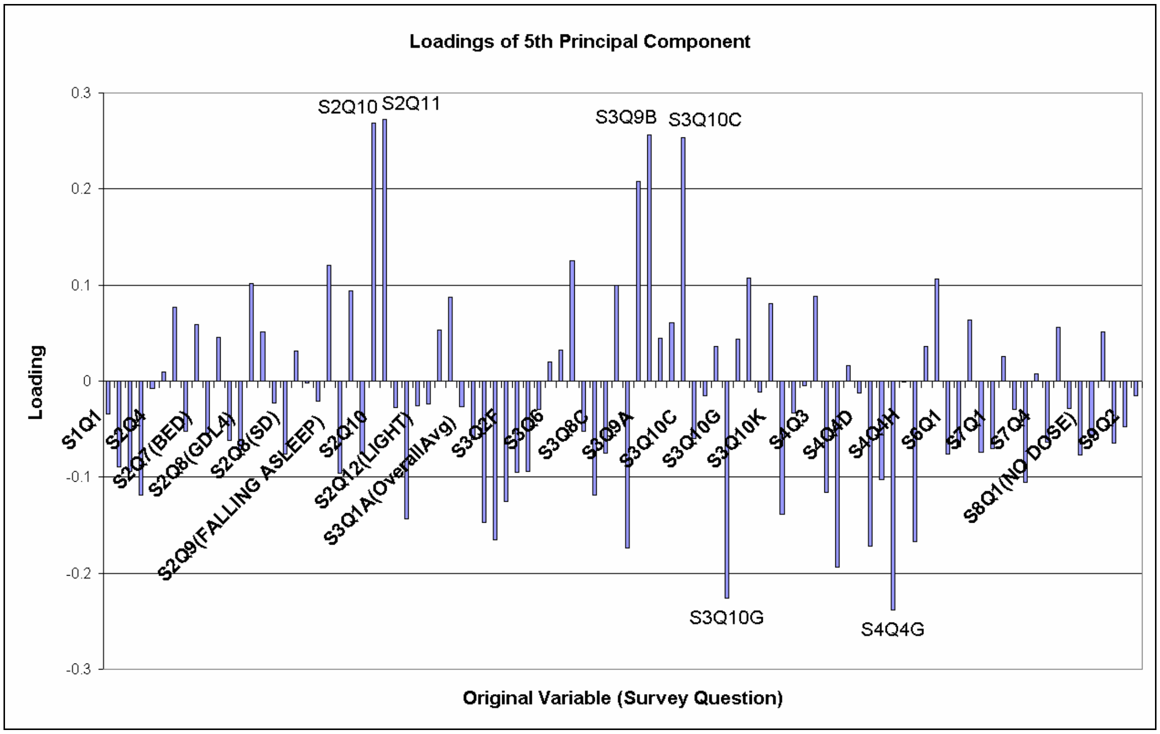


Figure 35. Loadings of the fifth principal component.

The fifth principal component, whose loadings are shown in Figure 35, is the last component we will interpret in this section. This component is also easily interpretable since the four largest loadings, all of which are greater than 0.25, correspond to original variables that ask questions about dreams and nightmares (S2Q10, S2Q11, S3Q9B, S3Q10C). This component clearly captures the difficulty of sleeping caused by bad dreams. Keeping this component increases the total explained variance to 29%.

As we saw with the second principal component (Figure 32), not every component has a clear interpretation. However, it will be useful for us to continue to look at the other significant components in order to identify clear, interpretable relationships that will help us refine our survey tool.

3. Factor Analysis

The next analysis technique we will look at in order to help us improve our survey tool is factor analysis. In survey analysis, we are often interested in quantifying results that are not directly measurable. Using factor analysis, we are often able to measure quantities that reflect the underlying variable of interest by attempting to explain the correlations between observable variables in terms of underlying factors. Factor analysis closely resembles principal components analysis in that both techniques use linear combinations of the original variables to explain sets of observations of many variables. Whereas principal components analysis provides us with the opportunity to simplify the original variables at relatively little loss of information, factor analysis provides us with the opportunity to measure the underlying factors based on these simplified variables. That is, once the data are simplified into their underlying factors, similar to principal components, we are able to compute factor scores from the factor analysis transformation. These factor scores provide us with a quantifiable measure for the underlying and interpretable factors (Hand et al., 2001; Hamilton, 1992; IC, 2001).

Factor analysis is easily implemented in S-Plus using the command factanal(X, factors = n), where X is the original matrix of data with columns corresponding to variables and rows corresponding to observations, and n is the number of factors we wish to consider. Based on the results of our principal components analysis, we construct our factor analysis model with 50 factors. With 896 degrees of freedom, this 50-factor model explains nearly 75% of the total variance in the original data. Once constructed, we are able to explore the factor loadings, the uniquenesses[12], and the factor scores in order to gain further insight regarding our survey.

We will start our analysis by exploring the loadings of the first five factors. The factor loadings are the numeric weights that each factor contributes to each of the original variables. These factor loadings provide us with a means to interpret the underlying factor (Hand et al., 2001; Hamilton, 1992; IC, 2001). We gain an intuitive feel for which variables are loaded most strongly on each factor by looking at the loadings visually. In order to use the factor analysis results to improve our survey tool, we will want to consider all 50 factors. However, for the purposes of this thesis, we will only consider the first five factors here.

[12] Uniquenesses are the variations in the observations not shared with the other variables. Specifically, the uniqueness of each variable equals the proportion of its variance not explained by the retained factors (Hand et al., 2001; Hamilton, 1992; IC, 2001).

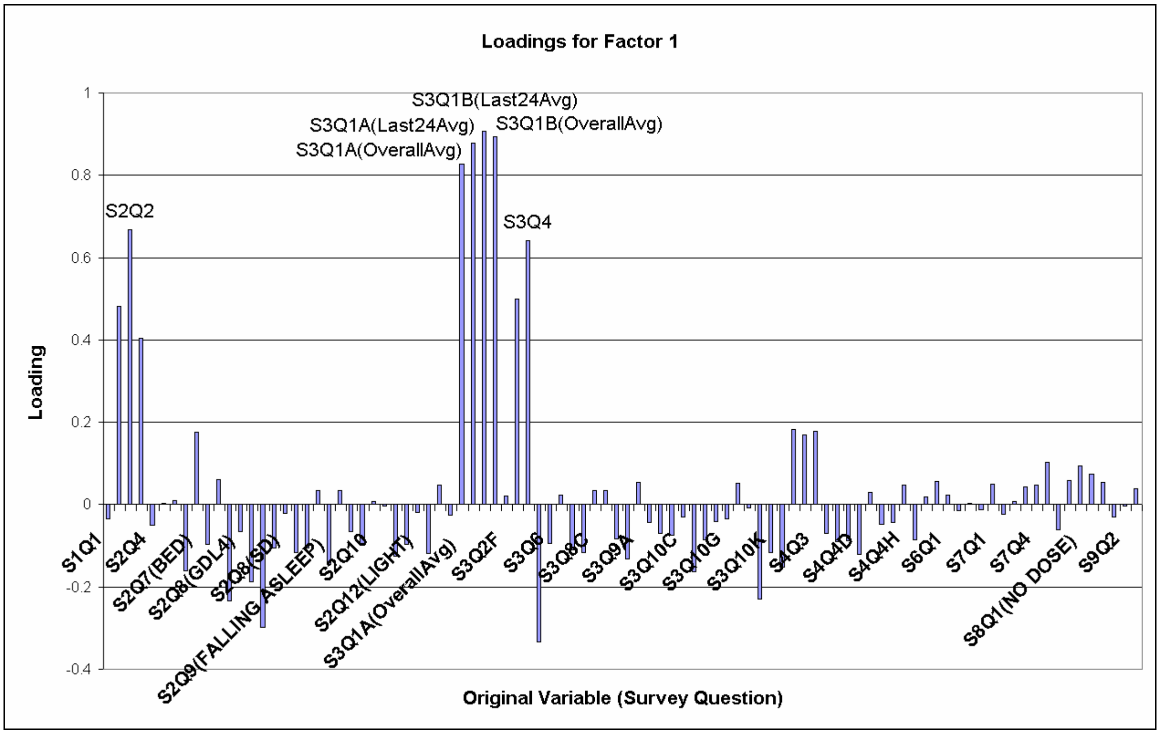


Figure 36. Loadings for the first factor.

The first factor, which explains 5.8% of the total variance in the original data (whose loadings are shown in Figure 36) seems to capture the performance effectiveness of the participant based on the actual and allowed sleep/wake history. Question SQ31A asks the participant to shade in the times when he/she was allowed to sleep (including naps) over the past 7 days. Question S3Q1B is similar, except that this question asks for the actual times, rather than the allowed times, of sleep. These times were then imported into FAST and used to calculate the performance effectiveness of the participant according to the reported sleep/wake schedule. Questions S2Q2 and S3Q4 ask participants to report the average amount of sleep they received each night. It seems reasonable to suggest that this factor provides a score to measure performance effectiveness based on sleep patterns of the individual.

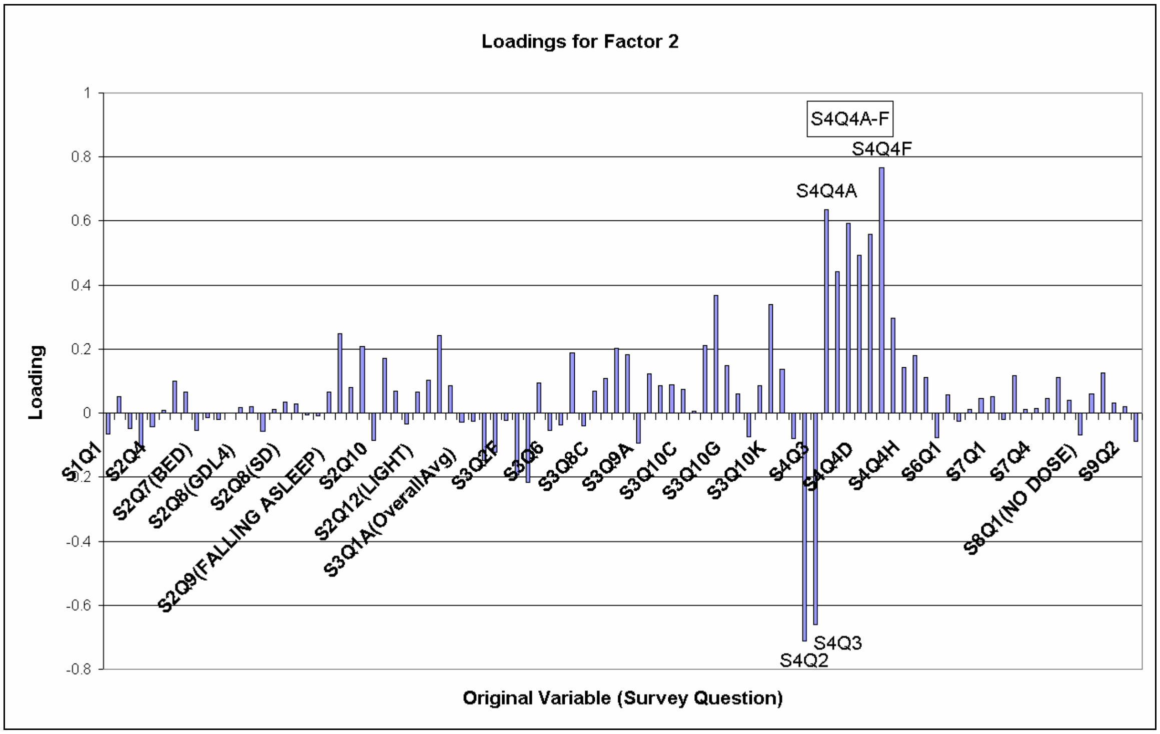


Figure 37. Loadings for the second factor.

The second factor, which explains 4.5% of the total variance in the original data and 10.3% of the total variance when combined with the first factor, seems to capture the symptoms of fatigue and sleep deprivation (Figure 37). Questions S4Q4A, B, C, D, E, and F all pertain to clear symptoms of fatigue and sleep deprivation as discussed in Chapter II, such as difficulty concentrating, difficulty staying awake, experiencing noticeable mood changes in oneself or others, difficulty waking up or getting out of bed, and still feeling tired 30 minutes after waking up. Additionally, questions S4Q2 and S4Q3 pertain to sleep latency and fatigue level just before falling asleep and just after waking up. When these questions are linearly combined into one factor, they provide a factor score that indicates fatigue, sleep deprivation, and sleep latency.

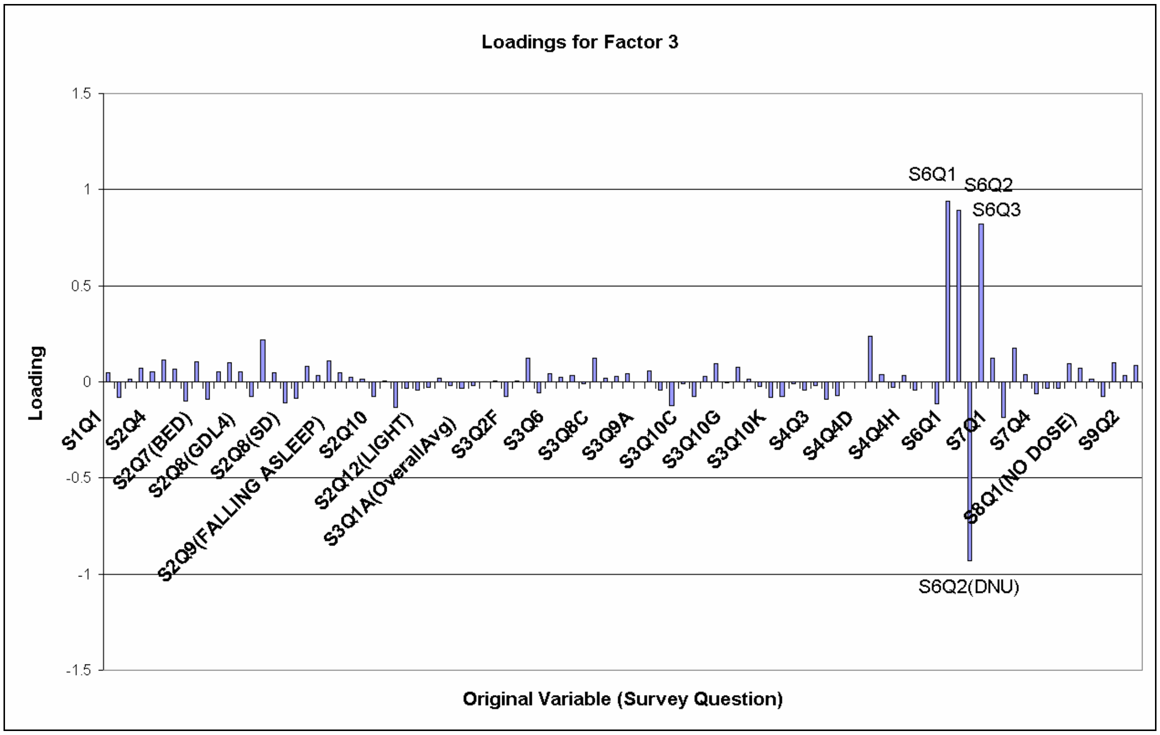


Figure 38. Loadings for the third factor.

The third factor, which explains 4.0% of the total variance in the original data and 14.3% of the total variance when combined with the other two factors, clearly captures a factor score for nicotine use (Figure 38). Questions S6Q1, S6Q2, S6Q2(DNU), and S6Q3 all have to do with nicotine use. When these questions are linearly combined into one factor, they provide us with a factor score to measure nicotine use.

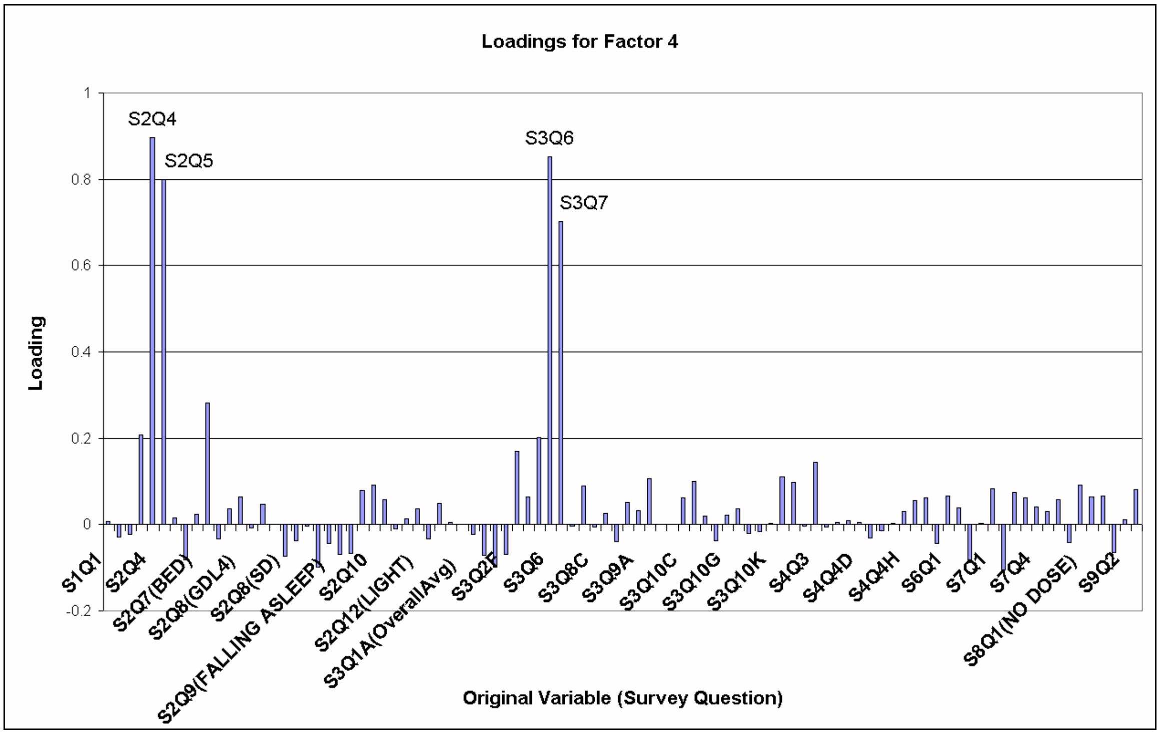


Figure 39. Loadings for the fourth factor.

The fourth factor, which explains 3.3% of the total variance in the original data and 17.6% of the total variance when combined with the other three factors, clearly captures the napping habits of the participant (Figure 39). Questions S2Q4, S2Q5, S3Q6, and S3Q7 all refer to napping habits, such as the duration of naps and the number of naps taken per day. When these questions are linearly combined into one factor, they provide a factor score that measures napping habits.

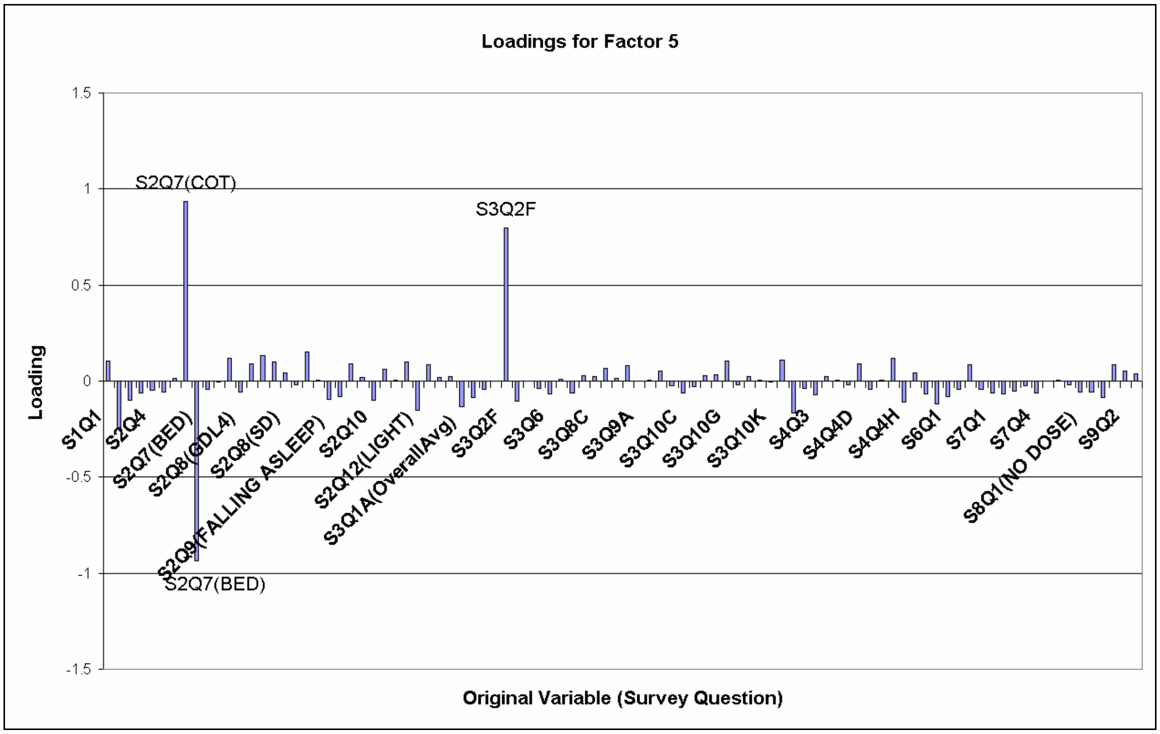


Figure 40. Loadings for the fifth factor.

The fifth factor, which explains 3.1% of the total variance in the original data and 20.7% of the total variance when combined with the other four factors, clearly captures where a participant slept (Figure 40). Questions S2Q7(COT), S2Q7(BED), and S3Q2F refer to where the participant got most of his or her sleep over a designated time period. When these questions are linearly combined into one factor, they provide a factor score that indicates where the participant gets most of his or her sleep and may indicate the overall sleep environment for that participant.

We can continue this interpretation process for each of the 50 factors. While not every factor will be as clearly interpretable as the first 5 factors, the factor scores provide us with measurable quantities that reflect the underlying variable of interest. For the purposes of this thesis, we will stop our interpretations of the factor loadings, but we will use the other interpretations in our survey refinement efforts.

An important use of factor analysis is to translate the original data into the planes of the factors using the factor scores as estimates of the interpretable quantities, such as those interpreted above. For example, we were able to use the scores from our second factor to provide a measurable quantity for symptoms of sleep deprivation. Using the factor scores for sleep deprivation, we were able to test several hypotheses regarding sleep deprivation in SWA. Using our factor analysis model, we are also able to predict estimated scores for new data. There is no question that factor analysis provides us with extremely useful means to analyze survey data and further provides us with insight on ways we might enhance our survey tool.

4. NPS Sleep Logistics Survey

Using the results from our principal components analysis and factor analysis, we were able to refine and improve our SWA survey. The resulting survey is shown in Appendix C and is titled Naval Postgraduate School Sleep Logistics Survey. The NPS Sleep Logistics Survey is a significant improvement to the original SWA survey and can be used to successfully analyze the sleep patterns of military personnel during many different operational environments, including environments ranging from training to CONOPS/SUSOPS. Based on the feedback from a 35-person Survey Working Group, the NPS Sleep Logistics Survey is a clear and concise survey that takes approximately 15 minutes to complete. While we will discuss the future research opportunities using the NPS Sleep Logistics Survey later in Chapter V, it is important to note here that the responses to the revised survey will provide unit leaders with a clearer picture of their unit's sleep patterns and fatigue level than the original SWA survey provided.

G. RELIABILITY OF DATA

Now that we have satisfactorily answered our research questions using the subjective survey data, it seems reasonable to investigate the reliability of the data. To this end, objective actigraphy data were compared with subjective survey data. Thirty-four volunteers wore an Actiwatch wrist activity monitor (WAM) for 7 days. At the end of the 7 days, the participants were asked to complete the *SOUTHWEST ASIA SLEEP, FATIGUE, AND ENDURANCE STUDY* survey. Using FAST, the predicted performance effectiveness scores of the raw activity data were compared with the predicted performance effectiveness scores based on the sleep/wake histories reported in question S3Q1B of the survey. Comparing these data provided us with an understanding of how accurately participants can recall sleep/wake histories over a 7-day period, as well as how accurately we evaluated those sleep/wake histories. For example, if the objective data indicated higher predicted performance effectiveness scores than the subjective scores, then the criteria used to answer our primary research questions are inaccurate. However, if the objective data indicate predicted performance effectiveness scores that are the same as or lower than the subjective scores, then our results hold.

Our participants for this reliability study consisted of 34 volunteers from the Naval Postgraduate School. The ages of the participants ranged from 25 to 47 years old (mean = 32.97 yrs, SD = 5.11 yrs). The sample consisted of 4 civilians (2 males, 2 females), 5 international officers (all males), 14 U.S. Army officers (13 males, 1 female), 6 U.S. Marine Corps officers (all males), and 9 U.S. Navy officers (8 males, 1 female). While the demographics of the reliability study differ from the demographics of the SWA study, we will assume that the ability to recall information over a 7-day period will be reasonably the same for both samples.

The Institutional Review Board at NPS approved the study design for research with human subjects. All of the participants completed informed consent forms at the start of the research. The informed consent forms were modified versions of Appendix A, which included an additional statement about wearing a WAM.

All of the participants were issued an Actiwatch WAM on 20 May 2004 and asked to wear the WAM continuously until 27 May 2004 (7 days). When the participants returned the WAM on 27 May 2004, they were then asked to complete the *SOUTHWEST ASIA SLEEP, FATIGUE, AND ENDURANCE STUDY* survey and related informed consent form. Participants were not told in advance that they would be asked to complete the survey, and they were not instructed to keep daily logs of sleep/wake histories. Since the purpose of this study was to gain insight regarding an individual’s ability to recall information pertaining to sleep habits over a 7-day period, participants were not told about the survey in advance in order to try to minimize bias associated with keeping sleep journals or anticipating the survey requirement.

Once the participants completed the survey and turned in their Actiwatch WAM, the sleep/wake histories reported in question S3Q1B were compared with the raw objective activity data from the WAM using FAST. Figure 41 shows the FAST plot of the predicted performance effectiveness for participant V635870 based on the sleep/wake history reported in question S3Q1B. The sleep history that was reported on the survey was entered into FAST using the schedule grid. Once the reported schedule was entered into FAST, the predicted performance effectiveness scores were calculated and averaged over all non-sleeping periods. An average performance score was reported for the same sleep schedule assuming three different sleep qualities – excellent, moderate, and poor.

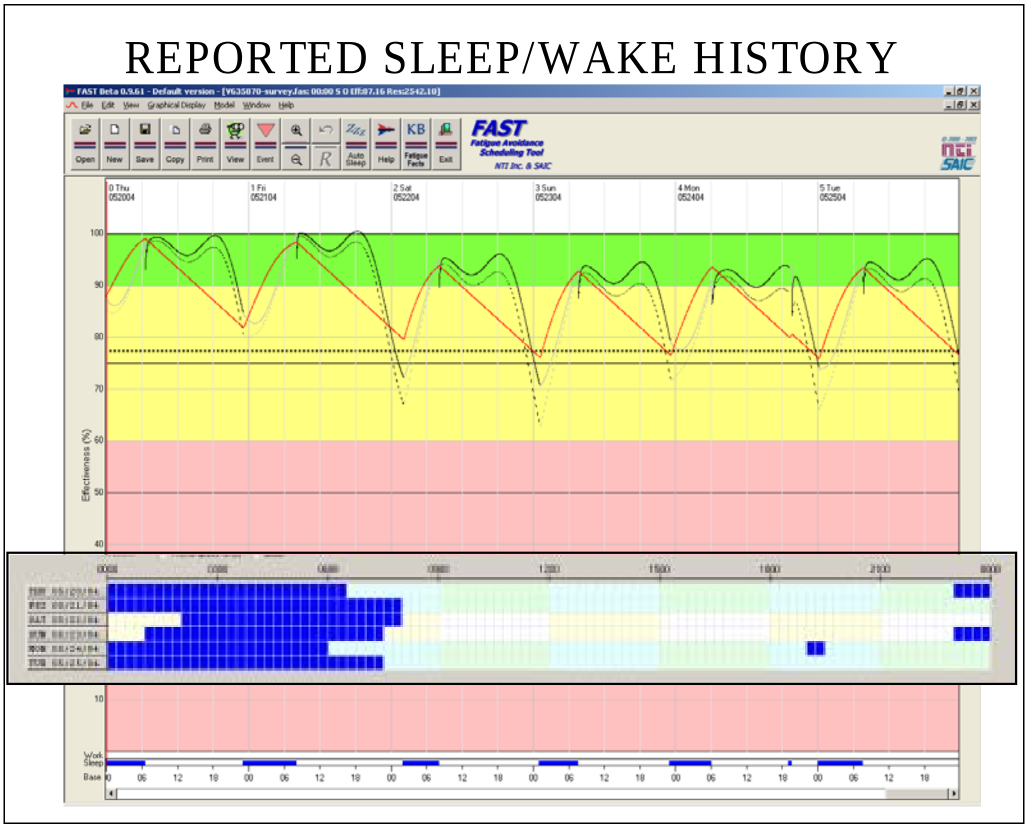


Figure 41. FAST output of participant V635870 for reported sleep/wake history obtained from S3Q1B. The reported sleep periods where entered into FAST using the schedule grid.

Once all of the reported sleep/wake histories were evaluated, they were compared with the objective activity data obtained from the Actiwatch WAM. The data from the WAM were downloaded using Actiware software. Figure 42 shows the raw activity data associated with participant V635870. The heavy black lines represent activity and the lack of activity suggests periods of sleep. Some participants may be restless sleepers and therefore show short periods of activity during known periods of sleep. Similarly, some participants may be engaged in activities, such as reading a book or watching TV, and therefore show short periods of scored sleep when they are not actually sleeping. These unique situations can be corrected by subjectively cleaning the data to eliminate such discrepancies. However, it seems reasonable to leave the raw data as scored by the WAM sleep/activity algorithm since activity during sleeping periods suggests degraded sleep quality. For example, a person with high activity during known sleep periods is experiencing moderate to poor sleep quality. Similarly, inactivity during non-sleep periods will slow the rate at which the sleep reservoir is depleted. For example, a person who is exercising will deplete their sleep reservoir faster than a person who is quietly reading a book. Keeping this in mind, we chose not to subjectively clean the data, but rather use the raw data as an indication of sleep quality.

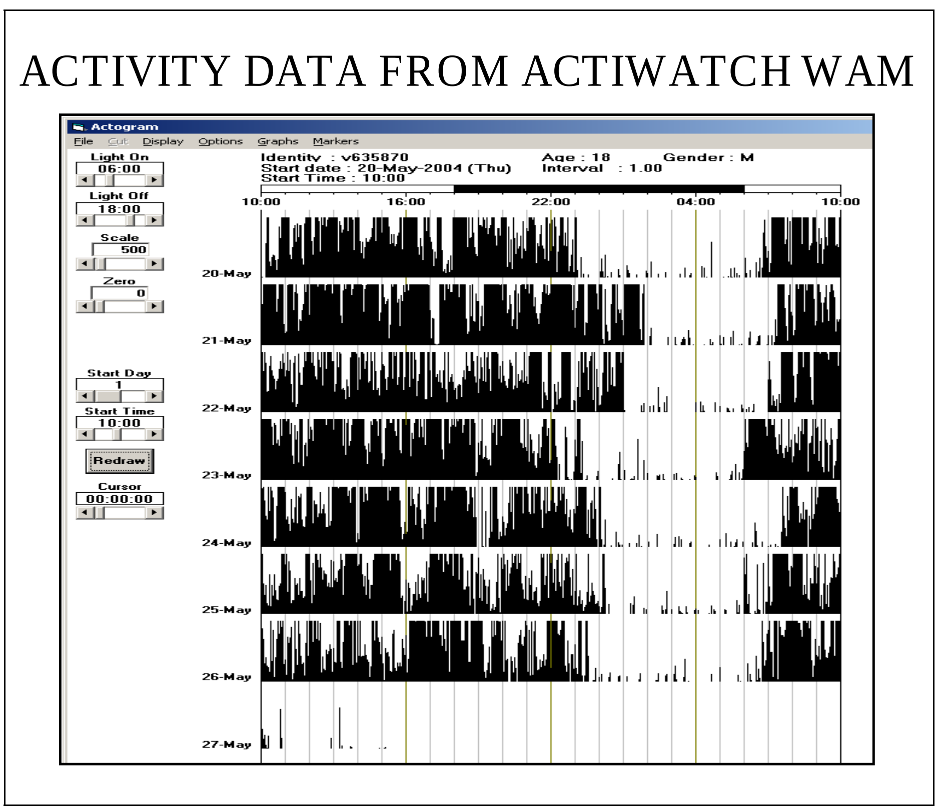


Figure 42. Raw activity data from participant V635870.

The raw activity data were then imported directly into FAST, as shown in Figure 43. There was no need to indicate the quality of the sleep for the reasons previously mentioned. Once imported, the performance effectiveness score was calculated and averaged over all non-sleep periods.

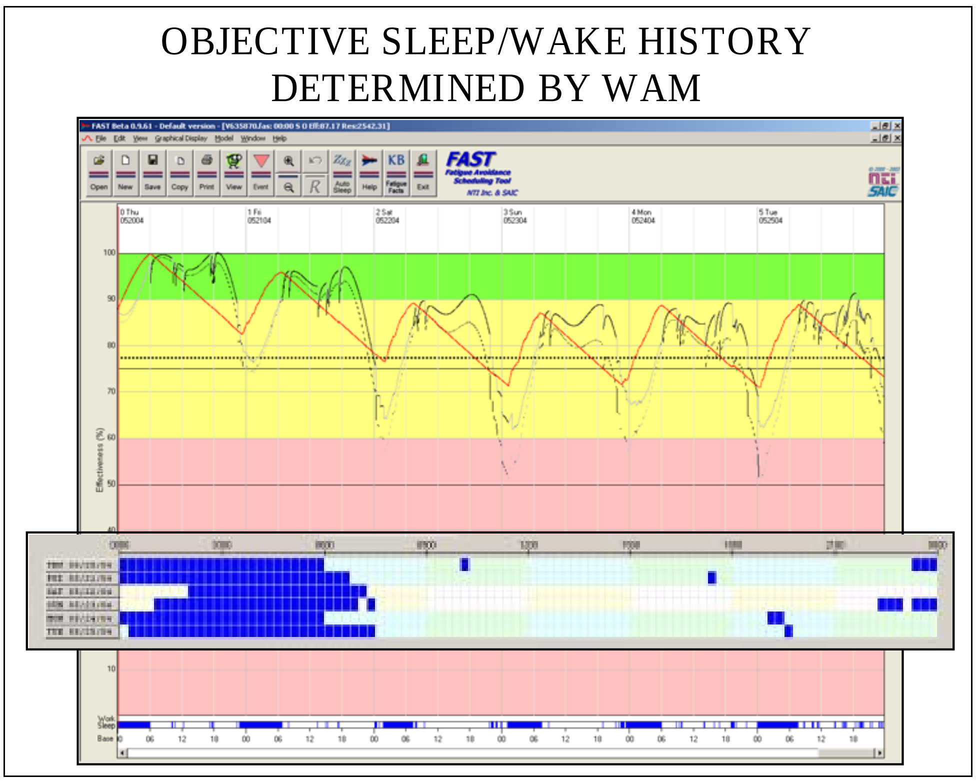
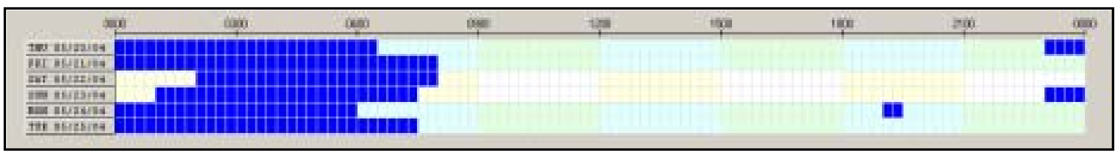


Figure 43. FAST output based on raw activity data for participant V635870.

The purpose of this analysis is to test the reliability of the subjective data based on the objective activity data. This could have been done by comparing each epoch and determining if the participant could, in fact, accurately remember when he or she slept when compared to the WAM’s sleep/activity algorithm. In the case of the objective and subjective schedules for participant V635870, shown in Figure 44, the reported data and the objective data are reasonably the same.

COMPARISON OF SUBJECTIVE AND OBJECTIVE SLEEP/WAKE SCHEDULES

REPORTED SLEEP/WAKE SCHEDULE FOR PARTICIPANT V635870 DETERMINED BY RESPONSE TO QUESTION S3Q1B



OBJECTIVE SLEEP/WAKE SCHEDULE FOR PARTICIPANT V635870 DETERMINED BY ACTIWATCH WAM

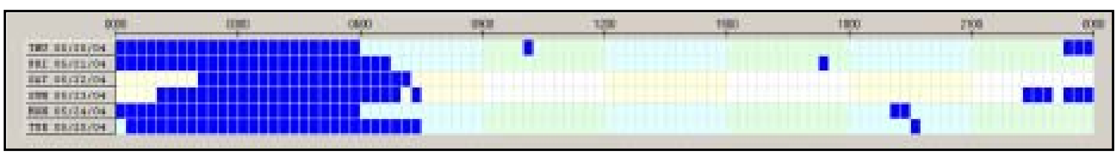


Figure 44. Comparison of subjective and objective sleep/wake schedules of participant V635870.

The intent of asking for the reported sleep/wake history on the survey was to estimate the predicted performance effectiveness of an individual based on the reported sleep/wake history. Therefore, rather than focusing on the schedule itself, we chose to compare the average predicted performance effectiveness during non-sleep periods of the subjective schedule with the average predicted performance effectiveness during non-sleep periods of the objective schedule.

To this end, we analyzed the paired data by conducting a paired t test of the differences in average predicted performance effectiveness scores between the objective schedule and the associated subjective schedule (Devore, 2000). We conducted the paired t test once assuming excellent sleep quality of the subjective schedule, once assuming moderate sleep quality, and once assuming poor sleep quality. The data consist of n=34 independently selected pairs (X_i, Y_i) with i going from 1 to 34, and where X_i is the average predicted performance score under the objective schedule and Y_i is the average predicted performance score under the subjective schedule with specified sleep quality. Let $D_i = X_i - Y_i$ be the difference within the pair. Then the D_i's are assumed to be normally distributed with mean μ_D and variance σ_D^2.

For the purposes of this research, we are more concerned if the objective performance scores are higher than the subjective performance scores. Throughout our research, we have assumed that a predicted performance effectiveness score below 77.5% indicated an unsatisfactory performance level. If it turns out that the objective scores are higher than the subjective scores that we have been using, then much of our research would not be valid. If, on the other hand, the objective scores are the same or less than the subjective scores, then it seems reasonable that our results for the primary research questions hold. Therefore, the hypothesis we wish to test is that the mean of the differences is less than zero. That is, our hypothesis test is written as:

$$H_o : \mu_D \geq \Delta_0$$
$$H_A : \mu_D < \Delta_0$$

Where $D = X - Y$ is the difference between paired observations, $\mu_D = \mu_{\text{obj}} - \mu_{\text{sub}}$ is the difference between the mean of the objective data and the subjective data, and Δ_0 is the expected difference between μ_{obj} and μ_{sub}.

Out test statistic is:

$$t^* = \frac{\bar{d} - \Delta_0}{S_D / \sqrt{n}}$$

Where $\bar{d}$ is the sample mean of the differences, Δ_0 is the expected difference between μ_{obj} and μ_{sub}, S_D is the sample standard deviation, and n is the sample size. Testing at a significance level of $\alpha = 0.05$, we will reject the null hypothesis, H_o, if $t^* \leq -t_{\alpha,n-1}$, where $t_{\alpha,n-1} = t_{0.05,33}$=2.03. The data used for this analysis and the associated results are found in Appendix H and are summarized here.

Assuming $\Delta_0 = 0$ and sleep quality for the reported sleep/wake history is excellent, we find that $\bar{d}$=-4.28, and S_D=4.47, which yields t^*=-5.59. Since $t^* <$ -2.03, we reject the null hypothesis under these assumptions (p-value = 1.59e-6). That is, the data suggest that average predicted performance effectiveness scores of the objective data are lower than the average predicted performance scores of the reported sleep/wake histories with excellent sleep quality.

Assuming $\Delta_0 = 0$ and sleep quality for the reported sleep/wake history is moderate, we find that $\bar{d}$=-1.77, and S_D=4.60, which yields t^*=-2.24. Since $t^* <$ -2.03, we reject the null hypothesis under these assumptions (p-value = 0.016). That is, the data suggest that average predicted performance effectiveness scores of the objective data are lower than the average predicted performance scores of the reported sleep/wake histories with moderate sleep quality.

Assuming $\Delta_0 = 0$ and sleep quality for the reported sleep/wake history is poor, we find that $\bar{d}$=7.02, and S_D=4.90, which yields t^*=8.35. Since $t^* >$ -2.03, we fail to reject the null hypothesis under these assumptions (p-value = 0.999). That is, the data do not suggest that average predicted performance effectiveness scores of the objective data are lower than the average predicted performance scores of the reported sleep/wake histories with poor sleep quality.

Since we based our performance effectiveness calculations on moderate sleep quality in our SWA survey data, and the results of the reliability test support that the objective data are in fact lower than the scores we reported, the analysis of the research questions provide a conservative evaluation of the data. The results from this reliability test suggest that, on average, the reported predicted performance scores of our NPS sample should be 1.77 percentage points lower than the performance scores we calculated from the self-reported sleep/wake histories, when assuming moderate sleep quality, and 4.28 percentage points lower than what we calculated when assuming excellent sleep quality.

These results further suggest that the NPS sample could reasonably recall their sleep/wake history over a 7-day period. While we did not specifically test the ability of participants to recall other information, such as remembering how many dreams they had or what made it difficult for them to sleep, it seems reasonable to suggest that their ability to recall this information will be approximately the same as recalling their sleep/wake history. Assuming that the ability to recall information pertaining to sleep patterns over a 7-day period is the same for our SWA sample, we suggest that the self-reported data obtained from our surveys does provide valuable and useful insight regarding that population, and so our previous results hold.

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V. DISCUSSION AND RECOMMENDATIONS

A. DISCUSSION

The purpose of this thesis was to examine sleep patterns, fatigue issues, and predicted performance effectiveness of warfighters deployed to the Southwest Asia Area of Operation in order to address four primary research questions.

Our first research question asks if sleep deprivation is a significant problem for forces currently deployed to the SWA region. We addressed this research question by analyzing the average reported sleep/wake histories, considering the predicted performance effectiveness levels for the 50^{th}, 25^{th}, and 10^{th} percentiles of the sample using the Fatigue Avoidance Scheduling Tool (FAST), by using factor analysis techniques to construct sleep deprivation scores, and by employing parametric statistics to test for differences in probabilities related to sleep deprivation. Our research for this question suggests that sleep deprivation is a significant problem facing our forces, especially those operating in Iraq (p-value = 0.0151 for the hypothesis tested). The data suggest that between 73% and 83% of the sample show moderate symptoms of sleep deprivation ($\overline{X} = 0.77, S = 0.025$) and that between 14% and 23% of the sample show significant symptoms of sleep deprivation ($\overline{X} = 0.187, S = 0.024$).

Our second research question asked if current sleep patterns of forces operating in SWA support a unit’s ability to accomplish assigned missions. We addressed this research question by constructing a binomial test based on the sleep/wake histories reported in the survey and the resulting predicted performance effectiveness levels obtained from FAST. Using the assumptions stated in Chapter IV, we believe the data suggest that the sleep patterns of our sample do not support mission accomplishment (p-value for the hypothesis tested = 0.000). We found that only between 45% and 57% of the sample's sleep/wake patterns satisfactorily support mission accomplishment ($\overline{X} = 0.51, S = 0.03$), which does not meet typical standards of operational readiness requiring 75% of the population to be mission capable. This does not mean that warfighters cannot or will not accomplish assigned missions, it simply means that the current sleep patterns of our sample warfighters hinders their ability to accomplish assigned missions.

Our third research question asked if statistically significant differences in sleep patterns and predicted performance effectiveness levels exist when we consider subsets of the general population such as subsets based on gender, rank, MOS, location, and those who reported that their unit had clear sleep plans. We addressed this research question by using nonparametric techniques, such as the Fisher's Exact Test and the Chi-squared Test for Independence, to analyze the reported sleep/wake histories of our sample by obtaining predicted performance effectiveness scores for the corresponding sleep/wake history using the Fatigue Avoidance Scheduling Tool. Presuming that the assumptions made in Chapter IV hold, the data suggest that units with effective sleep/rest plans have a higher probability of maintaining satisfactory performance effectiveness levels than those with no or ineffective sleep/rest plans (p-value for the hypothesis tested = 0.0035). Further, units located in Kuwait have a higher probability of maintaining satisfactory performance effectiveness levels than units in Iraq, which supports the decision to rotate units out of Iraq and into Kuwait for rest and recovery (p-value for the hypothesis tested = 0.0029). The data did not suggest, however, that there were differences in the probabilities associated with maintaining satisfactory performance effectiveness levels when we considered gender, MOS categories, or rank; it seems equally difficult for males and females of all ranks and MOS's to maintain sleep/wake schedules that promote satisfactory performance effectiveness levels, which in turn support mission accomplishment.

Our fourth research question asked if the current survey method supported the research objectives. As we can see from our analysis of the first three research questions, the SWA survey was useful for our purposes. However, using the results of factor analysis and principal components analysis, we were able to refine and improve the SWA survey and produce a clearer, more concise, and user-friendlier survey titled The Naval Postgraduate School Sleep Logistics Survey. The NPS Sleep Logistics Survey will provide unit leaders with a clearer picture of their unit's sleep patterns and fatigue level than the SWA survey provided. Due to the availability of the NPS Sleep Logistics Survey through Scantron Corporation, we encourage unit leaders to use the survey on their own in order to assess their unit's success at managing sleep and fatigue.

As a direct follow-on to the fourth research question, we tested the reliability of self-reported data with objective actigraphy data over a 7-day period (n = 34) by comparing the differences between the predicted performance effectiveness score based on the actigraphy data and the self-reported sleep/wake history. Based on the results of this follow-on research conducted at the Naval Postgraduate School, we found that when we assumed excellent or moderate sleep quality that the self-reported survey data provided a reliable and conservative estimate for the predicted performance effectiveness based on actigraphy data. That is, we found that actigraphy-based performance effectiveness scores were actually lower than the predicted performance effectiveness scores based on the self-reported sleep/wake histories (p-value for the hypothesis tested < 0.0001 when we assumed excellent sleep quality and the p-value for the hypothesis tested = 0.016 when we assumed moderate sleep quality). Presuming that the ability to recall information over a 7-day period is the same for our SWA sample as for our NPS sample, the results from our reliability test reinforce the results of our primary research questions.

B. RECOMMENDATIONS

As military professionals, we understand that war is "an act of force to compel our enemy to do our will" (Clausewitz, 1989, p. 75). Since war is then a clash between opposing human wills, it seems reasonable to suggest that the human dimension is central to warfighting. MCDP-1 (1997, p. 13) states:

> It is the human dimension which infuses war with its intangible moral factors. War is shaped by human nature and is subject to the complexities,

> inconsistencies, and peculiarities which characterize human behavior.

It is vital for military leaders and professionals to consider the effects of exhaustion and privation on those who are required to do the fighting. Further, since the means and methods we use in warfare continuously change and evolve, so must our tactics change to maximize our capabilities, minimize our limitations, and counteract our enemy’s will. If we fail to refine and improve our approach to warfighting, then we risk becoming “outdated, stagnant, and defeated” (MCDP-1, preface). Understanding the significant impact of sleep deprivation on warfighter performance is one of the crucial elements of human nature that can directly influence the battlefield tactically, operationally, and even strategically. Contributing to the fog of war and increasing the likelihood of making decisions that have adverse strategic consequences, the effects of sleep deprivation cannot be ignored.

Therefore, we encourage military professionals of all ranks and at all levels of leadership to develop effective sleep logistics and sleep management plans. Extensive research has been done on the subject of managing fatigue during continuous and sustained combat operations. Leaders are encouraged to review the known effective fatigue countermeasures discussed in the research and summarized in Chapter II. Further, the Naval Postgraduate School Sleep Logistics Survey provides unit leaders with a means to assess the effectiveness of their unit’s sleep logistics planning during training so as to ensure success in combat.

There is no question that many of the fatigue countermeasures listed in the literature are difficult to implement in the combat environment. However, it is imperative that leaders at all levels establish clear guidance when it comes to sleep logistics. With proper sleep logistics, individual and unit performance is significantly enhanced; but poor sleep logistics, as argued previously, can have strategic consequences. By refining and improving our approach to warfighting in this area, we ensure success on the future battlefield.

C. FUTURE RESEARCH

This research opens up a wide possibility of follow-on research in all areas of Operations Research. Specifically, Applied Statisticians might consider administering the Naval Postgraduate School Sleep Logistics survey (Appendix C) to warfighters currently deployed in the Southwest Asia area of operation or other active combat areas in order to compare results and validate this research. The simulation community might consider developing a simulation to model performance effectiveness of individual warfighters and/or combat units based on how a unit implements a specific sleep/rest plan given a tactical scenario. Optimization researchers might consider determining the optimal sleep/rest plan that maximizes individual or unit performance effectiveness within tactical constraints. Finally, Human Performance researchers are encouraged to develop a detailed model of human performance that expands, refines, and improves the Sleep Activity Fatigue and Task Effectiveness Model to account for individual differences, use of fatigue countermeasures, and use of performance enhancing medications in order to better predict individual and/or unit performance effectiveness under realistic tactical scenarios.

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APPENDIX A. INFORMED CONSENT FORM

Participant Consent Form:

PARTICIPANT CONSENT FORM

1. **Introduction.** The purpose of this survey is to collect data directly related to sleep patterns, fatigue issues, and endurance capabilities. The Army Material Command (AMC) Southwest Asia (SWA) Science and Technology team is administering this survey. Data analysis will be conducted at the Naval Postgraduate School (NPS) in order to identify statistically significant factors related to sleep plans, sleep patterns, fatigue concerns, and endurance capabilities. Conclusions and recommendations drawn from this survey may contribute to improving policies and procedures related to sleep plans and endurance factors. This survey is voluntary, anonymous, and cannot be traced back to you.

2. **Background Information.** The Naval Postgraduate School Operations Research Department is conducting this study, with assistance from the Army Material Command.

3. **Procedures.** If you agree to participate, you will be asked to complete one survey as honestly and as accurately as you can. We expect that the survey will take approximately 30 to 60 minutes to complete. The survey asks questions about your sleep patterns over the past 24-hour period, 7-day period, and 30-day period. The survey also asks questions about possible confounding issues related to sleep, fatigue, and endurance.

4. **Risks and Benefits.** This research involves no risks or discomforts greater then those encountered in completing a survey. The benefits to the participants include contributing to current research in sleep and fatigue issues related.

5. **Compensation.** No tangible reward will be given. A copy of the results will be available to you through your chain-of-command at the conclusion of the study.

6. **Confidentiality.** The records of this study will be kept confidential. No information will be publicly accessible which could identify you as a participant.

7. **Voluntary Nature of the Study.** If you agree to participate, you are free to withdraw from the study at any time without prejudice. You will be provided a copy of this form for your records.

8. **Points of Contact.** If you have any further questions or comments after the completion of the study, you may contact the research supervisor, Dr. Nita L. Miller, (831) 656-2281, E-mail: nlmiller@nps.navy.mil.

9. **Statement of Consent.** I have read the above information. I have asked all questions and have had my questions answered. I agree to participate in this study.

--	--------------------------
Participant's Signature	Date
--	--------------------------
Researcher's Signature	Date

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APPENDIX B. SWA SURVEY

The original survey, Page 1:

SOUTHWEST ASIA SLEEP, FATIGUE, AND ENDURANCE STUDY

The purpose of this survey is to collect data directly related to sleep patterns, fatigue issues, and endurance capabilities. The Army Material Command (AMC) Southwest Asia (SWA) Science and Technology team is administering this survey. Data analysis will be conducted at the Naval Postgraduate School (NPS) in order to identify statistically significant factors related to sleep plans, sleep patterns, fatigue concerns, and endurance capabilities. Conclusions and recommendations drawn from this survey may contribute to improving policies and procedures related to sleep plans and endurance factors. This survey is voluntary, anonymous, and cannot be traced back to you. If you are willing to participate, please answer the questions below as honestly and accurately as you can. We appreciate your time and willingness to complete this survey. Thank you!

DEMOGRAPHICS:

	EXAMPLE	YOUR RESPONSE		EXAMPLE	YOUR RESPONSE
Pay Grade: (E-1, E-2, O-1, O-2, etc.)	E-5		Rank:	Sergeant	
Age (years)	27		Gender (M/F)	M	
Height (inches)	71		Weight (pounds)	185	
Location (Iraq or Kuwait)	Iraq		Date you deployed (YYYY MMM DD)	2003 JAN 10	
Are you working in a **garrison** environment (Y/N)	N		Are you working in a **field** environment (Y/N)	Y	
MOS	0302		Branch of Service	U. S. Army	

	EXAMPLE	YOUR RESPONSE
MOS Description:	Infantry	
Billet:	Platoon Sergeant	
Billet Description:	Platoon Sergeant for 30-man mechanized infantry platoon.	

SECTION 1: ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR UNIT'S SLEEP PLAN STANDARD OPERATING PROCEDURE (SOP).

1. I have been briefed on a sleep plan. **(Yes / No)**

   a. (If yes) In general, my unit has been able to stick with the sleep plan as it was described to me. **(Yes / No)**

2. To the best of my knowledge, the sleep plan that was described to me is a written Standard Operating Procedure (SOP) for my unit. **(Yes / No / I don't know)**

   a. (If yes) To the best of my knowledge, the sleep plan that was described to me was written by this leader or commander:

Squad Leader	Section Leader	Platoon Leader	Company Commander	Battalion Commander	Regimental Commander	Brigade Commander	Division Commander	Higher
O	O	O	O	O	O	O	O	O

3. I feel my unit's sleep plan:

Never works.	Almost never works.	Sometimes doesn't work.	Doesn't make much of a difference	Sometimes works well.	Almost always woks well.	Always works well.
O	O	O	O	O	O	O

4. My unit works in shifts (For example: day shifts and night shifts). **(Yes / No)**

SECTION 2: ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR SLEEP OVER THE PAST 24 HOURS.

1. During the past 24 hours, I was allowed to get sleep during these times: **(shade in all boxes that apply)**

0000-0100	0100-0200	0200-0300	0300-0400	0400-0500	0500-0600	0600-0700	0700-0800	0800-0900	0900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700	1700-1800	1800-1900	1900-2000	2000-2100	2100-2200	2200-2300	2300-2400

2. During the past 24 hours, I actually slept, including naps if applicable, during these hours: **(shade in all boxes that apply)**

0000-0100	0100-0200	0200-0300	0300-0400	0400-0500	0500-0600	0600-0700	0700-0800	0800-0900	0900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700	1700-1800	1800-1900	1900-2000	2000-2100	2100-2200	2200-2300	2300-2400

3. In the past 24 hours, I got approximately ________hours of sleep, including naps if applicable. **(Example: 8 ½, 4 ¼, 7, etc.)**

4. In the past 24 hours, I took this many naps:

0	1	2	3	4	5	6	7	>7
O	O	O	O	O	O	O	O	O

Page 2:

SOUTHWEST ASIA SLEEP, FATIGUE, AND ENDURANCE STUDY

5. If I add the time of all the naps I took, I napped for a total of about _______hours. **(Example: 0, ½, ¾, 2 ½, etc.)**

6. Check the box that best describes how long it took you to fall asleep.

I fell asleep immediately	I slowly drifted to sleep	It took me just a few minutes to fall asleep	I laid awake for a little while	I laid awake for about an hour	It took me a long time to fall asleep
O	O	O	O	O	O

7. When I got most of my sleep, I was located: (Check the box that most closely fits)

In a bed	On a cot	On the ground	In a vehicle	On top of a vehicle	Other
O	O	O	O	O	O

If other, please list: ______________________________

8. During the past 24 hours, I have done the following duties: (check all that apply)

Patrol	Guard Duty (less than 4 hours)	Guard Duty (more than 4 hours)	Radio Watch	Duty Driver	Staff Duty	Duty Officer	Operational Mission	Other
O	O	O	O	O	O	O	O	O

If other, please explain: ______________________________

9. I had trouble: (Please check all that apply.)

Falling asleep	Waking up	Staying asleep	Staying awake
O	O	O	O

10. I remember dreaming during the past 24 hours. **(Yes / No)**

11. I had a nightmare during the past 24 hours. **(Yes / No)**

12. The following things made it difficult for me to sleep: (Check all that apply.)

Noise	Temperature	Light	Physical Discomfort	Stress/Worry	Other
O	O	O	O	O	O

If other, please explain: ______________________________

SECTION 3: ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR SLEEP HABITS OVER THE PAST WEEK.

For the following questions, please answer to the best of your knowledge. Here is an example of how to fill in the boxes assuming that you slept from midnight to 0130, then from 0300 to 0530, and again from 1200 to 1300:

	0000-0100	0100-0200	0200-0300	0300-0400	0400-0500	0500-0600	0600-0700	0700-0800	0800-0900	0900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700
Monday	■	■		■	■	■							■				

1. Over the past week:

   a. According to my unit's sleep plan, shift schedule, or normal plan of the day, I was <u>allowed</u> to get sleep during the following hours:

	0000-0100	0100-0200	0200-0300	0300-0400	0400-0500	0500-0600	0600-0700	0700-0800	0800-0900	0900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700	1700-1800	1800-1900	1900-2000	2000-2100	2100-2200	2200-2300	2300-2400
Monday																								
Tuesday																								
Wednesday																								
Thursday																								
Friday																								
Saturday																								
Sunday																								

   b. Over the past week, I generally slept during these hours (these may be different from the answers to the last question because you either found more time to get sleep or got less sleep than you were allowed to):

	0000-0100	0100-0200	0200-0300	0300-0400	0400-0500	0500-0600	0600-0700	0700-0800	0800-0900	0900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700	1700-1800	1800-1900	1900-2000	2000-2100	2100-2200	2200-2300	2300-2400
Monday																								
Tuesday																								
Wednesday																								
Thursday																								
Friday																								
Saturday																								
Sunday																								

Page 3:

SOUTHWEST ASIA SLEEP, FATIGUE, AND ENDURANCE STUDY

For the following questions, think of average time when you actually slept. The time you "actually slept" may be different from the time you were in a bed or in a sleeping bag.

2. On average over the past week, I slept about this many hours (total for the week):

	Total Hours for the week (Ex: 0, 1 ½, 5, Etc.)
a. On the ground, in a sleeping bag	
b. On the ground, not in a sleeping bag	
c. On or in a vehicle, with a sleeping bag	
d. On or in a vehicle, not with a sleeping bag	
e. In a bed (even if you slept with a sleeping bag or something similar)	
f. On a cot (even if you slept with a sleeping bag or something similar)	

3. On average, I got approximately _______ hours of sleep every day. **(Example: 8 ½, 4 ¼, 7, etc.)**

4. On average, I got approximately _______ hours of sleep while it was DARK outside every day. **(Example: 8 ½, 4 ¼, 7, etc.)**

5. On average, I got approximately _______ hours of sleep while it was LIGHT outside every day. **(Example: 8 ½, 4 ¼, 7, etc.)**

6. On average, I took this many naps every day:

0	1	2	3	4	5	6	7	>7
O	O	O	O	O	O	O	O	O

7. On average, if I add the time of all the naps I took, I napped for a total of about _______ hours every day. **(Example: 0, ½, ¼, 2 ½, Etc.)**

8. Please answer this question by checking the number of days this past week that the following statement was true.

I had trouble:	0	1	2	3	4	5	6	7
a. falling asleep in general	O	O	O	O	O	O	O	O
b. falling asleep specifically because it was too bright outside.	O	O	O	O	O	O	O	O
c. waking up under normal conditions (i.e. waking up for normal duties).	O	O	O	O	O	O	O	O
d. waking up under extreme conditions (i.e. alarms, combat action, etc).	O	O	O	O	O	O	O	O
e. staying asleep.	O	O	O	O	O	O	O	O
f. staying awake.	O	O	O	O	O	O	O	O

9. Please answer this question by checking the number of days this past week that the following statement was true:

I remember:	0	1	2	3	4	5	6	7
a. dreaming.	O	O	O	O	O	O	O	O
b. having a bad dream or nightmare.	O	O	O	O	O	O	O	O

10. Please answer this question by checking the number of days this past week that the following statement was true:

I had trouble sleeping or was woken up after falling asleep because:	0	1	2	3	4	5	6	7
a. I had to go to the bathroom.	O	O	O	O	O	O	O	O
b. I was snoring loudly.	O	O	O	O	O	O	O	O
c. I had bad dreams.	O	O	O	O	O	O	O	O
d. It was too bright out.	O	O	O	O	O	O	O	O
e. I was not in a comfortable sleeping position.	O	O	O	O	O	O	O	O
f. I was in pain.	O	O	O	O	O	O	O	O
g. I was too hot.	O	O	O	O	O	O	O	O
h. I was too cold.	O	O	O	O	O	O	O	O
i. I had trouble breathing.	O	O	O	O	O	O	O	O
j. I could not adjust to my new sleep schedule.	O	O	O	O	O	O	O	O
k. of some other reason.	O	O	O	O	O	O	O	O

11. Please answer this question by checking the number of days this past week that the following statement was true:

	0	1	2	3	4	5	6	7
I fell asleep when I was supposed to be awake.	O	O	O	O	O	O	O	O

12. During the past week, I have performed the following missions: (check all that apply)

Patrol	Guard Duty (less than 4 hours)	Guard Duty (more than 4 hours)	Radio Watch	Duty Driver	Staff Duty	Duty Officer	Operational Mission	Other
O	O	O	O	O	O	O	O	O

If other, please explain: ______________________________

Page 4:

SOUTHWEST ASIA SLEEP, FATIGUE, AND ENDURANCE STUDY

SECTION 4: ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR RECENT SLEEP PATTERNS.

1. On average, comparing my sleep pattern of the last month to my sleep pattern of the last week, I would say that my quality of sleep was _______ compared to last week.

Much Worse	Somewhat Worse	Worse	About The Same	Better	Somewhat Better	Much Better
O	O	O	O	O	O	O

2. On average over the past month, I felt _______ just after I woke up.

Completely Drained	Worn-out	A bit tired	Fine	Lively	Energetic	Very Energetic
O	O	O	O	O	O	O

3. On average over the past month, I physically felt ________ just before I fell asleep.

Completely exhausted	Drained	Pretty tired	Tired	Comfortable	Pretty relaxed	Very relaxed
O	O	O	O	O	O	O

4. When thinking about the past month, please indicate how often this statement was true:

	Never	Seldom	Sometimes	Often	Always
a. I feel so tired that I cannot concentrate.	O	O	O	O	O
b. I have difficulty staying awake.	O	O	O	O	O
c. I experience noticeable mood changes.	O	O	O	O	O
d. I notice mood changes of others.	O	O	O	O	O
e. I have difficulty waking up or getting out of bed.	O	O	O	O	O
f. I still feel tired 30 minutes after waking up.	O	O	O	O	O
g. I wake up regularly because I am too hot.	O	O	O	O	O
h. I wake up regularly because I am too cold.	O	O	O	O	O
i. I wake up regularly because it is too bright out.	O	O	O	O	O
j. I wake up regularly because I have trouble breathing.	O	O	O	O	O

SECTION 5: ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR PHYSICAL FITNESS.

1. On average in the past month, I spend ____________ hours per **week** on physical fitness.

2. I am _______ physically fit now than I was prior to deploying.

Much Less Fit	Less fit	A little less fit	About The Same	A little more fit	More fit	Much More Fit
O	O	O	O	O	O	O

3. I am pleased with my level of fitness. **(Yes / No)**

SECTION 6: ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR TOBACCO USE.

1. During the past week, I have smoked cigarettes, used smokeless tobacco, or other tobacco products. **(Yes / No)**

2. I smoke cigarettes, use smokeless tobacco, or other tobacco products __________ as before I deployed:

Do Not Use	Much less frequently	Less frequently	A little less frequently	About the same	Somewhat more frequently	More frequently	Much more frequently
O	O	O	O	O	O	O	O

3. On average, I use tobacco products ___________ times a **day**. (Please consider one use of tobacco as one cigarette, one pinch of dip, or one single use of another form of tobacco.)

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	>20
O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

SECTION 7: ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR CAFFEINE USE.

1. I use _______ products containing caffeine now than I did prior to deployment.

Do Not Use	Much fewer	Fewer	A little fewer	The same amount of	A little more	More	Much More
O	O	O	O	O	O	O	O

2. On average, I drink __________ beverages containing caffeine in a **day**. (Please consider a single beverage containing caffeine as one 12-oz soda, one 8-oz cup of coffee, one 8-oz cup of tea, or similar size.)

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	>20
O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

4

Page 5:

3. Recently, I have used products like No-Doze or other caffeine supplements. **(Yes / No)**

4. Recently, I have used products like Ripped Fuel or other ephedra-based supplements. **(Yes / No)**

SECTION 8: ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR MEDICATION USE.

1. Within the past week, I have taken, or am currently taking, medication (either prescribed or over-the-counter) for: (Check all that apply.)

Malaria	Pain medication	Sleep Aids (including over-the-counter)	Helping me stay awake (including over-the-counter)	Other
O	O	O	O	O

If other, please list:

____

____

2. I have received the following vaccinations and/or shots in the past **week**:

____

____

3. I have received the following vaccinations and/or shots in the past **month**:

____

____

SECTION 9: ANSWER THE FOLLOWING QUESTIONS ABOUT RECENT DISCIPLINE ACTION.

Please remember that this survey is voluntary, anonymous, and cannot be traced back to you.

1. I received Non-Judicial Punishment (NJP) during the past week. **(Yes / No)**

2. I received Extra Military Instruction or extra duty in connection with NJP during the past week. **(Yes / No)**

3. I received other type(s) of disciplinary action during the past week. **(Yes / No)**

THANK YOU FOR COMPLETING THIS SURVEY. YOUR PARTICIPATION IS VERY IMPORTANT TO US. WE BELIEVE THAT YOUR PARTICIPATION WILL DIRECTLY HELP US IDENTIFY AREAS WE CAN IMPROVE IN THE FIELD OF SLEEP, FATIGUE, AND ENDURANCE. THIS CONCLUDES THE SURVEY.

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APPENDIX C. NPS SLEEP LOGISTICS SURVEY

The Naval Postgraduate School Sleep Logistics Survey can be ordered through the Scantron Corporation. The custom form number for this survey is No. F-18236-NAVYP. To reorder this survey through Scantron, call 1-800-722-6876. The questions and format of the survey are shown on the following pages.

Page 1:

NAVAL POSTGRADUATE SCHOOL SLEEP LOGISTICS SURVEY

Introduction. This survey primarily focuses on the sleep logistics of U.S. military ground forces during continuous/sustained operations and has three main objectives. The first objective is to determine if current sleep patterns of military ground forces support a unit's ability to accomplish assigned missions within a given tactical area of responsibility. The second objective is to determine if statistically significant differences in sleep patterns exist between subset populations. The third objective is to determine the significance level of sleep deprivation throughout a specified area of operation. Conclusions and recommendations drawn from this survey may contribute to improving policies and procedures throughout the specified area of operation.

Procedures. If you agree to participate, you will be asked to complete one survey as honestly and as accurately as you can. We expect that the survey will take approximately 15 to 30 minutes to complete.

Risks and Benefits. This research involves no risks or discomforts. The benefits to the participants include contributing to the improvement of policies and procedures related to sleep planning during continuous/sustained operations, as well as contributing to current research in fatigue avoidance.

Compensation. No tangible reward will be given. A copy of the results will be available to you through your chain-of-command at the conclusion of the study.

Confidentiality. This survey is strictly voluntary, anonymous, and cannot be traced back to you. The records of this study will be kept confidential. No information that could identify you as a participant will be publicly accessible.

Voluntary Nature of the Study. If you agree to participate, you are free to withdraw from the study at any time without prejudice.

Points of Contact. If you have any further questions or comments after the completion of the study, you may contact the research supervisor at the address provided. A separate document containing the information outlined above as well as contact information will be provided to you when you return this survey to the administrator.

Statement of Consent. I have read the above information and I agree to participate in this study.

Participant's Signature ____________________ Date / Current Local Time ____________________

Survey Administrator's Signature ____________________ Date / Current Local Time ____________________

DEMOGRAPHICS

	EXAMPLES	MY ANSWER		EXAMPLES	MY ANSWER
Pay Grade	E1, E2, W1, W2, O1, O2, etc.		**Height (inches)**	71 inches	
Rank	PFC, Sergeant, Captain, etc.		**Weight (pounds)**	185 pounds	
Age (years)	25 years old		**Gender (Male or Female)**	Male	
Current Location (City, Country)	Baghdad, Iraq		**Branch of Service**	Army, Marine Corps, Air Force, Navy	
Date I deployed (YYYY MMM DD)	2003 JAN 03		**Service Component:**	Regular, Reserve, National Guard, Etc.	

	EXAMPLES	MY ANSWER
MOS	11B for infantry in the Army 0302 for infantry in the Marine Corps	
MOS Description	Infantry, Artillery, Administration, etc.	
My billet or job description:	Fire Team Leader, Squad Leader, Platoon Sergeant, etc.	

PLEASE INDICATE WHICH CATEGORY BEST FITS YOUR MOS

Ground Combat	Air Combat Support	Ground Combat Support	Combat Service Support	Other
○	○	○	○	○

Page 2:

NAVAL POSTGRADUATE SCHOOL SLEEP LOGISTICS SURVEY

SECTION 1: SLEEP PATTERNS

It is very important for this study that you answer the following question to the best of your ability. The following question asks you to shade in ALL of the times that you slept (INCLUDING NAPS) during the past week. For this example, the person slept from 2200 to 0600 for the past 6 days and took a nap from 1230 to 1300 everyday except Day 4. Notice that this person woke up every night for approximately 15 minutes, possibly to go to the bathroom. This person could not remember when he or she slept during Day 7, so this person checked, "I do not remember" for the last day.

	Day of the week	I do not remember	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
Day 1 (last 24 hours)	Sunday	○																								
Day 2 (last 48 hours)	Saturday	○																								
Day 3 (last 72 hours)	Friday	○																								
Day 4 (last 96 hours)	Thursday	○																								
Day 5	Wednesday	○																								
Day 6	Tuesday	○																								
Day 7	Monday	●																								

Please shade in ALL of the times that you slept (INCLUDING NAPS) during the past week. If you cannot remember when you slept on a particular day, please check the box that says, "I do not remember."

	Day of the week	I do not remember	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
Day 1 (last 24 hours)		○																								
Day 2 (last 48 hours)		○																								
Day 3 (last 72 hours)		○																								
Day 4 (last 96 hours)		○																								
Day 5		○																								
Day 6		○																								
Day 7		○																								

SECTION 2: SLEEP QUALITY

Using the times you indicated that you slept in the previous question, please evaluate the overall quality of your sleep for that day.

- **Good quality sleep** is considered uninterrupted sleep. That is, you slept throughout the night without waking up or being woken up by others.
- **Moderate quality sleep** is considered minimally interrupted sleep. That is, you slept throughout the night and were woken up only a few times during the night for very short periods.
- **Poor quality sleep** is considered very interrupted sleep. That is, you were woken up throughout the night and were not able to go back to sleep for a few minutes after each awakening.

Things that may affect sleep quality include:

- Enemy fire (small arms, mortar, etc.)
- Temperature, bright light, and weather conditions (sand storms, rain, wind, etc.)
- Physical discomfort and sleeping conditions, such as where you slept (vehicle, cot, etc.)
- Waking up several times per night because of bad dreams or needing to go to the bathroom
- Having trouble staying asleep because of excessive noise or other factors

	Overall, I would consider my sleep quality for:	Mostly Good	Somewhere in between Good and Moderate	Mostly Moderate	Somewhere in between Moderate and Poor	Mostly Poor	I do not remember
1	Day 1 as:	○	○	○	○	○	○
2	Day 2 as:	○	○	○	○	○	○
3	Day 3 as:	○	○	○	○	○	○
4	Day 4 as:	○	○	○	○	○	○
5	Day 5 as:	○	○	○	○	○	○
6	Day 6 as:	○	○	○	○	○	○
7	Day 7 as:	○	○	○	○	○	○

SECTION 3: OPERATIONAL TEMPO AND WORKLOAD

Next, please consider your individual operational tempo (OPTEMPO) over the past few days. Some days may have been extremely busy and other days may have been fairly slow. Please indicate which days were extremely busy and which days were fairly slow compared to a typical day performing your normal duties by considering the following examples of things that may affect OPTEMPO:

- Constantly on the move from one position to another position
- Participating in daily patrols
- Engaged in numerous firefights or regularly in contact with enemy forces
- A high level of physical activity (including physical fitness)
- Participating in a high number of operational missions (including flight operations, convoy operations, etc.)
- Performing multiple duties such as guard duty, radio watch, staff duty officer, etc.

	I feel that my OPTEMPO for:	Much Higher Than Normal	A Little Higher Than Normal	Normal or Average	A Little Slower Than Normal	Much Slower Than Normal	I do not remember
8	Day 1 was:	○	○	○	○	○	○
9	Day 2 was:	○	○	○	○	○	○
10	Day 3 was:	○	○	○	○	○	○
11	Day 4 was:	○	○	○	○	○	○
12	Day 5 was:	○	○	○	○	○	○
13	Day 6 was:	○	○	○	○	○	○
14	Day 7 was:	○	○	○	○	○	○

SECTION 4: SLEEP PLANNING

Your unit may use a unit-level sleep plan in order to manage the sleep routines of the unit. Some indications that your unit has a sleep plan include:

- Working in shifts
- Encouraging and monitoring naps
- Designating dark and quiet areas for rest
- Trying to enforce sleep schedules

		Yes	No			
15	I have been briefed on a sleep-management plan.	○	○			
		Very Effective	Somewhat Effective	Neutral / No Opinion	Somewhat Ineffective	Very Ineffective
16	I feel my unit's ability to manage sleep routines is:	○	○	○	○	○
		Strongly Agree	Agree	Neutral / No Opinion	Disagree	Strongly Disagree
17	My unit uses sleep management tools like those listed above (or others).	○	○	○	○	○
18	My unit works in shifts; for example, day shifts and night shifts, or 6 hrs on / 6 hrs off.	○	○	○	○	○
19	My unit encourages me to take naps when possible.	○	○	○	○	○
20	I believe that fatigue is a serious problem in my unit.	○	○	○	○	○

SECTION 5: CIRCADIAN PERSONALITY AND EPWORTH SLEEPINESS SCALE

Question 21 is used to determine your sleep personality. That is, are you more a "morning person," a "night person," or something in between? Please use the following definitions to answer the question below:

- A "Lark" personality is someone who naturally gets up very early in the morning and has difficulty sleeping past 0800, even if they are forced to stay up past their normal bedtime. A Lark-type person (morning person) generally gets up with the sun and gets their best work done before the afternoon.
- An "Owl" personality is someone who prefers to stay up until after midnight (and maybe even until 0100 or 0200). An Owl-type person (night person) generally performs best in the afternoon or evening and typically does not enjoy mornings.
- A "Robin" personality is someone who is fairly flexible when it comes to sleep patterns. They generally go to bed before midnight (but not before 2200), usually wake up after 0600 (but usually not after 0800), and adapt fairly easily to changes in this schedule.

Things that may help you identify your circadian type / sleep personality include considering:

- When you naturally want to wake up
- When you naturally want to go to bed
- How alert you feel during the first 30 minutes after waking up
- How flexible you are to changes in your sleep schedule

		Definitely a Lark	More likely a Lark than an Owl	A Robin	More Likely an Owl than a Lark	Definitely an Owl
21	My Circadian Type / Sleep Personality is:	○	○	○	○	○

The following questions are used to determine your sleep latency. While not every situation is applicable to your environment, please try to consider how likely your chance of dozing off to sleep is if you were in the following situations:

		I would never doze	Slight chance I might doze	Moderate chance I might doze	High chance I might doze	Not applicable
22	Sitting and reading a book	○	○	○	○	○
23	Sitting in a public place	○	○	○	○	○
24	Sitting in a vehicle as a passenger for an hour without a break	○	○	○	○	○
25	Lying down to rest in the afternoon	○	○	○	○	○
26	Sitting and talking to someone	○	○	○	○	○
27	Sitting quietly after lunch (assuming no alcohol)	○	○	○	○	○
28	In a vehicle, while stopped for a few minutes	○	○	○	○	○
29	Watching a movie or listening to the radio	○	○	○	○	○

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NAVAL POSTGRADUATE SCHOOL SLEEP LOGISTICS SURVEY

SECTION 6: SYMPTOMS OF SLEEP DEPRIVATION

Symptoms of sleep deprivation include:

- Difficulty concentrating
- Difficulty staying awake
- Difficulty waking up or getting out of bed when you are supposed to
- Still feeling very tired 30 minutes after waking up
- Experiencing noticeable mood changes
- Difficulty falling asleep or staying asleep

		All of the symptoms	Most of the symptoms	Some of the symptoms	None of the symptoms	
30	Based on the symptoms of sleep deprivation listed above, I believe I exhibit:	○	○	○	○	
		Strongly Agree	Agree	Neutral / No Opinion	Disagree	Strongly Disagree
31	I believe I am sleep deprived.	○	○	○	○	○
32	Sleep deprivation is a serious problem in my unit.	○	○	○	○	○

SECTION 7: STRESS AND AROUSAL LEVEL

Stress and arousal are important components to performance and fatigue. When answering the following questions, please consider the following items:

- The number and intensity of recent enemy engagements
- Exposure to danger
- Mental and/or physical workload
- Tension
- Strain
- Personal issues at home

		Never	Rarely	Sometimes	Often	Always
33	I am exposed to significant sources of stress (like those listed above or others):	○	○	○	○	○
		Very Low	Low	Medium	High	Very High
34	I would characterize my overall stress level as:	○	○	○	○	○
		Bored	More bored than anxious	Neutral / No Opinion	More anxious than bored	Anxious
35	Most of the time, I feel:	○	○	○	○	○

SECTION 8: ADDITIONAL LIFESTYLE FACTORS

Studies have shown that products such as caffeine, nicotine, and others can have an affect on performance and fatigue. Please answer the following questions about your use of the following products.

		1 – 5 per day	6 - 10 per day	11 – 15 per day	16 – 20 per day	Greater than 20 per day	I do not use these products
36	Caffeinated Beverages (8 – 12 oz. servings per day) Examples: Coffee, Tea, Soda, etc.	○	○	○	○	○	○
37	Smoking Tobacco Use (per day) Examples: Cigarettes, cigars, pipe tobacco	○	○	○	○	○	○
38	Smokeless Tobacco Use (per day) Examples: Nicotine gum, dip, chew, etc.	○	○	○	○	○	○
		1 per day	2 per day	3 per day	4 per day	Greater than 4 per day	I do not use these products
39	Energy / Performance Enhancer Use (per day) Examples: Go-Pills, No-Doze, Energy-Boost, etc.	○	○	○	○	○	○
		Malaria	Other	(Please specify)			None
40	Please list all medications you are currently taking. Use additional space below if necessary.	○	○				○

SECTION 9: ADDITIONAL COMMENTS

Thank you for participating in this study. We know how valuable your time is, so we greatly appreciate your input in this survey. If you have any additional comments regarding sleep, sleep planning, or additional input you feel would be relevant to the focus of this study, please provide them in the space provided below (feel free to attach a separate piece of paper):

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APPENDIX D. SWA SURVEY QUESTIONS AND SCALES

Description of question numbers, corresponding questions, and scales/codes used for analysis.

SURVEY QUESTION # (Section # Question #)	QUESTION	VARIABLE TYPE	CODE/SCALE
S1Q1	I have been briefed on a sleep plan	Binary	Y = 1, N = 0
S1Q1A	In general, my unit has been able to stick with the sleep plan as it was described to me	Binary	Y = 1, N = 0
S1Q2(Y)	To the best of my knowledge, the sleep plan that was described to me is a written Standard Operating Procedure (SOP) for my unit	Binary	1 if indicated Y, 0 otherwise
S1Q2(N)	To the best of my knowledge, the sleep plan that was described to me is a written Standard Operating Procedure (SOP) for my unit	Binary	1 if indicated N, 0 otherwise
S1Q2(IDK)	To the best of my knowledge, the sleep plan that was described to me is a written Standard Operating Procedure (SOP) for my unit	Binary	1 if indicated I DON'T KNOW, 0 otherwise
S1Q2A	To the best of my knowledge, the sleep plan that was described to me was written by this leader or commander	Ordinal	Likert Scale {1, 2, 3, 4, 5, 6, 7, 8, 9}
S1Q3	I feel my unit's sleep plan	Ordinal	Likert Scale {1, 2, 3, 4, 5, 6, 7}
S1Q4	My unit works in shifts (For example: day shifts and night shifts)	Binary	Y = 1, N = 0
S2Q1	During the past 24 hours, I was <u>allowed</u> to get sleep during these times (Shade in times)	Numeric	[0, 110] (Corresponding performance effectiveness from FAST)
S2Q2	During the past 24 hours, I <u>actually</u> slept, including naps if applicable, during these hours (shade in times)	Numeric	[0, 110] (Corresponding performance effectiveness from FAST)
S2Q3	In the past 24 hours, I got approximately ________hours of sleep, including naps if applicable	Numeric	[0, 24]
S2Q4	In the past 24 hours, I took this many naps	Integer	[0, 8]
S2Q5	If I add the time of all the naps I took, I napped for a total of about _______hours	Numeric	[0, 24]
S2Q6	Check the box that best describes how long it took you to fall asleep	Ordinal	Likert Scale {1, 2, 3, 4, 5, 6}
S2Q7(COT)	When I got most of my sleep, I was located	Binary	1 if indicated COT, 0 otherwise
S2Q7(BED)	When I got most of my sleep, I was located	Binary	1 if indicated BED, 0 otherwise
S2Q7(ONV)	When I got most of my sleep, I was located	Binary	1 if indicated ON VEHICLE, 0 otherwise
S2Q7(INV)	When I got most of my sleep, I was located	Binary	1 if indicated IN VEHICLE, 0 otherwise
S2Q7(GND)	When I got most of my sleep, I was located	Binary	1 if indicated GROUND, 0 otherwise
S2Q7(OTH)	When I got most of my sleep, I was located	Binary	1 if indicated OTHER, 0 otherwise
S2Q8(P)	During the past 24 hours, I have done the following duties	Binary	1 if indicated PATROL, 0 otherwise
S2Q8(GDL4)	During the past 24 hours, I have done the following duties	Binary	1 if indicated GUARD DUTY LESS THAN 4 HRS, 0 otherwise
S2Q8(GDM4)	During the past 24 hours, I have done the following duties	Binary	1 if indicated GUARD DUTY MORE THAN 4 HRS, 0 otherwise

SURVEY QUESTION # (Section # Question #)	QUESTION	VARIABLE TYPE	CODE/SCALE
S2Q8(DD)	During the past 24 hours, I have done the following duties	Binary	1 if indicated DUTY DRIVER, 0 otherwise
S2Q8(SD)	During the past 24 hours, I have done the following duties	Binary	1 if indicated STAFF DUTY, 0 otherwise
S2Q8(DO)	During the past 24 hours, I have done the following duties	Binary	1 if indicated DUTY OFFICER, 0 otherwise
S2Q8(OM)	During the past 24 hours, I have done the following duties	Binary	1 if indicated OPERATIONAL MISSION, 0 otherwise
S2Q8(OTHER)	During the past 24 hours, I have done the following duties	Binary	1 if indicated OTHER, 0 otherwise
S2Q9(FALLING ASLEEP)	I had trouble	Binary	1 if indicated TROUBLE FALLING ASLEEP, 0 otherwise
S2Q9(WAKING UP)	I had trouble	Binary	1 if indicated TROUBLE WAKING UP, 0 otherwise
S2Q9(STAY ASLEEP)	I had trouble	Binary	1 if indicated TROUBLE STAYING ASLEEP, 0 otherwise
S2Q9(STAY AWAKE)	I had trouble	Binary	1 if indicated TROUBLE STAYING AWAKE, 0 otherwise
S2Q10	I remember dreaming during the past 24 hours	Binary	Y = 1, N = 0
S2Q11	I had a nightmare during the past 24 hours	Binary	Y = 1, N = 0
S2Q12(NOISE)	The following things made it difficult for me to sleep	Binary	1 if indicated NOISE, 0 otherwise
S2Q12(TEMP)	The following things made it difficult for me to sleep	Binary	1 if indicated TEMPERATURE, 0 otherwise
S2Q12(LIGHT)	The following things made it difficult for me to sleep	Binary	1 if indicated LIGHT, 0 otherwise
S2Q12(PHYS DISCOMF)	The following things made it difficult for me to sleep	Binary	1 if indicated PHYSICAL DISCOMFORT, 0 otherwise
S2Q12(STRESS)	The following things made it difficult for me to sleep	Binary	1 if indicated STRESS/WORRY, 0 otherwise
S2Q12(OTHER)	The following things made it difficult for me to sleep	Binary	1 if indicated OTHER, 0 otherwise
S3Q1A(OverallAvg)	According to my unit's sleep plan, shift schedule, or normal plan of the day, I was <u>allowed</u> to get sleep during the following hours	Numeric	[0, 110] (Corresponding performance effectiveness from FAST)
S3Q1A(Last24Avg)	According to my unit's sleep plan, shift schedule, or normal plan of the day, I was <u>allowed</u> to get sleep during the following hours	Numeric	[0, 110] (Corresponding performance effectiveness from FAST)
S3Q1B(OverallAvg)	Over the past week, I generally slept during these hours (these may be different from the answers to the last question because you either found more time to get sleep or got less sleep than you were allowed to)	Numeric	[0, 110] (Corresponding performance effectiveness from FAST)
S3Q1B(Last24Avg)	Over the past week, I generally slept during these hours (these may be different from the answers to the last question because you either found more time to get sleep or got less sleep than you were allowed to)	Numeric	[0, 110] (Corresponding performance effectiveness from FAST)
S3Q2A	On average over the past week, I slept about this many hours (total for the week) on the ground, in a sleeping bag	Numeric	[0, 70]
S3Q2B	On average over the past week, I slept about this many hours (total for the week) on the ground, not in a sleeping bag	Numeric	[0, 70]

SURVEY QUESTION # (Section # Question #)	QUESTION	VARIABLE TYPE	CODE/SCALE
S3Q2D	On average over the past week, I slept about this many hours (total for the week) on or in a vehicle, not with a sleeping bag	Numeric	[0, 70]
S3Q2E	On average over the past week, I slept about this many hours (total for the week) in a bed (even if you slept with a sleeping bag or something similar)	Numeric	[0, 70]
S3Q2F	On average over the past week, I slept about this many hours (total for the week) on a cot (even if you slept with a sleeping bag or something similar)	Numeric	[0, 70]
S3Q3	On average, I got approximately ________hours of sleep every day	Numeric	[0, 24]
S3Q4	On average, I got approximately ________hours of sleep while it was DARK outside every day	Numeric	[0, 24]
S3Q5	On average, I got approximately ________hours of sleep while it was LIGHT outside every day	Numeric	[0, 24]
S3Q6	On average, I took this many naps every day	Integer	[0, 8]
S3Q7	On average, if I add the time of all the naps I took, I napped for a total of about _______hours every day	Numeric	[0, 24]
S3Q8A	Please answer this question by checking the number of days this past week that the following statement was true: a. falling asleep in general	Integer	[0, 7]
S3Q8B	Please answer this question by checking the number of days this past week that the following statement was true: b. falling asleep specifically because it was too bright outside	Integer	[0, 7]
S3Q8C	Please answer this question by checking the number of days this past week that the following statement was true: c. waking up under normal conditions (i.e. waking up for normal duties)	Integer	[0, 7]
S3Q8D	Please answer this question by checking the number of days this past week that the following statement was true: d. waking up under extreme conditions (i.e. alarms, combat action, etc)	Integer	[0, 7]
S3Q8E	Please answer this question by checking the number of days this past week that the following statement was true: e. staying asleep	Integer	[0, 7]
S3Q8F	Please answer this question by checking the number of days this past week that the following statement was true: f. staying awake	Integer	[0, 7]
S3Q9A	I remember: a. dreaming	Integer	[0, 7]
S3Q9B	I remember: b. having a bad dream or nightmare	Integer	[0, 7]
S3Q10A	I had trouble sleeping or was woken up after falling asleep because: a. I had to go to the bathroom	Integer	[0, 7]
S3Q10B	I had trouble sleeping or was woken up after falling asleep because: b. I was snoring loudly	Integer	[0, 7]
S3Q10C	I had trouble sleeping or was woken up after falling asleep because: c. I had bad dreams	Integer	[0, 7]
S3Q10D	I had trouble sleeping or was woken up after falling asleep because: d. It was too bright out	Integer	[0, 7]
S3Q10E	I had trouble sleeping or was woken up after falling asleep because: e. I was not in a comfortable sleeping position	Integer	[0, 7]
S3Q10F	I had trouble sleeping or was woken up after falling asleep because: f. I was in pain	Integer	[0, 7]
S3Q10G	I had trouble sleeping or was woken up after falling asleep because: g. I was too hot	Integer	[0, 7]

SURVEY QUESTION # (Section # Question #)	QUESTION	VARIABLE TYPE	CODE/SCALE
S3Q10J	I had trouble sleeping or was woken up after falling asleep because: j. I could not adjust to my new sleep schedule	Integer	[0, 7]
S3Q10K	I had trouble sleeping or was woken up after falling asleep because: k. of some other reason	Integer	[0, 7]
S3Q11	I fell asleep when I was supposed to be awake	Integer	[0, 7]
S4Q1	On average, comparing my sleep pattern of the last month to my sleep pattern of the last week, I would say that my quality of sleep was _______ compared to last week	Ordinal	Likert Scale {1, 2, 3, 4, 5, 6, 7}
S4Q2	On average over the past month, I felt _______ just after I woke up	Ordinal	Likert Scale {1, 2, 3, 4, 5, 6, 7}
S4Q3	On average over the past month, I physically felt ________ just before I fell asleep	Ordinal	Likert Scale {1, 2, 3, 4, 5, 6, 7}
S4Q4A	When thinking about the past month, please indicate how often this statement was true: a. I feel so tired that I cannot concentrate	Ordinal	Likert Scale {1, 2, 3, 4, 5}
S4Q4B	When thinking about the past month, please indicate how often this statement was true: b. I have difficulty staying awake	Ordinal	Likert Scale {1, 2, 3, 4, 5}
S4Q4C	When thinking about the past month, please indicate how often this statement was true: c. I experience noticeable mood changes	Ordinal	Likert Scale {1, 2, 3, 4, 5}
S4Q4D	When thinking about the past month, please indicate how often this statement was true: d. I notice mood changes of others	Ordinal	Likert Scale {1, 2, 3, 4, 5}
S4Q4E	When thinking about the past month, please indicate how often this statement was true: e. I have difficulty waking up or getting out of bed	Ordinal	Likert Scale {1, 2, 3, 4, 5}
S4Q4F	When thinking about the past month, please indicate how often this statement was true: f. I still feel tired 30 minutes after waking up	Ordinal	Likert Scale {1, 2, 3, 4, 5}
S4Q4G	When thinking about the past month, please indicate how often this statement was true: g. I wake up regularly because I am too hot	Ordinal	Likert Scale {1, 2, 3, 4, 5}
S4Q4H	When thinking about the past month, please indicate how often this statement was true: h. I wake up regularly because I am too cold	Ordinal	Likert Scale {1, 2, 3, 4, 5}
S4Q4I	When thinking about the past month, please indicate how often this statement was true: i. I wake up regularly because it is too bright out	Ordinal	Likert Scale {1, 2, 3, 4, 5}
S4Q4J	When thinking about the past month, please indicate how often this statement was true: j. I wake up regularly because I have trouble breathing	Ordinal	Likert Scale {1, 2, 3, 4, 5}
S5Q1	On average in the past month, I spend _____________ hours per week on physical fitness	Numeric	[0, 40]
S5Q2	I am _______ physically fit now than I was prior to deploying	Ordinal	Likert Scale {1, 2, 3, 4, 5, 6, 7}
S5Q3	I am pleased with my level of fitness	Binary	Y = 1, N = 0
S6Q1	During the past week, I have smoked cigarettes, used smokeless tobacco, or other tobacco products	Binary	Y = 1, N = 0
S6Q2(DNU)	I smoke cigarettes, use smokeless tobacco, or other tobacco products ___________as before I deployed	Binary	1 if indicated DO NOT USE, 0 otherwise
S6Q2(USE)	I smoke cigarettes, use smokeless tobacco, or other tobacco products ___________as before I deployed	Ordinal	Likert Scale {1, 2, 3, 4, 5, 6, 7}
S6Q3	On average, I use tobacco products _____ times a day	Integer	[0, 21]

SURVEY QUESTION # (Section # Question #)	QUESTION	VARIABLE TYPE	CODE/SCALE
S7Q2	On average, I drink ___ beverages containing caffeine in a day. (Please consider a single beverage containing caffeine as one 12-oz soda, one 8-oz cup of coffee, one 8-oz cup of tea, or similar size.)	Integer	[0, 21]
S7Q3	Recently, I have used products like No-Doze or other caffeine supplements	Binary	Y = 1, N = 0
S7Q4	Recently, I have used products like Ripped Fuel or other ephedra-based supplements	Binary	Y = 1, N = 0
S8Q1(MALARIA)	Within the past week, I have taken, or am currently taking, medication (either prescribed or over-the-counter) for: (Check all that apply.)	Binary	1 if indicated MALARIA PILL, 0 otherwise
S8Q1(PAIN)	Within the past week, I have taken, or am currently taking, medication (either prescribed or over-the-counter) for: (Check all that apply.)	Binary	1 if indicated PAIN MEDICATION, 0 otherwise
S8Q1(SLEEP AID)	Within the past week, I have taken, or am currently taking, medication (either prescribed or over-the-counter) for: (Check all that apply.)	Binary	1 if indicated SLEEP AID, 0 otherwise
S8Q1(NO DOSE)	Within the past week, I have taken, or am currently taking, medication (either prescribed or over-the-counter) for: (Check all that apply.)	Binary	1 if indicated NO DOSE, 0 otherwise
S8Q1(OTHER)	Within the past week, I have taken, or am currently taking, medication (either prescribed or over-the-counter) for: (Check all that apply.)	Integer	# of other meds indicated
S8Q2	I have received the following vaccinations and/or shots in the past week	Integer	# of vaccinations listed
S8Q3	I have received the following vaccinations and/or shots in the past month	Integer	# of vaccinations listed
S9Q1	I received Non-Judicial Punishment (NJP) during the past week	Binary	Y = 1, N = 0
S9Q2	I received Extra Military Instruction or extra duty in connection with NJP during the past week	Binary	Y = 1, N = 0
S9Q3	I received other type(s) of disciplinary action during the past week	Binary	Y = 1, N = 0
RANK(E1-E3)	Rank	Binary	1 if rank fell in this bin, 0 otherwise
RANK(E4-E5)	Rank	Binary	1 if rank fell in this bin, 0 otherwise
RANK(E6-E9)	Rank	Binary	1 if rank fell in this bin, 0 otherwise
RANK(WO1-O3)	Rank	Binary	1 if rank fell in this bin, 0 otherwise
RANK(O4+)	Rank	Binary	1 if rank fell in this bin, 0 otherwise
AGE	Age	Numeric	[17, 60]
GENDER	Gender	Binary	M = 1, F = 0
HEIGHT	Height	Numeric	[50, 80]
WEIGHT	Weight	Numeric	[100, 300]
LOC(IRAQ)	Location	Binary	1 if indicated IRAQ, 0 otherwise

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APPENDIX E. MOS DISTRIBUTION

MOS component:

REPORTED MOS	REPORTED MOS DESCRIPTION	COUNT
00Z	COMMAND SERGEANT MAJOR (ENGINEER BN)	1
00Z	COMMAND SERGEANT MAJOR (TRANSPORTATION BN)	1
11	INFANTRY	1
11A	INFANTRY	1
11B	INFANTRY	53
11C	INFANTRY	9
11H	INFANTRY	1
13A	FIELD ARTILLERY	6
13M	FIELD ARTILLERY	23
13P	FIELD ARTILLERY	17
13Z	FIELD ARTILLERY	2
15P	AVIATION	1
15T	AVIATION	2
21B	ENGINEER	3
25C	SIGNAL OFFICER	2
27D	SIGNAL	1
31A	MILITARY POLICE	1
31L	WIRE SPECIALIST	1
31R	COMMUNICATIONS	1
31U	COMMUNICATIONS	7
31Y	COMMUNICATIONS	1
31Z	SIGNAL	1
35D	INTEL OFFICER	1
35H	COMMUNICATIONS	3
35R	AVIATION	2
420A	PERSONNEL	1
54B	NBC DEFENSE	2
55B	ORDNANCE	3
62E	HEAVY CONSTRUCTION EQUIP	2
62H	ENGINEER	1
63B	LIGHT WHEEL MECHANIC	3
63S	HEAVY WHEELED MECHANIC	2
63T	MECHANIC	1
63W	MECHANIC	1

REPORTED MOS	REPORTED MOS DESCRIPTION	COUNT
63Y	MECHANIC	1
63Z	MAINTENANCE	1
67N	AVIATION	1
67S	AVIATION	1
67T	AVIATION	3
67V	AVIATION	1
67Z	AVIATION	1
68	AVIATION	2
68D	AVIATION	4
68K	AVIATION	2
68N	AVIATION	3
68X	AVIATION	1
71L	ADMINISTRATION	5
74B	INFORMATION SYSTEMS ANALYST	3
75B	INFORMATION SYSTEMS ANALYST	2
75H	SIGNAL	1
77F	FUEL HANDLER	10
77W	LAUNDRY AND SHOWERS	1
88A	TRANSPORTATION	1
88M	TRANSPORTATION	12
90A	ORDNANCE/MAINTENANCE	1
915A	ORDNANCE/MAINTENANCE	1
91B	MEDICAL	1
91W	MEDICAL	6
92	SUPPLY	1
92A	SUPPLY	7
92F	SUPPLY	1
92G	FOOD SERVICE	9
92S	FIELD SERVICE	5
92Y	SUPPLY	5
95B	MILITARY POLICE	13
96B	INTEL ANALYST	2
NA	NO RESPONSE	7
TOTAL	**TOTAL PARTICIPANTS (INCLUDING NA'S)**	**273**

APPENDIX F. AGE AND GENDER DISTRIBUTION

Complete distribution of age by gender:

MALE				FEMALE		
Age (years)	*Frequency*	*Cumulative %*		*Age (years)*	*Frequency*	*Cumulative %*
18	1	.41%		18	0	.00%
19	7	3.32%		19	0	.00%
20	17	10.37%		20	2	9.09%
21	17	17.43%		21	3	22.73%
22	21	26.14%		22	0	22.73%
23	15	32.37%		23	3	36.36%
24	15	38.59%		24	1	40.91%
25	11	43.15%		25	1	45.45%
26	7	46.06%		26	2	54.55%
27	11	50.62%		27	1	59.09%
28	10	54.77%		28	0	59.09%
29	4	56.43%		29	0	59.09%
30	3	57.68%		30	0	59.09%
31	9	61.41%		31	1	63.64%
32	8	64.73%		32	1	68.18%
33	6	67.22%		33	0	68.18%
34	8	70.54%		34	0	68.18%
35	3	71.78%		35	1	72.73%
36	12	76.76%		36	0	72.73%
37	3	78.01%		37	0	72.73%
38	9	81.74%		38	0	72.73%
39	6	84.23%		39	0	72.73%
40	9	87.97%		40	2	81.82%
41	5	90.04%		41	2	90.91%
42	3	91.29%		42	0	90.91%
43	4	92.95%		43	1	95.45%
44	2	93.78%		44	0	95.45%
45	1	94.19%		45	0	95.45%
46	1	94.61%		46	0	95.45%
47	1	95.02%		47	0	95.45%
48	0	95.02%		48	0	95.45%
49	4	96.68%		49	0	95.45%
50	0	96.68%		50	1	100.00%
51	2	97.51%		51	0	100.00%
52	0	97.51%		52	0	100.00%
53	0	97.51%		53	0	100.00%
54	2	98.34%		54	0	100.00%
55	0	98.34%		55	0	100.00%
56	2	99.17%		56	0	100.00%
57	2	100.00%		57	0	100.00%
More	0	100.00%		More	0	100.00%

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APPENDIX G. RESULTS OF TWO-SAMPLE T-TEST

Results of two-sample t test between subsets. Sample(1) contains missing values and was removed from the data for the purposes of implementing principal component analysis and factor analysis. Sample(2) does not contain missing values. P-values with (*) are statistically different when tested at the 0.05 level.

VARIABLE	COUNT (1)	COUNT (2)	MEAN (1)	MEAN (2)	STD DEV (1)	STD DEV (2)	Test Statistic	P-value
S1Q1	74	195	0.405	0.369	0.494	0.484	0.539	0.590
S2Q1	77	195	96.522	97.629	5.861	5.648	-1.418	0.156
S2Q2	77	195	95.829	95.511	4.525	4.304	0.529	0.597
S2Q3	76	195	7.342	7.282	1.757	2.396	0.227	0.821
S2Q4	77	195	0.675	0.605	1.106	0.857	0.501	0.616
S2Q5	76	195	0.872	0.865	1.446	1.339	0.033	0.974
S2Q6	76	195	3.803	3.713	1.633	1.485	0.417	0.677
S2Q7(COT)	78	195	0.769	0.718	0.424	0.451	0.886	0.376
S2Q7(BED)	78	195	0.154	0.251	0.363	0.435	-1.889	0.059
S2Q7(INV)	78	195	0.000	0.015	0.000	0.123	-1.741	0.082
S2Q7(GND)	78	195	0.000	0.010	0.000	0.101	-1.418	0.156
S2Q8(P)	78	195	0.128	0.082	0.336	0.275	1.076	0.282
S2Q8(GDL4)	78	195	0.090	0.092	0.288	0.290	-0.066	0.947
S2Q8(GDM4)	78	195	0.167	0.179	0.375	0.385	-0.253	0.800
S2Q8(RW)	78	195	0.141	0.123	0.350	0.329	0.389	0.697
S2Q8(DD)	78	195	0.051	0.133	0.222	0.341	-2.342	**0.019***
S2Q8(SD)	78	195	0.038	0.072	0.194	0.259	-1.161	0.245
S2Q8(DO)	78	195	0.051	0.026	0.222	0.158	0.930	0.353
S2Q8(OM)	78	195	0.474	0.369	0.503	0.484	1.578	0.115
S2Q8(OTHER)	78	195	0.205	0.272	0.406	0.446	-1.190	0.234
S2Q9(FALLING ASLEEP)	78	195	0.397	0.395	0.493	0.490	0.039	0.969
S2Q9(WAKING UP)	78	195	0.269	0.251	0.446	0.435	0.302	0.762
S2Q9(STAY ASLEEP)	78	195	0.423	0.359	0.497	0.481	0.971	0.331
S2Q9(STAY AWAKE)	78	195	0.179	0.154	0.386	0.362	0.504	0.614
S2Q10	76	195	0.447	0.487	0.501	0.501	-0.588	0.557
S2Q11	74	195	0.149	0.174	0.358	0.380	-0.517	0.605
S2Q12(NOISE)	78	195	0.423	0.344	0.497	0.476	1.208	0.227
S2Q12(TEMP)	78	195	0.256	0.308	0.439	0.463	-0.858	0.391
S2Q12(LIGHT)	78	195	0.205	0.231	0.406	0.422	-0.466	0.641
S2Q12(PHYS DISCOMF)	78	195	0.346	0.287	0.479	0.454	0.933	0.351
S2Q12(STRESS)	78	195	0.282	0.400	0.453	0.491	-1.897	0.058
S2Q12(OTHER)	78	195	0.090	0.103	0.288	0.304	-0.327	0.744
S3Q1A(OverallAvg)	77	195	94.525	95.044	10.158	7.282	-0.409	0.683
S3Q1A(Last24Avg)	77	195	94.356	95.734	12.108	9.290	-0.899	0.369
S3Q1B(OverallAvg)	77	195	90.785	90.969	10.942	8.473	-0.133	0.895
S3Q1B(Last24Avg)	77	195	89.347	89.447	14.313	11.535	-0.055	0.956
S3Q2F	66	195	37.102	29.348	19.013	20.139	2.821	**0.005***
S3Q3	77	195	6.744	6.644	1.430	1.599	0.499	0.618
S3Q4	75	195	5.602	5.493	2.143	2.256	0.369	0.712
S3Q5	76	195	1.587	1.607	1.832	1.974	-0.079	0.937
S3Q6	77	195	0.753	0.646	1.183	0.801	0.731	0.465
S3Q7	66	195	0.678	0.803	1.459	1.216	-0.628	0.530
S3Q8A	77	195	3.091	3.159	2.792	2.669	-0.183	0.854
S3Q8B	75	195	0.813	0.605	1.799	1.616	0.876	0.381
S3Q8C	74	195	2.216	2.390	2.746	2.729	-0.464	0.643
S3Q8D	75	195	0.653	0.492	1.590	1.321	0.780	0.436
S3Q8E	77	195	2.935	2.821	2.797	2.672	0.308	0.758

Continued results of two-sample t test between subsets. Sample(1) contains missing values and was removed from the data for the purposes of implementing principal component analysis and factor analysis. Sample(2) does not contain missing values. P-values with (*) are statistically different when tested at the 0.05 level.

VARIABLE	COUNT (1)	COUNT (2)	MEAN (1)	MEAN (2)	STD DEV (1)	STD DEV (2)	Test Statistic	P-value
S3Q8F	73	195	1.753	1.333	2.165	1.950	1.452	0.147
S3Q9A	76	195	2.618	2.497	2.361	2.382	0.378	0.705
S3Q9B	69	195	1.159	0.867	1.796	1.597	1.197	0.231
S3Q10A	77	195	2.519	2.467	2.365	2.405	0.165	0.869
S3Q10B	75	195	0.267	0.185	0.890	0.906	0.675	0.500
S3Q10C	74	195	0.689	0.662	1.354	1.471	0.146	0.884
S3Q10D	75	195	0.640	0.600	1.420	1.487	0.205	0.838
S3Q10E	76	195	2.197	1.851	2.361	2.202	1.104	0.269
S3Q10F	75	195	1.307	1.036	2.137	2.032	0.945	0.345
S3Q10G	75	195	1.347	1.226	2.030	2.096	0.435	0.664
S3Q10H	75	195	0.707	0.636	1.592	1.491	0.333	0.739
S3Q10I	72	195	0.361	0.185	1.066	0.848	1.265	0.206
S3Q10J	75	195	0.560	0.323	1.473	1.146	1.255	0.210
S3Q10K	72	195	0.917	1.097	1.970	2.124	-0.651	0.515
S3Q11	72	195	1.042	0.805	1.682	1.433	1.060	0.289
S4Q1	73	195	4.151	3.928	1.009	1.146	1.547	0.122
S4Q2	71	195	3.070	2.759	1.073	0.957	2.153	**0.031***
S4Q3	72	195	3.750	3.185	1.371	1.242	3.065	**0.002***
S4Q4A	74	195	2.203	2.077	0.891	0.957	1.013	0.311
S4Q4B	74	195	2.257	2.128	1.034	0.879	0.947	0.344
S4Q4C	73	195	2.562	2.615	1.130	1.154	-0.345	0.730
S4Q4D	73	195	3.055	3.077	0.984	1.069	-0.160	0.873
S4Q4E	72	195	2.361	2.431	1.092	1.179	-0.453	0.651
S4Q4F	72	195	2.583	2.682	1.058	1.285	-0.637	0.524
S4Q4G	74	195	2.000	1.959	1.020	1.170	0.282	0.778
S4Q4H	73	195	1.685	1.626	0.941	0.962	0.456	0.648
S4Q4I	73	195	1.616	1.574	0.907	0.919	0.337	0.736
S4Q4J	73	195	1.397	1.226	0.795	0.556	1.696	0.090
S5Q2	74	195	3.973	4.174	1.433	1.744	-0.967	0.333
S6Q1	74	195	0.527	0.574	0.503	0.496	-0.692	0.489
S6Q2	73	195	3.425	3.610	2.645	2.551	-0.516	0.606
S6Q2(DNU)	73	195	0.466	0.400	0.502	0.491	0.960	0.337
S6Q3	71	195	6.141	7.190	7.774	8.085	-0.963	0.336
S7Q1	75	195	3.547	3.744	1.877	2.002	-0.758	0.448
S7Q1(DNU)	75	195	0.147	0.128	0.356	0.335	0.388	0.698
S7Q2	74	195	3.297	2.826	3.100	3.309	1.094	0.274
S7Q3	70	195	0.071	0.036	0.259	0.187	1.053	0.293
S7Q4	69	195	0.087	0.072	0.284	0.259	0.390	0.697
S8Q1(MALARIA)	78	195	0.513	0.574	0.503	0.496	-0.917	0.359
S8Q1(PAIN)	78	195	0.179	0.236	0.386	0.426	-1.058	0.290
S8Q1(SLEEP AID)	78	195	0.051	0.041	0.222	0.199	0.355	0.723
S8Q1(NO DOSE)	78	195	0.013	0.015	0.113	0.123	-0.165	0.869
S8Q1(OTHER)	78	195	0.167	0.210	0.408	0.409	-0.797	0.426
S8Q2	78	195	0.000	0.031	0.000	0.247	-1.741	0.082
S8Q3	78	195	0.154	0.195	0.363	0.457	-0.780	0.435
S9Q2	72	195	0.028	0.005	0.165	0.072	1.123	0.261
S9Q3	72	195	0.042	0.031	0.201	0.173	0.407	0.684

APPENDIX H. RESULTS OF PAIRED T-TEST

Reliability test data assuming excellent sleep quality:

Observation	Avg Predicted Performance Score Based on Objective Actigraphy Data	Avg Predicted Performance Score Based on Subjective Survey Data Assuming Excellent Sleep Quality	Difference (assuming excellent sleep quality)	Censored Observation (An observation is censored if only partial actigraphy data was obtained because the participant took off the WAM)	# of days used for comparison
1	91.63	94.08	-2.45	NO	all
2	90.73	96.66	-5.93	NO	all
3	95.4	94.81	0.59	NO	all
4	91.82	98.51	-6.69	NO	all
5	85.08	94.94	-9.86	NO	all
6	93.95	97.73	-3.78	YES	partial (4 days)
7	97.04	96.04	1	YES	partial (4 days)
8	93.5	95.8	-2.3	NO	all
9	90.02	95.67	-5.65	NO	all
10	92.41	95.67	-3.26	NO	all
11	100.6	97.89	2.71	NO	all
12	98.52	97.34	1.18	NO	all
13	90.68	96.66	-5.98	NO	all
14	98.77	95.42	3.35	YES	partial (5 days)
15	94.44	96.72	-2.28	YES	partial (3 days)
16	92.95	98.57	-5.62	NO	all
17	93.38	96.19	-2.81	NO	all
18	96.55	94.31	2.24	NO	all
19	90.54	98.62	-8.08	NO	all
20	86.15	96.02	-9.87	NO	all
21	93.16	90.92	2.24	NO	all
22	92.23	91.45	0.78	NO	all
23	90.66	95.81	-5.15	NO	all
24	84.14	97.16	-13.02	NO	all
25	88.71	97.84	-9.13	NO	all
26	93.16	98.36	-5.2	NO	all
27	92.87	96.47	-3.6	NO	all
28	86.46	88.44	-1.98	NO	all
29	95.86	97.42	-1.56	NO	all
30	90.29	98.36	-8.07	NO	all
31	87.53	98.22	-10.69	NO	all
32	83.81	96.11	-12.3	NO	all
33	87.58	95.1	-7.52	NO	all
34	88.89	95.88	-6.99	YES	partial (4 days)
		Sample mean of differences	-4.284705882		
		Sampe stdev	4.465437123		
		# of observations	34		
Ho:	d=0	t(alpha=0.05,n-1)	2.03451691		
Ha:	d<0	Test Statistic	-5.594953684		
		P-value	1.59232E-06		
		Reject null hypothesis	TRUE		

Reliability test data assuming moderate sleep quality:

Observation	Avg Predicted Performance Score Based on Objective Actigraphy Data	Avg Predicted Performance Score Based on Subjective Survey Data Assuming Moderate Sleep Quality	Difference (assuming moderate sleep quality)	Censored Observation (An observation is censored if only partial actigraphy data was obtained because the participant took off the WAM)	# of days used for comparison
1	91.63	92.54	-0.91	NO	all
2	90.73	94.23	-3.5	NO	all
3	95.4	92	3.4	NO	all
4	91.82	96.81	-4.99	NO	all
5	85.08	92.4	-7.32	NO	all
6	93.95	95.71	-1.76	YES	partial (4 days)
7	97.04	93.34	3.7	YES	partial (4 days)
8	93.5	92.89	0.61	NO	all
9	90.02	92.41	-2.39	NO	all
10	92.41	92.41	0	NO	all
11	100.6	94.98	5.62	NO	all
12	98.52	94.86	3.66	NO	all
13	90.68	94.49	-3.81	NO	all
14	98.77	92.95	5.82	YES	partial (5 days)
15	94.44	95.4	-0.96	YES	partial (3 days)
16	92.95	96.76	-3.81	NO	all
17	93.38	93.91	-0.53	NO	all
18	96.55	91.11	5.44	NO	all
19	90.54	97.07	-6.53	NO	all
20	86.15	92.82	-6.67	NO	all
21	93.16	87.84	5.32	NO	all
22	92.23	87.89	4.34	NO	all
23	90.66	92.72	-2.06	NO	all
24	84.14	94.27	-10.13	NO	all
25	88.71	94.92	-6.21	NO	all
26	93.16	96.59	-3.43	NO	all
27	92.87	93.94	-1.07	NO	all
28	86.46	84.84	1.62	NO	all
29	95.86	95.81	0.05	NO	all
30	90.29	96.59	-6.3	NO	all
31	87.53	95.84	-8.31	NO	all
32	83.81	93.32	-9.51	NO	all
33	87.58	92.64	-5.06	NO	all
34	88.89	93.3	-4.41	YES	partial (4 days)
		Sample mean of differences	-1.767352941		
		Sampe stdev	4.598879514		
		# of observations	34		
Ho:	d=0	t(alpha=0.05,n-1)	2.03451691		
Ha:	d<0	Test Statistic	-2.240839307		
		P-value	0.015942233		
		Reject null hypothesis	TRUE		

Reliability test data assuming poor sleep quality:

Observation	Avg Predicted Performance Score Based on Objective Actigraphy Data	Avg Predicted Performance Score Based on Subjective Survey Data Assuming Poor Sleep Quality	Difference (assuming poor sleep quality)	Censored Observation (An observation is censored if only partial actigraphy data was obtained because the participant took off the WAM)	# of days used for comparison
1	91.63	83.63	8	NO	all
2	90.73	85.68	5.05	NO	all
3	95.4	82.27	13.13	NO	all
4	91.82	87.97	3.85	NO	all
5	85.08	84.35	0.73	NO	all
6	93.95	89.69	4.26	YES	partial (4 days)
7	97.04	85.38	11.66	YES	partial (4 days)
8	93.5	83.26	10.24	NO	all
9	90.02	82.27	7.75	NO	all
10	92.41	82.27	10.14	NO	all
11	100.6	85.62	14.98	NO	all
12	98.52	85.68	12.84	NO	all
13	90.68	86.09	4.59	NO	all
14	98.77	85	13.77	YES	partial (5 days)
15	94.44	90.41	4.03	YES	partial (3 days)
16	92.95	87.87	5.08	NO	all
17	93.38	84.81	8.57	NO	all
18	96.55	81.19	15.36	NO	all
19	90.54	89.99	0.55	NO	all
20	86.15	82.88	3.27	NO	all
21	93.16	78.25	14.91	NO	all
22	92.23	77.18	15.05	NO	all
23	90.66	83.04	7.62	NO	all
24	84.14	84.87	-0.73	NO	all
25	88.71	85.52	3.19	NO	all
26	93.16	87.62	5.54	NO	all
27	92.87	85.34	7.53	NO	all
28	86.46	74.71	11.75	NO	all
29	95.86	90.22	5.64	NO	all
30	90.29	87.62	2.67	NO	all
31	87.53	86.61	0.92	NO	all
32	83.81	84.03	-0.22	NO	all
33	87.58	83.77	3.81	NO	all
34	88.89	85.78	3.11	YES	partial (4 days)
		Sample mean of difference	7.018823529		
		Sampe stdev	4.903772058		
		# of observations	34		
Ho:	d=0	t(alpha=0.05,n-1)	2.03451691		
Ha:	d<0	Test Statistic	8.345906351		
		P-value	0.999999999		
		Reject null hypothesis	FALSE		

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