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A comparative analysis between the Navy Standard Workweek and the actual work/rest patterns of sailors aboard U.S. Navy frigates

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A COMPARATIVE ANALYSIS BETWEEN THE NAVY STANDARD WORKWEEK AND THE ACTUAL WORK/REST PATTERNS OF SAILORS ABOARD U.S. NAVY FRIGATES

by

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December 2009

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A COMPARATIVE ANALYSIS BETWEEN THE NAVY STANDARD WORKWEEK AND THE ACTUAL WORK/REST PATTERNS OF SAILORS ABOARD U.S. NAVY FRIGATES

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ABSTRACT

Crew fatigue is a major factor in mishaps aboard ships. Despite empirical evidence that fewer personnel and longer working hours are primary factors of crew fatigue, U.S. Navy budgeting constraints and increased automation on ships has resulted in reduced manning onboard Navy vessels. This study expands research by Haynes (2007) and Mason (2009) comparing the Navy Standard Workweek (NSWW) Model to Sailors' self-reported activities onboard U.S. Navy destroyers and cruisers. Research by both Haynes (2007) and Mason (2009) showed that a majority of Sailors worked longer hours and received less sleep than allotted in the NSWW model. The objective of this study was to determine if similar patterns would exist onboard U.S. Navy frigates. Results indicated that 61% of the participants exceeded the 81 hours of Available Time (work) allotted by the NSWW. On average, Sailors in this current study, excluding officers, worked 20.24 hours more per week than in the NSWW, while sleeping 8.98 fewer hours per week than in the NSWW. Results suggest that the NSWW does not accurately reflect Sailors' work/rest patterns onboard ships.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
BAE	Blood Alcohol Equivalent
CG	Guided Missile Cruiser
CNA	Center for Navy Analyses
CO	Commanding Officer
DDG	Guided Missile Destroyer
FAST	Fatigue Avoidance Scheduling Tool
FFG	Guided Missile Frigates
FSA	Food Service Attendant
IMPRINT	Improved Performance Research Integration Tool
IRB	Institutional Review Board
MOOTW	Military Operations Other Than War
MPH	Miles per Hour
N	Number of Participants
NAVMAC	Naval Manpower Analysis Center
NAVADMIN	Navigation and Administration Department
NEC	Navy Enlisted Code
NJP	Non-Judicial Punishment
NSWW	Navy Standard Workweek
NREM	Nonrapid Eye Movement
OPNAVINST	Chief of Naval Operations Instructions
ORM	Operational Risk Management
PST	Pacific Standard Time
REM	Rapid Eye Movement
SAFTE	Sleep, Activity, Fatigue, Task Effective
SAIC	Science Application International Corporation
SMD	Ship’s Manning Documents
USAF	United States Air Force
WAM	Wrist Activity Monitor

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EXECUTIVE SUMMARY

Within the U.S. Navy today, budget constraints are dictating that the U.S. Navy pursue a smaller total force. This reduction in force compels the U.S. Navy to limit the number of personnel assigned to vessels. However, at the same time as the U.S. Navy is experiencing a reduction in force, it is also experiencing building more ships. This increase in the total number of ships compounds the issues involved with reduced manning of those vessels. With more ships and fewer personnel, U.S. Navy leadership must weigh Operational Risk Management (ORM) factors in planning for the future.

In order to mitigate these ORM issues with this ever-increasing issue of proper manning of U.S. Naval vessels, some have championed automation and more technically advanced systems to reduce the burden upon the Sailors. However, literature suggests the presence of automated transportation systems is associated with unpredictable levels of individual performance among the crew members (Dinges, 1995). Other research indicates when left alone, fatigued watchstanders are more likely to rely on the automated systems to function properly, rather than developing their own situational awareness. Crew fatigue is a reoccurring theme in several papers as a major factor in mishaps aboard ships (Brown 1989; Smith, Lane and Bloor, 2001; Miller 2005; Houtman, Miedema, Jettinghoff, Starren, Heinrich, Gort, Wulder and Wubbolts, 2005; Arendt, Middleton, Williams, Francis, and Luke, 2006).

To mitigate the issues surrounding fatigue, Naval Manpower Analysis Center (NAVMAC), as the primary agent for the U.S. Navy, works with Type Commanders and Warfighting Enterprises to determine and document ships' manning requirements. The critical driver in developing ship manning documents is the Navy Standard Work Week (NSWW). The NSWW accounts for all hours within a week (168 hours) for assignment or use by a Sailor. It is broken down into Available (81 hours) and Non-available (87 hours) time. Proper manning is determined by evaluating the amount of work required to operate a specific ship type (expressed in hours per week) and evaluating the amount of work by the NSWW per Sailor to yield the number of Sailors required to accomplish the work.

This research was an observational study of Sailors' work/rest patterns aboard USS RENTZ (FFG 46). The data collected was used to conduct a comparative analysis of Sailors' actual recorded work/rest patterns to the NSWW model. This thesis found that RENTZ participants, excluding officers, on average, worked 20.24 hours per week in excess of the hours set forth in the NSWW model, while sleeping 8.98 fewer hours per week than mandated by the NSWW. Overall, 61% of participants exceeded the Available Time allotted in the NSWW model. Similar results were found on U.S. Navy cruisers and destroyers during Haynes's (2007) and Mason's (2009) studies. In light of these findings, this study recommends the following future research: (1) this research be repeated over a longer time span and in varying conditions to validate these findings; (2) use a larger sample of the population aboard additional frigates and other vessel types; (3) conduct a study specifically targeting the sleep patterns of higher-ranking Officers and enlisted Sailors; and (4) all research be conducted in tandem with the Improved Performance Research Integration Tool (IMPRINT), a task network modeling tool. Overall, recommendations to the U.S. Navy include: (1) educate all Sailors on the effects of fatigue, and (2) revisit the current NSWW to determine if the current model is a good fit for the additional challenges and requirements facing today's Sailors while afloat.

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I. INTRODUCTION

You must not needlessly fatigue the troops.

Napoleon Bonaparte

Crew fatigue is a major factor in mishaps aboard ships (Brown, 1989; Smith, Lane, & Bloor, 2001; Miller, 2005; Houtman, Miedema, Jettinghoff, Starren, Heinrich, Gort, Wulder, & Wubbolts, 2005; Arendt, Middleton, Williams, Francis, & Luke, 2006). Symptoms of fatigue are increased anxiety, decreased work effectiveness and efficiency, and decreased vigilance (Mohler, 1966; Dinges, 1995; National Sleep Foundation, 2006). Fatigued Sailors play a direct or indirect role in safety mishaps, collisions, and near misses afloat (Smith et al., 2001). According to a recent review of fatigue-related ship accidents from 1996 to 2002, fatigue may be a causal factor in 11% to almost 23% of grounding and collision cases in European shipping (Houtman et al., 2005). Although the reasons for merchant ship collisions and near misses vary, a recurring theme is fatigue (Houtman et al., 2005). Additionally, Miller (2005) cites fatigue as a major or causal factor in 26 United States Air Force (USAF) Class A mishaps (a Class A mishap is the loss of life or property damage of $1 million or more) from 1972 to 2000, costing the Air Force an average of $54 million per year. Fatigued Sailors can be costly for the U.S. Navy as well.

A number of studies have found that reducing personnel on ships and working longer hours were primary factors causing crew fatigue (Brown, 1989; Smith et al., 2001; Miller, 2005; Houtman et al., 2005; Arendt et al., 2006). Two of the reasons that the United States Navy has reduced the number of Sailors aboard ships are budget constraints and the development of more technologically advanced ships. Budget constraints that are driving a smaller armed force, in part, are compelling the Navy to limit the number of personnel on existing ships. Conversely, while downsizing the Fleet's personnel, the Navy is building more ships. The Navy's move toward smaller crews aboard its vessels presents challenges such as increased crew workload, fatigue, decreased human performance, and consequently, difficulties with risk management. According to a Center of Navy Analyses (CNA) 2002 report titled *Inside the Black Box: Assessing the Navy's Manpower Requirements Process*, "if too few people are on board, the ship's capability, readiness, and performance will suffer" (Moore, Hattiangadi, Sicilia, & Gasch, 2002, p. 256). As a consequence, the challenge of delivering increased capabilities with reduced personnel limits the Navy's ability to effectively complete its missions. Another justification for decreasing crew size is that today's naval ships are more technologically advanced. Relying on the use of automated systems, today's naval ships require fewer personnel. However, literature suggests that the presence of automated transportation systems is associated with unpredictable levels of individual performance among crew members (Dinges, 1995). Research further suggests that when left alone, fatigued watchstanders are more likely to rely on the automated systems to function correctly, rather than developing their own situational awareness. Fatigued Sailors can also result from improper scheduling of Sailors' work/rest patterns (Dinges, 1995; Miller, 2005).

Currently, military leaders are scheduling Sailors' work/rest hours based upon a Navy Standard Workweek (NSWW) model that may not accurately reflect Sailors' actual work/rest patterns onboard ship. A Navy's workweek, for sea duty units, is based upon operational requirements projected during wartime conditions (OPNAVINST 1000.16K, 2007). Haynes (2007) found that a majority of Sailors onboard CHUNG HOON obtained inadequate sleep and worked longer hours than allocated by the NSWW. Working long and unconventional hours increases the likelihood of accidents and poor performance such as sleeping on watch, misreading readouts, slow reaction to emergencies, and failure to follow procedures. Unconventional working hours are defined as hours outside the traditional working hours of 0900 to 1700 or rotating shifts (e.g., regularly changing working hours, three-section watch rotation) (Knutsson & Boggild, 2000).

In a similar study, Mason (2009) found that Sailors on PORT ROYAL and LAKE ERIE, on average, worked more hours per week than allocated by the NSWW and obtained inadequate sleep. Shortly following the data collection of the Mason (2009) study, a U.S. Navy investigation cited a "sleep-deprived" skipper as one of the underlying factors leading to the PORT ROYAL's grounding on February 5, 2009, causing an estimated $40 million in repairs to the ship (Cole, 2009). The Commanding Officer of

PORT ROYAL reportedly had only 15 hours of sleep in the three days preceding the ship's grounding (Navy Times, 2009). Haynes and Mason both recommended that the current NSWW model be revised to more accurately reflect current and future Sailors' work/rest patterns.

This research seeks to expand the research scope of Haynes's 2007 study on a U.S. Navy destroyer and Mason's 2009 study on two U.S. Navy cruisers. The objectives of the current study are to (1) determine the actual work/rest patterns of Sailors aboard U.S. Navy frigates; (2) determine if the NSWW (afloat) accurately estimates the total number of hours Sailors work each week aboard U.S. Navy frigates; (3) determine if work/rest patterns differ among departments aboard U.S. Navy frigates; and (4) recommend whether the NSWW needs to be revised to more accurately reflect Sailors' actual standard workweek by department. Two potential benefits of this research will be to (1) assist in ensuring that ships are properly manned to complete missions during times of peace and war by ensuring that the NSWW more accurately reflects Sailor's activities, and (2) ensure Sailors' work/rest patterns are properly scheduled so that Sailors obtain adequate amounts of sleep needed to perform at an optimal level. A limitation of this observational research is that it is conducted aboard a U.S. Navy frigate during a high-caliber underway evolution. This limitation may restrict generalization of findings to other U.S. Navy vessels during other operational conditions.

The following chapter provides an overview of the literature related to sleep and fatigue circadian rhythms, shiftwork, operational risk management, the NSWW model, and previous research conducted on Sailors' work/rest patterns aboard naval vessels. Chapter III describes the methods used in the thesis research. Chapter IV includes the results of the analysis while Chapter V contains the discussion of the results. Chapter VI gives the conclusion and recommendations from the study.

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II. LITERATURE REVIEW

A. FATIGUE

Fatigue is defined as an "abstract term that describes an internal state of a human operator" (Miller, 2005, p. 1). Symptoms of fatigue include increased anxiety, decreased work efficiency, decreased short-term memory, slowed reaction time, reduced motivational drive, decreased vigilance, variable work performance, and increased risk-taking when time and pressure is added to the task (Battelle Memorial Institute, 1998; Dinges, 1995; Mohler, 1966). Furthermore, fatigue negatively affects a Sailor's judgment, slows reaction time, leads to poor situational awareness, and increases mental mistakes and memory errors (Dinges, 1995; Houtman et al., 2005). Overall, fatigue can adversely affect a Sailor's performance, leading to an increase in accidents and mishaps onboard ships.

Fatigue comes from inadequate amounts of sleep. When the brain receives lack of sleep, it experiences involuntary sleep episodes, known as "microsleeps," which can last from half a second to 10 seconds. In the fast-paced, decision-making environments onboard a ship, 10 seconds is a significant amount of time. Dinges (1995) reports that during a 1-second lapse of attention caused by microsleep, a motor vehicle traveling at a rate of 60 mph covers 88 feet, a train at 120 mph travels 176 feet, and a plane flying at 250 knots travels approximately 370 feet. A lapse of a couple of seconds onboard a naval vessel can have dire consequences, possibly resulting in the loss of human lives. Dinges (1995) indicates that "as sleepiness increases so also do microsleeps and performance lapses . . . as fatigue increases, the brain appears to fall asleep involuntarily, against the will of the operator" (p. 42). The longer an individual is awake without sleep beyond 14-16 hours, the more frequent and longer in duration the lapses will be (Dinges, 1995).

The literature shows that the adverse affects of fatigue among Sailors cannot be prevented by, and does not vary by, personality, education, training, motivation, or an individual's professionalism (Dinges, 1995). Currently, the "best countermeasure to fatigue is sleep, which is the only countermeasure that provides full and complete recovery. Importantly, sleep as a countermeasure reduces the probability that fatigue will affect mission safety and, concomitantly, reduces the exposure to fatigue" (Miller, 2005, p. 7).

B. SLEEP

Sleep is defined as partial or full unconsciousness during which time voluntary functions of the body are suspended, while the body rests and is restored (Encarta, 2007). Adequate amounts of sleep are necessary to ensure optimal performance among Sailors. Without adequate sleep, a Sailor's performance may be substandard, consequently impacting mission effectiveness. The National Sleep Foundation (2006) reports that sleep-deprived humans will exhibit

> . . . excessive sleepiness, poor sleep, loss of concentration, poor motor control, slowed reflexes, nausea, and irritability . . . those who perform shiftwork [which is common on Navy vessels], particularly night shift, also may experience the effects of disrupted circadian sleep-wake cycle. (p. 8)

Sleep patterns differ among adolescents and adults. Adults require approximately eight hours of sleep, while adolescents require 8.5 to 9.25 hours of sleep each night for optimal performance and to offset sleep debt (Miller et al., 2007; Anch, Browman, Mitler, & Walsh, 1998; Bouchier, 1999). This is important because many young people enlist in the Navy and, until they are fully grown, require considerably more sleep than their adult counterparts.

The human brain experiences two basic categories of sleep: rapid eye movement (REM) and nonrapid eye movement (NREM) (Miller et al., 2007). NREM sleep consists of four stages. Figure 1 is a graphical representation of the stages of sleep by hour that an individual is a sleep. The primary stage of NREM, Stage 0, represents the stage in which an individual is fully awake. Stage 1 NREM sleep is when the individual begins to drift off, whereas Stage 2 NREM is an intermediate stage of sleep. Stage 3 is when an individual starts to fall into a deep sleep and Stage 4 NREM is the deepest stage of sleep. Adequate amounts of both REM and NREM sleep are required for optimal human performance.

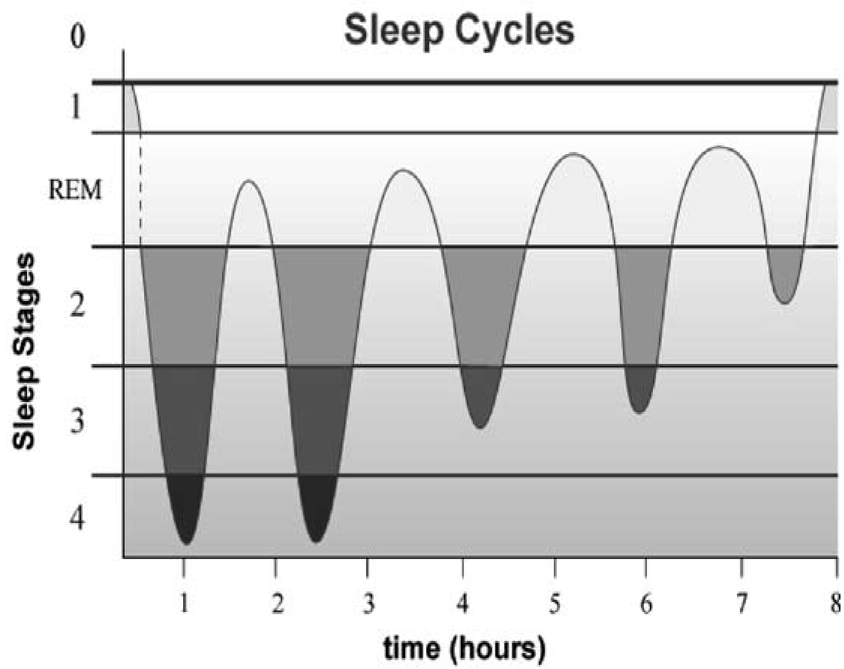

Figure 1. Sleep Cycle Over 8 Hours (From: Miller et al., 2007).

Missing a single stage of sleep results in partial sleep deprivation (Miller et al., 2007). Total sleep deprivation occurs when an individual is awake continuously without proper regenerative sessions of sleep (Miller et al., 2007). According to Shay (1998), sleep deprivation in a military domain enhances the possibility of catastrophic operational failure, fratricide, preventable noncombatant casualties, loss of emotional control, poor social judgment, and blind obedience to illegal orders. Overall, a Sailor's sleep is regulated (i.e., the timing of sleep and wakefulness) by the number of hours of sleep, the number of hours awake, the amount of sleep debt, and the circadian rhythm (Eddy & Hursh, 2001).

C. CIRCADIAN RHYTHM

An individual's circadian rhythm controls numerous physiological factors in the human body such as core body temperature and endocrine functions. Military leaders need to be cognizant of Sailors' circadian rhythms when scheduling their work and rest patterns, as an individual's circadian rhythm is a vital element in predicting human performance (Battelle Memorial Institute, 1998; Dinges, 1995; Knutsson & Boggild, 2000; Eddy & Hursh, 2001; Miller, 2005). See Figure 2 for a graphical representation of some physiological processes controlled by the circadian rhythm.

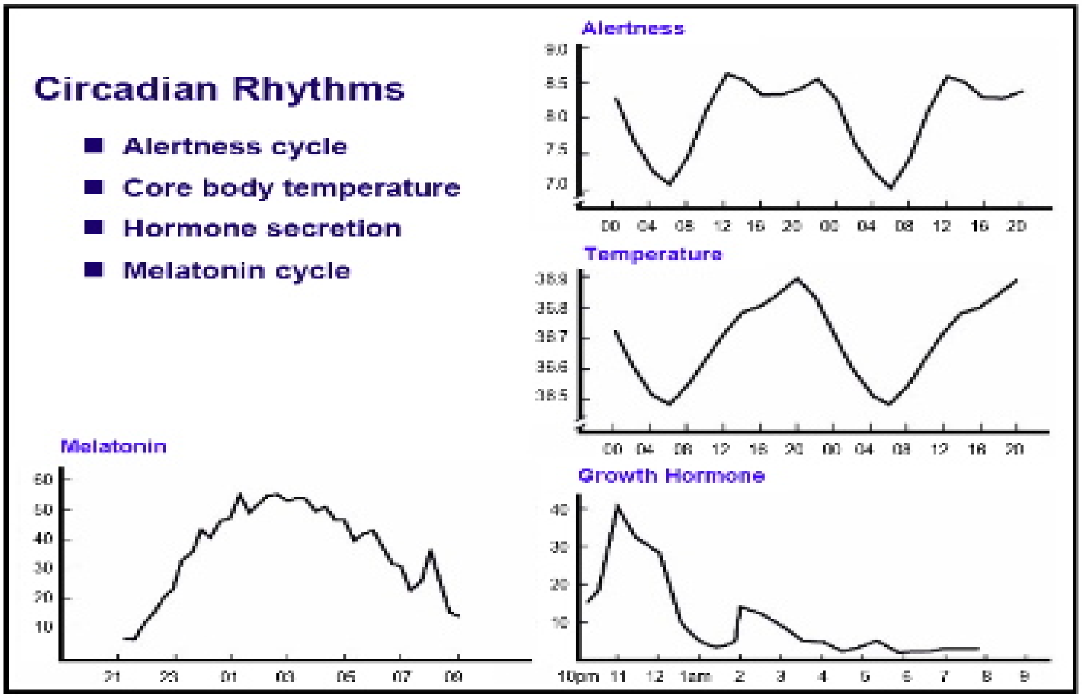

Figure 2. Alertness, Core Body Temperature, Hormone Secretion, and Melatonin Cycle Circadian Rhythms (From: McCallum, Sanquist, Mitler, & Krueger, 2003).

Circadian rhythms are associated with alertness levels and are closely related to human performance. During the peak times, Sailors are highly alert and performance is optimal. Johnson, Duffy, Dijk, Ronda, Dyal, and Czeisler (1992) conducted research to determine the relationship between the circadian rhythm as measured by core body temperature, and its effect on short-term memory, subjective alertness, and cognitive performance. The results of their study indicate that when the circadian rhythm is at the lowest point and the core body temperature is low, substandard performance is present in all three areas. A report by the Battelle Memorial Institute (1998) suggests that human performance and mental processing decrease when an individual is operating at his or her circadian low point, further supporting the idea that when Sailors' circadian rhythms are low, their performance will be degraded. A Sailor's cognitive and physical effectiveness is directly affected by his or her circadian rhythm and sleep/wake pattern (Dinges, 1995; Miller, 2005).

Circadian desynchronization can occur due to lack of sleep and sleep deprivation due to inaccurate work/rest scheduling, longer working hours, and shiftwork. During this time, the individual is operating in a circadian trough (when alertness is at its lowest point) instead of at the crest (when alertness is at its peak). Consequences of circadian desynchronization include performance and safety concerns for seagoing vessels. Sailors experiencing circadian desynchronization will have disturbed sleep. If a Sailor's circadian cycle is not synchronized, that individual's alertness and situational awareness will be negatively affected.

D. SHIFTWORK

U.S. Navy vessels operate in a 24/7 environment and Sailors are subjected to changing sleep patterns, changes in time zones, long working hours, and unconventional working hours. Thus, Sailors frequently shift their sleep and work intervals or perform "shiftwork." Shiftwork is defined as unconventional working hours or varying work hours outside of daytime hours (Knutsson & Boggild, 2000). This includes regularly changing work hours, three-section watch rotation, and evening and night work. Poor sleep cycles occur due to shiftwork because the body's biological clock is not able to adapt to rapid changes in a work schedule (Arendt et al., 2006). Figure 3 illustrates the potential problems associated with shiftwork, including stress, strain, and intervening variables.

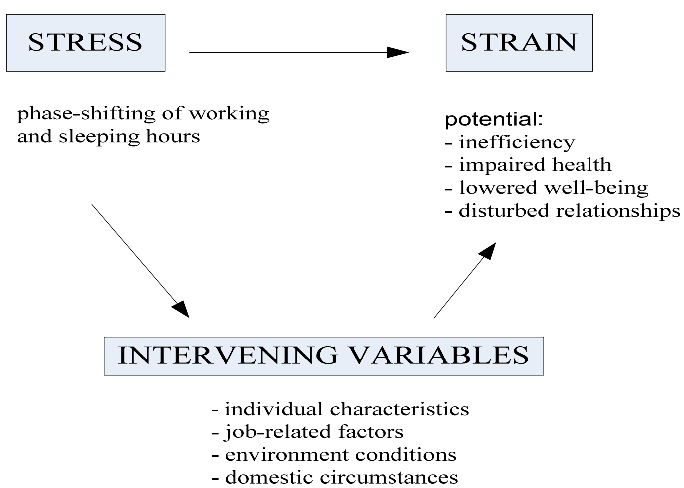

Figure 3. Model of Potential Problems Associated with Shiftwork (From: Knutsson & Boggild, 2000).

In the civilian world, stress, social problems, behavioral problems (i.e., smoking and unhealthy eating habits), and disturbed circadian rhythms are all factors associated with shiftwork (Knutsson & Boggild, 2000). Shiftwork contributes to the desynchronization of an individual's circadian rhythm, which can cause experiences of "jet lag" leading to tiredness, poor concentration, and depression (Knutsson & Boggild, 2000). Empirical studies have linked shiftwork to increase in injuries on the job (Knutsson & Boggild, 2000; Smith, Folkard, & Poole, 1994). On-the-job injuries associated with shiftwork are more likely to occur at night because individuals' circadian rhythm are unable to adjust to night shiftwork, negatively impacting individual performance and alertness. Several major disasters that occurred during nighttime hours (0000-0800) are Chernobyl, Three Mile Island, and Bhophal (Smith et al., 1994; Miller, 2005; Miller, Matsangas, & Shattuck, 2007). Sleep studies have concluded, in part, that fatigued night-time operators contributed to these safety disasters (Jha, Duncan, & Bates, 2001).

A combination of fatigue, individuals not being able to adapt to shiftwork, and substandard performance can lead to costly incidents, safety errors, and lack of Sailor retention (Smith et al., 2001). Furthermore, Knutsson and Boggild (2000) suggest that the interaction between physical activity patterns associated with shiftwork and desynchronized circadian rhythms increase the risk of acute heart disease. See Figure 4 for Knutsson's and Boggild's (2000) conceptual model of disease mechanisms and shiftwork.

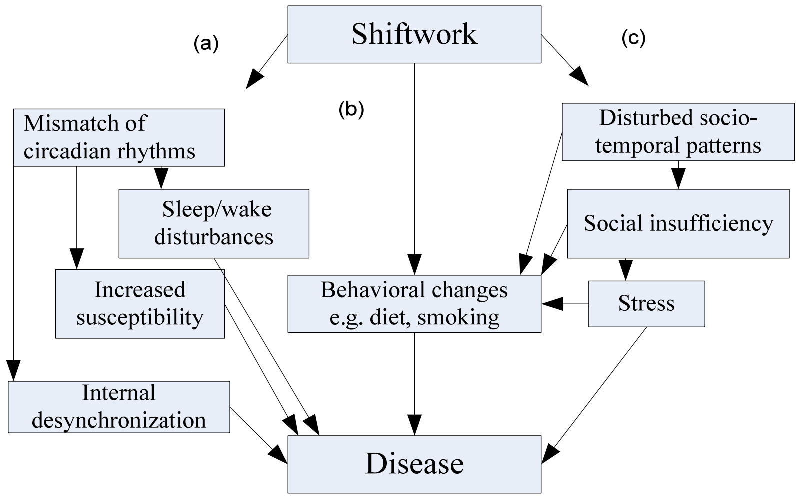

Figure 4. Conceptual Model of Disease Mechanisms in Shiftworkers (From: Knutsson & Boggild, 2000).

The long-term effects of shiftwork, as indicated in Figure 4, can become an additional medical cost for the Navy. Shiftwork can lead to mismatch of individuals' circadian rhythm causing sleep and wake disturbances, internal circadian desynchronization, and stress which can increase an individual's susceptibility to clinical illnesses (Knutsson and Boggild, 2000).

E. NAVY STANDARD WORKWEEK (NSWW) (AFLOAT)

It is important to assess the current model for scheduling Sailors' work-rest patterns, since lack of sleep and fatigue can result from improper scheduling of those patterns.. *The Manual of Navy Total Force Manpower Policies and Procedures*, OPNAV INSTRUCTION 1000.16K (2007), provides primary guidance, policies, and procedures to develop, review, approve, implement, and update Total Force manpower for all naval activities. The Naval Manpower Analysis Center (NAVMAC) uses OPNAV INSTRUCTION 1000.16 as guidance for manning the Fleet. NAVMAC, primary agent, works with Type Commanders and Warfighting Enterprises to determine Fleet manpower requirements. The Navy Standard Workweek (NSWW) is a critical driver in developing a ship's manning document (OPNAVINST 1000.16, 2007).

The NSWW for sea-going vessels is determined based upon operational requirements under projected wartime conditions. This model serves as a guideline for commanders to sustain personnel utilization under Conditions I, II, and III (wartime/forward deployment cruising readiness). The intent of the conditions is to reflect the limits of Sailors' endurance (Williams-Robinson, 2007). At Condition I, the ship is at General Quarters (battle readiness), all personnel are continuously alert, and all watchstations are manned. Maximum expected crew endurance during Condition I is 24 hours of continuous operations. At Condition II, Sailors' maximum expected duration is 10 days, with 4 to 6 hours of rest each day. While at Condition III, the ship is at wartime steaming and all essential navigational watches are manned, along with several additional watchstations. Maximum expected crew endurance during Condition III is 60 days, with 8 hours of rest per day. See Table 1 for maximum expected crew endurance during each condition.

Readiness Conditions	**Wartime/Forward Deployed Cruising Readiness Requirements**
Condition I	Sailors are expected to perform for up to 24 hours continuously
Condition II	The maximum expected duration is 10 days, with a minimum of 4 to 6 hours of rest provided per man per day
Condition III	The maximum expected crew endurance is 60 days, with an opportunity for 8 hours of rest provided per man per day

Table 1. U.S. Navy Wartime Readiness Condition Chart (OPNAVINST 9010.318B, 2007)

A ship's standard workweek consists of 168 hours (Table 2). The 168-hour workweek is divided into available (on duty) and nonavailable (off duty) hours. The Available Time per week is 81 hours, which includes watchstanding, work, training, and service diversion. Fifty-six hours are allocated for watchstanding, 14 hours are allocated for maintenance (productive work), 7 hours are allocated for training, and the remaining 4 hours are allocated for service diversion to include, but not limited to, meetings, administrative time, inspections, quarters, and sick call. Nonavailable Time per week consists of 87 hours which include sleep, messing, personal time, and free time on Sunday. Nonavailable Time is further broken down to 56 hours for sleep, 14 hours for messing, 14 hours for personal time, and 3 hours for free time on Sunday.

Navy Standard Workweek (OPNAVINST 1000.16K)	
Ship Standard Workweek	81 Hours
Productive Workweek(Note 1)	70 Hours
Total Hours Available Weekly	**168 Hours**
Less Nonavailable Time:	
Sleeping	56 Hours
Messing	14 Hours
Personal Time	14 Hours
Sunday Free Time	3 Hours
Less:	
Training (Note 2)	7 Hours
Service Diversion (Note 3)	4 Hours
Total Hours Available for Productive Work (Note 1)	70 Hours
Note 1: For watchstanders, 56 hours is allocated to watch stations (8 hours X 7 days) (14 hours available for work in addition to 56 hours watchstanding = 70 hours)	
Note 2: Training is an activity of an instructional nature, which contributes directly to combat readiness and deducts from the individual's capability to do productive work. Training hours are factored to reflect those scheduled events (e.g., general drills, engineering casualty damage control) for all hands. Hours indicated have been standardized for Condition III in ship's manning documents (SMDs).	
Note 3: Service diversion consists of actions required of military personnel regulations or the nature of shipboard/staff routine. Service diversion includes, but is not limited to, the following types of activities:	
•	Quarters, inspections, and sick call.
•	Other administrative requirements including: Commanding Officers Non-Judicial Punishment (NJP), participation on boards and committees, interviews, and non-training-related assemblies.
•	Flight and hangar deck integrity watches.

Table 2. Detailed Description of Navy Standard Workweek for Afloat (Wartime) Military Personnel (From OPNAVINST 1000.16K – Appendix C)

The NSWW was changed in 2001, following a CNA report. The change added three additional hours to productive work, while removing three hours from service diversion. Productive hours per week increased from 67 hours to 70 hours per week and service diversion decreased from seven to four hours per week. In essence, the change decreased manpower requirements, but did not reduce the workload required to properly operate the ship (Miller & Firehammer, 2007).

The general assumption of the afloat NSWW is that a unit is steaming in Condition III, using a three-section watch rotation. The maximum endurance for Sailors in Condition III is 60 days, with the opportunity for eight hours of rest per person per day. While at sea, watches are manned based upon the unit's readiness condition.

F. PREVIOUS STUDIES ON THE NAVY STANDARD WORKWEEK (NSWW)

Haynes (2007) conducted a study on the CHUNG HOON to compare Sailors' actual work/rest patterns to estimated work/rest patterns of the NSWW. His results suggest that the NSWW model does not accurately reflect Sailors' daily activities afloat. Haynes found that, when using the Fatigue Avoidance Scheduling Tool (FAST), many Sailors' predicted effectiveness level was at or below 80%, indicating that a majority of Sailors were operating at less than an optimal level. Additionally, Haynes's results indicate that 85% of participants in his study worked longer than the 81 work hours per week allotted by the NSWW. Mason's (2009) study of LAKE ERIE and PORT ROYAL found similar results, and argued that the NSWW does not accurately reflect Sailors' work/rest patterns afloat. Mason found that 85% of his participants exceeded the 81 hours of Available Time allotted by the NSWW. Additionally, Mason found that, when using the FAST tool, 54% of the participants in his study had predicted effectiveness levels at or lower than 65%, indicating that a majority of these Sailors were operating at seriously degraded levels of effectiveness.

G. HUMAN PERFORMANCE MODEL AND TOOL

Researchers from the Air Force Research Laboratory, Brooks Air Force Base (AFB); Walter Reed Army Institute of Research; Federal Railroad Association; NTI, Inc.; and Science Application International Corporation (SAIC) worked together to develop the Sleep, Activity, Fatigue, Task Effective (SAFTE) model, and FAST. SAFTE, a model used to predict fatigue, predicts how circadian rhythm and sleep/wake stages impact humans' cognitive process and performance. The model predicts workers' fatigue, optimizes scheduling to reduce human performance error, and improves safety, effectiveness, and quality of life (Eddy & Hursh, 2001). This model predicts human vigilance performance for numerous work schedules at various levels of sleep deprivation. See Figure 5 for the SAFTE model.

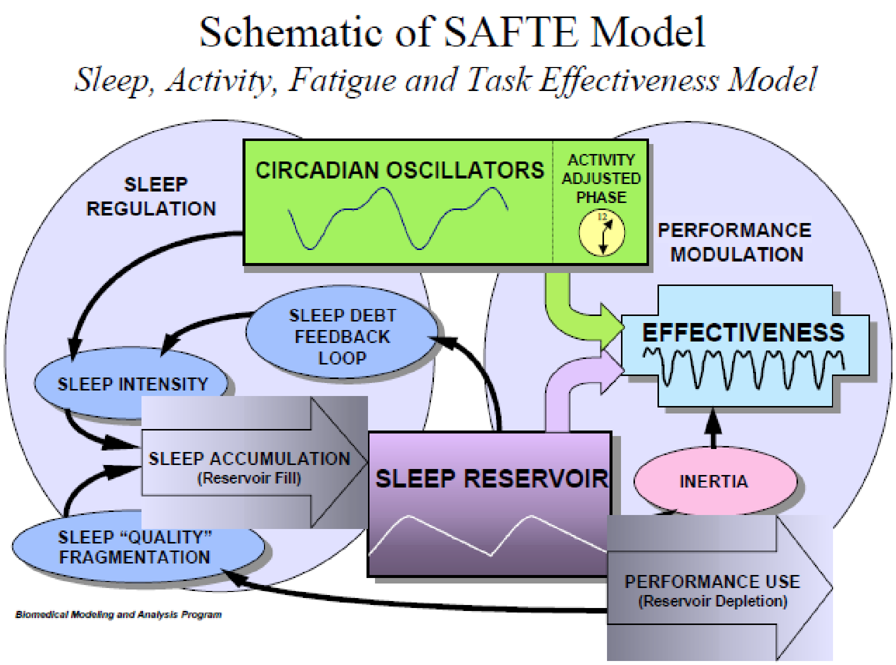

Figure 5. SAFTE Model (From: Eddy & Hursh, 2001).

The SAFTE model begins at the lower center block titled Sleep Reservoir. The jagged lines within the block indicate levels of the sleep reservoir. At the trough, the sleep reservoir is entirely depleted, while at the peak, the reservoir is full. The Sleep Reservoir is filled during sleep and depletes while awake. This reservoir is filled based upon an individual's sleep quality and sleep intensity. Sleep intensity is based upon the time of day (circadian process) and sleep reservoir level (sleep debt), and sleep quality is determined by the amount of sleep fragmentation (Hursh, Redmond, Johnson, Throne, Belenky, Balkin, Storm, Miller, & Eddy, 2004). The end result of the model is to predict the effectiveness of an individual's human performance.

FAST uses the SAFTE model to estimate an individual's predicted effectiveness, especially vigilance. FAST is a tool developed to assist in scheduling work activities and rest periods, and it predicts fatigue under various work/rest schedules. Using this tool to schedule work/rest patterns can facilitate optimization of human performance.

> FAST allows a user to predict cognitive performance . . . provides the military planner the ability to optimize performance under conditions of limited sleep and minimizes the need for pharmacological aids. (Eddy & Hursh, 2001, p. 1)

Additionally, FAST allows users to calculate an individual's circadian rhythm and performance compared to a blood alcohol equivalent (BAE). Figure 6 is a depiction of a FAST chart.

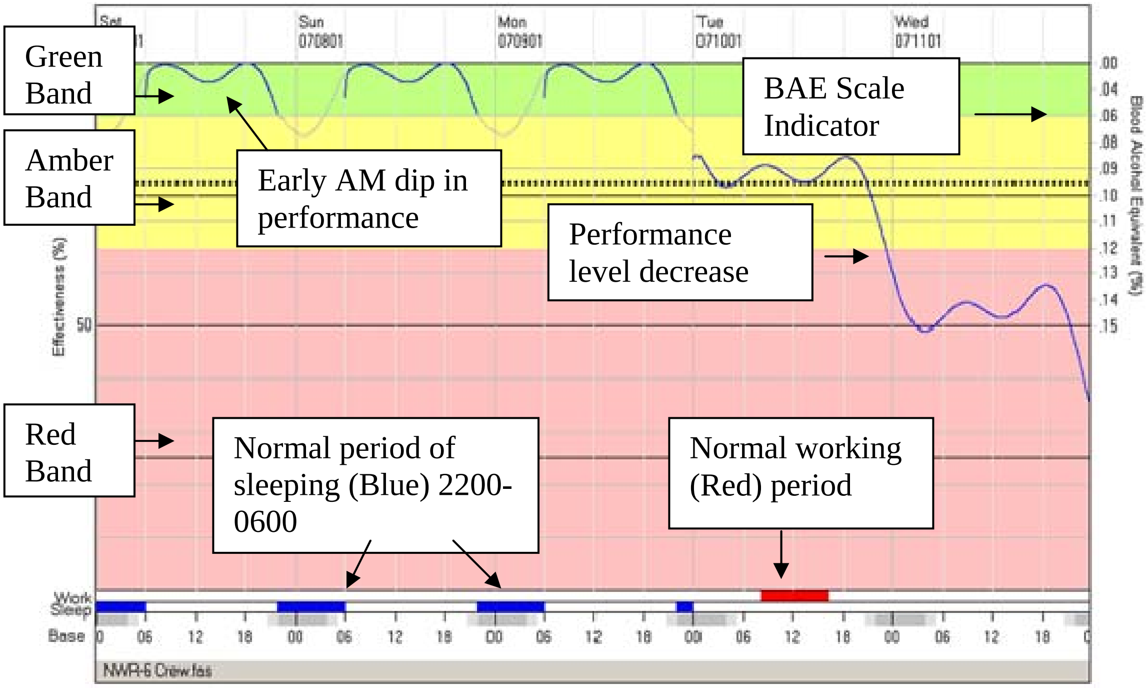

Figure 6. FAST Chart (After: Miller et al., 2007).

The blue- and red-shaded bars at the bottom of the chart indicate the work and rest activities that an individual experiences throughout the day and night. Colors on the bars correlate to activity: blue indicates sleep, while red indicates work. The scale on the left-hand side of the chart indicates the level of effectiveness (0%-100%). The lower red horizontal band indicates an individual's predicted effectiveness at levels less than 65%. The yellow band indicates an individual's predicted effectiveness at levels between 65% and 90%. The green band is the optimal level and represents predicted effectiveness levels above 90%. Dates are specified at the top of the chart and time, in a 24-hour span, is annotated at the bottom of the chart. The FAST tool can be used to assist leaders in scheduling Sailors' work/rest patterns in order to minimize the potential operational risk associated with sleep-deprived and fatigued Sailors.

H. OPERATIONAL RISK MANAGEMENT (ORM)

"ORM is a decision-making tool used by military personnel at all levels, to increase operational effectiveness by anticipating hazards and reducing the potential for loss, thereby increasing the probability of a successful mission" (OPNAVINST 3500.39B, 2004, p. 7). ORM is the primary tool used to minimize operational risk onboard U.S. Navy vessels. To evaluate ORM, military leaders must continuously be aware that fatigue, lack of sleep, and sleep deprivation pose a risk of loss of life, and lessen the probability of a successful mission. The Navy, therefore, should not take fatigue-related performance lightly, as it is a concern for all modes of transportation since human performance errors are frequently identified as the cause of accidents (Dinges, 1995). Irregular sleep patterns, coupled with fatigue, will have an adverse impact upon ORM and the safety of ship and crew (Haynes, 2007).

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III. METHODOLOGY

This research was an observational study of Sailors' work/rest patterns aboard USS RENTZ (FFG 46). The data collected was used to conduct a comparative analysis of Sailors' actual recorded work/rest patterns with the NSWW model.

A. PARTICIPANTS

Fifty Sailors volunteered to take part in the research. The age of the participants ranged from 19 to 45, and participants' race and gender varied. Volunteers (officers and enlisted) represented a subset of the ship's overall manning to include various rates, ranks, skills, years of experience, departments, Navy Enlisted Code (NEC) specialty, and watchstations.

B. IMPLEMENTATION AND DATA COLLECTION OF SLEEP DATA

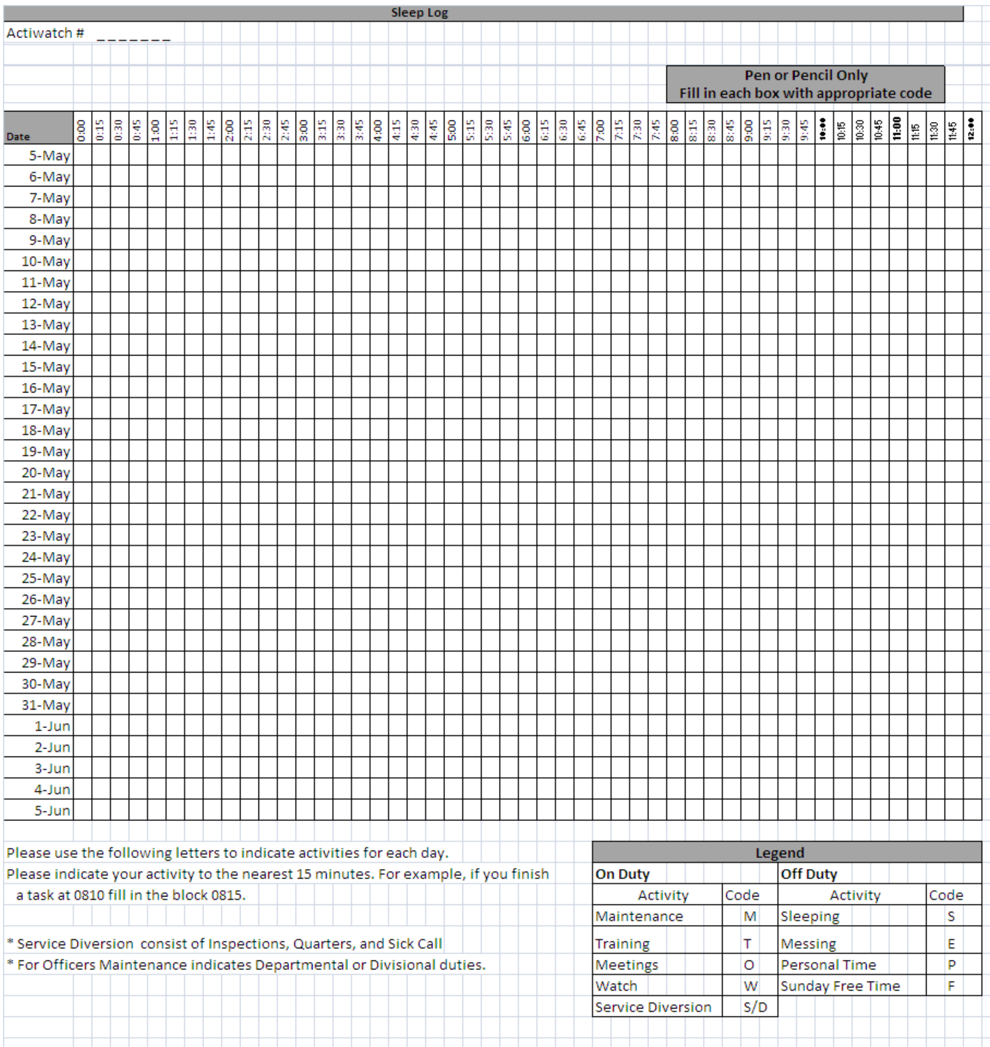
1. Institutional Review Board

The research was submitted to the Naval Postgraduate School's Institutional Review Board (IRB). The purpose of submission was to determine the risk that participants would encounter by taking part in this research. The IRB indicated minimal to no risk was involved in the research. Prior to the research, participants were fully briefed and signed consent forms. See Appendix A for a copy of the Informed Consent Form.

2. Data Collection

a. Daily Activity Log

Each participant was provided with a Daily Activity Log (Figure 7). The log sheet was dated from May 5, 2009 to June 5, 2009, capturing the total number of days underway. The first six days of data collection, before the ship was underway, allowed time for participants to become familiar with wearing the wrist activity monitors (WAMs), annotating daily activity, and FAST program preconditioning. FAST preconditioning accounts for Sailors not being well-rested prior to research. Each line of the log covered a span of 24 hours, blocked into 15-minute intervals. Each participant was instructed to log daily activities to the nearest 15-minute interval each day of the study. Additionally, each participant was instructed to annotate their WAM identification number at the top of their respective Daily Activity Log. The log was divided into both on duty (available) and off duty (nonavailable) time. Available Time includes maintenance, training, meeting watch, and service diversion, while Nonavailable Time includes sleep, messing, personal time, and Sunday's free time.



Sleep Log

Actiwatch # _______

Pen or Pencil Only
Fill in each box with appropriate code

Date | 0:00 | 0:15 | 0:30 | 0:45 | 1:00 | 1:15 | 1:30 | 1:45 | 2:00 | 2:15 | 2:30 | 2:45 | 3:00 | 3:15 | 3:30 | 3:45 | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 | 6:00 | 6:15 | 6:30 | 6:45 | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 | 9:00 | 9:15 | 9:30 | 9:45 | [illegible] | 10:15 | 10:30 | 10:45 | 11:00 | 11:15 | 11:30 | 11:45 | [illegible]

5-May, 6-May, 7-May, 8-May, 9-May, 10-May, 11-May, 12-May, 13-May, 14-May, 15-May, 16-May, 17-May, 18-May, 19-May, 20-May, 21-May, 22-May, 23-May, 24-May, 25-May, 26-May, 27-May, 28-May, 29-May, 30-May, 31-May, 1-Jun, 2-Jun, 3-Jun, 4-Jun, 5-Jun

Please use the following letters to indicate activities for each day.
Please indicate your activity to the nearest 15 minutes. For example, if you finish a task at 0810 fill in the block 0815.

* Service Diversion consist of Inspections, Quarters, and Sick Call
* For Officers Maintenance indicates Departmental or Divisional duties.

Legend

On Duty		Off Duty	
Activity	Code	Activity	Code
Maintenance	M	Sleeping	S
Training	T	Messing	E
Meetings	O	Personal Time	P
Watch	W	Sunday Free Time	F
Service Diversion	S/D		

Figure 7. Participants' Daily Activity Log

b. Wrist Activity Monitor (WAM)

WAMs (Figure 8) were distributed to all participants, who were instructed to wear the WAM at all times, excluding evolutions onboard the ship that required removal of the WAM. If participants removed the watch, they were instructed to annotate such event on their Daily Activity Log by writing “off.” Each WAM had an identification number and that number was logged on the Daily Activity Log to ensure that the WAMs corresponded to their respective activity log.

Figure 8. Wrist Activity Monitor (From: Mason, 2009)

c. Data Analysis

Participants were briefed on equipment (WAM and Daily Activity Log) usage prior to getting underway. Upon completion of the underway period, the Daily Activity Logs and WAMs were collected from each participant. Data from the Daily Activity Logs were entered into Microsoft Excel spreadsheets for initial comparison to the NSWW model. Next, WAM data corresponding to the respective activity log data were downloaded using the Actiware 5.0 program. Data were examined to verify participants’ sleep time. Following this step, the data were exported into FAST for additional analyses. Once the data were imported into FAST, they were compared to the actigraphic data to ensure that Sailors were actually sleeping and working when stated. Following the examination of participants' sleep and work activity, participants' predicted effectiveness was calculated using FAST.

IV. RESULTS

Work and rest data from May 11, 2009 through June 4, 2009 were analyzed to capture a 3-week period. The ship's port visit, May 22 through May 25, was excluded from the analysis.

A. DEMOGRAPHIC ANALYSIS

Initially, 50 Sailors volunteered to take part in this research. At the end of data collection, only 24 of the original 50 volunteers completed the Daily Activity Log and wore WAMs. The 26 participants who did not complete the study failed to do so for various reasons, including injuries, loss of their WAMs, and failure to complete the Daily Activity Log. All 24 participants who completed the research were males and their average age was 31.

Participants included officers (*n*=3) and enlisted personnel (*n*=21) from various watchstations, rates, ranks, and departments including operations (*n*=6), combat systems (*n*=4), engineering (*n*=3), supply (*n*=4), and navigation and administration (NavAdmin) (*n*=4). The letter "*n*" denotes the number of participants. The number of participants by department refers only to enlisted Sailors who participated and excludes officers.

B. NAVY STANDARD WORKWEEK (NSWW) VERSUS SAILORS' SELF-REPORTED WORK/REST PATTERNS (BY WEEK AND PER DAY)

To determine if the NSWW (afloat) accurately estimates the total number of hours Sailors work each week, each participant was asked to fill out a Daily Activity Log. Each log covered a span of 24 hours, blocked into 15-minute intervals, starting at 0000 and ending at 2359 each day. Each participant logged their daily activities to the nearest 15-minute interval. Activities included these categories: Maintenance, Training, Service Diversion, Watch, Sleep, Messing, Personal Time, and Free Time. The Daily Activity Logs were used to determine how much time each Sailor spent on each category. That information was then compared to the NSWW model from the *Manual of Navy Total Force Manpower Policies and Procedures* (OPNAVINST 1000.16K, 2007) to determine if the NSWW accurately reflects Sailors' self-reported time. For the purpose of this research, personal time and free time were combined because participants used the terms interchangeably, i.e., Sunday free time was reported as personal time.

Table 3 shows the average of the enlisted Sailors' weekly self-reported work and rest patterns. The results show that participants worked, on average, 20.24 hours more than the time allotted per week for maintenance. Training time, 2.08 hours per week, was consistently below the seven hours allotted for each week by the NSWW. With respect to service diversion (meetings), the time exceeds the allotted time per week in the NSWW model by 7.93 hours. The average time spent standing watch per week is 16.56 fewer hours than allotted for by the NSWW model. All participants slept approximately 8.98 fewer hours per week than allotted by the NSWW. Self-reported mess time was at 6.99 hours less than the time set forth in the NSWW model, while personal time was 9.29 hours more than the time allotted for in the NSWW model per week.

RENTZ AVERAGE NUMBER OF HOURS SPENT PER WEEK							
Participant	Maintenance	Training	Meetings	Watch	Sleep	Messing	Personal Time
NSWW	14	7	4	56	56	14	17
728	29.47	0	5.67	88.2	30.31	8.19	6.16
1365	44.1	0	23.31	0	42.77	0	57.82
1367	0	0	0	101.64	56.42	0	9.94
3517	52.64	0	2.03	30.45	44.66	5.67	32.83
5318	10.64	2.73	28.28	57.61	36.33	9.45	23.03
5325	20.3	2.66	6.3	48.3	53.06	8.82	28.42
5368	47.74	3.43	0	58.17	54.39	1.61	2.66
5381	50.47	1.82	5.11	1.26	48.09	8.4	52.85
5421	30.8	5.95	2.24	64.68	46.69	4.83	12.81
5438	3.22	4.55	3.64	83.44	50.05	9.17	13.86
5593	39.41	1.68	0	54.25	52.57	0	20.09
5594	44.52	1.89	3.43	40.81	37.52	8.68	31.15
5596	95.06	3.5	3.01	0	46.9	1.89	17.57
5597	0	0	73.15	7	48.65	9.1	30.1
5599	44.03	0	13.02	38.5	53.2	3.64	15.68
5600	26.18	7.42	45.64	38.57	38.01	10.85	1.33
5601	0.14	1.47	12.32	38.85	35.91	7.98	71.26
6188	37.73	0	1.82	45.85	40.53	17.01	24.99
6189	25.76	1.89	10.15	29.47	48.93	7.42	44.31
6366	45.99	4.48	6.65	1.26	73.08	10.5	25.97
6567	70.77	0.14	4.69	0	49.28	14	29.19
Average	34.24	2.08	11.93	39.44	47.02	7.01	26.29
Std. Deviation	24.17	2.18	17.92	30.54	9.23	4.59	18.12

Table 3. RENTZ Average Number of Hours per Week

Results indicate that 61% of Available Time of enlisted Sailor study participants exceeds the NSWW model of 81 hours per workweek afloat. Figure 9 indicates that the NSWW allotted 81 hours per week for Available (work) Time. The bars to the left of the yellow NSWW bar indicate participants whose Available Time is fewer than 81 hours a week, whereas the bars to the right of the NSWW indicate participants whose Available Time is in excess of the time allocated by the NSWW model. See Appendix F for a summary table of Sailors' reported Available and Nonavailable Time.

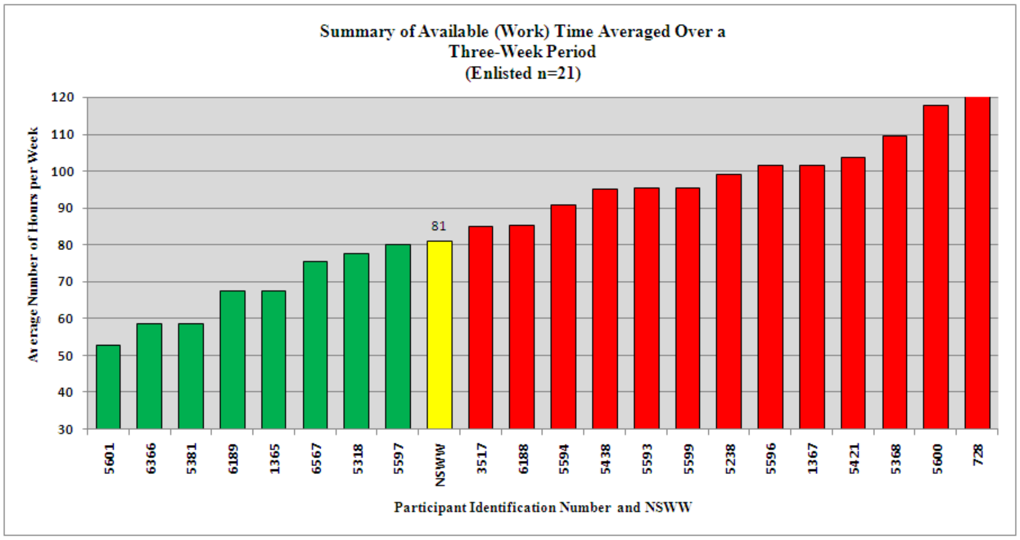


Figure 9. Summary of Available (Work) Time Over a 3-Week Period for Enlisted Participants

Table 4 indicates averages for self-reported work and rest patterns of enlisted Sailors broken down per day. The results indicate that participants worked 2.89 hours per day more than allotted for maintenance. Training time, 0.30 hours per day, was consistently below the one hour allotted by the NSWW model. In general, reported service diversion (meetings) exceeded the time allotted in the NSWW model by 1.13 per day hours. The average time spent standing watch per day was 2.37 fewer hours than the NSWW model. On average, enlisted Sailors slept approximately 1.28 fewer hours per day than the NSWW. Self-reported mess time was one hour less than the allotted time set forth in the NSWW model, while personal time was 1.33 hours per day more than the time allotted for in the NSWW model.

RENTZ AVERAGE # OF HOURS TIME PER DAY							
Participant	Maint.	Training	Meetings	Watch	Sleep	Messing	Pers.Time
728	4.21	0	0.81	12.6	4.33	1.17	0.88
1365	6.3	0	3.33	0	6.11	0	8.26
1367	0	0	0	14.52	8.06	0	1.42
3517	7.52	0	0.29	4.35	6.38	0.81	4.69
5318	1.52	0.39	4.04	8.23	5.19	1.35	3.29
5325	2.9	0.38	0.9	6.9	7.58	1.26	4.06
5368	6.82	0.49	0	8.31	7.77	0.23	0.38
5381	7.21	0.26	0.73	0.18	6.87	1.2	7.55
5421	4.4	0.85	0.32	9.24	6.67	0.69	1.83
5438	0.46	0.65	0.52	11.92	7.15	1.31	1.98
5593	5.63	0.24	0	7.75	7.51	0	2.87
5594	6.36	0.27	0.49	5.83	5.36	1.24	4.45
5596	13.58	0.5	0.43	0	6.7	0.27	2.51
5597	0	0	10.45	1	6.95	1.3	4.3
5599	6.29	0	1.86	5.5	7.6	0.52	2.24
5600	3.74	1.06	6.52	5.51	5.43	1.55	0.19
5601	0.02	0.21	1.76	5.55	5.13	1.14	10.18
6188	5.39	0	0.26	6.55	5.79	2.43	3.57
6189	3.68	0.27	1.45	4.21	6.99	1.06	6.33
6366	6.57	0.64	0.95	0.18	10.44	1.5	3.71
6567	10.11	0.02	0.67	0	7.04	2	4.17
MEDIAN	5.39	0.26	0.73	5.55	6.87	1.17	3.57
NSWW	2.00	1.00	0.57	8.00	8.00	2.00	2.43
AVERAGE	4.89	0.30	1.70	5.63	6.72	1.00	3.76
STDEV	3.45	0.31	2.56	4.36	1.32	0.66	2.59

Table 4. Average Number of Hours per Day Spent in Various Activities

Table 5 compares RENTZ weekly averages to the NSWW. Due to the small sample size, a Mann-Whitney U Test was used. The Mann-Whitney U test for the equality of means revealed significant differences between RENTZ participants and the NSWW for maintenance, training, watch, sleep, messing, and personal time.

Comparison of RENTZ Weekly Averages to NSSW

		NSSW	RENTZ	
			(n=21)	
Available Time		81	87.69	(168)
	Maintenance**	14	34.24	(105)
	Trainings***	7	2.08	(21)
	Meetings	4	11.93	(189)
	Watch**	56	39.44	(126)
Non Available Time		87	80.31	(168)
	Sleep***	56	47.02	(42)
	Messing***	14	7.01	(31.5)
	Personal Time*	17	26.29	(147)

Note: Mann–Whitney U in parentheses.
*** p ≤ .000, ** p ≤.01, * p ≤ .05 (two tailed)

Table 5. Mann-Whitney U Means Test: Comparision of RENTZ Weekly Averages to NSWW

Figure 10 shows of self-reported activities of Participant 728 compared to the NSWW. Participant 728 showed the greatest variation from the NSWW. Participant 728 stood a three-section watch rotation in radio, notionally resulting in 8 hours a day spent standing watch. Participant 728's reported activities were fairly consistent while underway. On average, Participant 728 reported standing watch 12.60 hours per day, exceeding the NSWW model time by 4.60 hours. He spent 4.21 hours per day conducting maintenance, 2.21 hours over the time allotted for in the NSWW model.

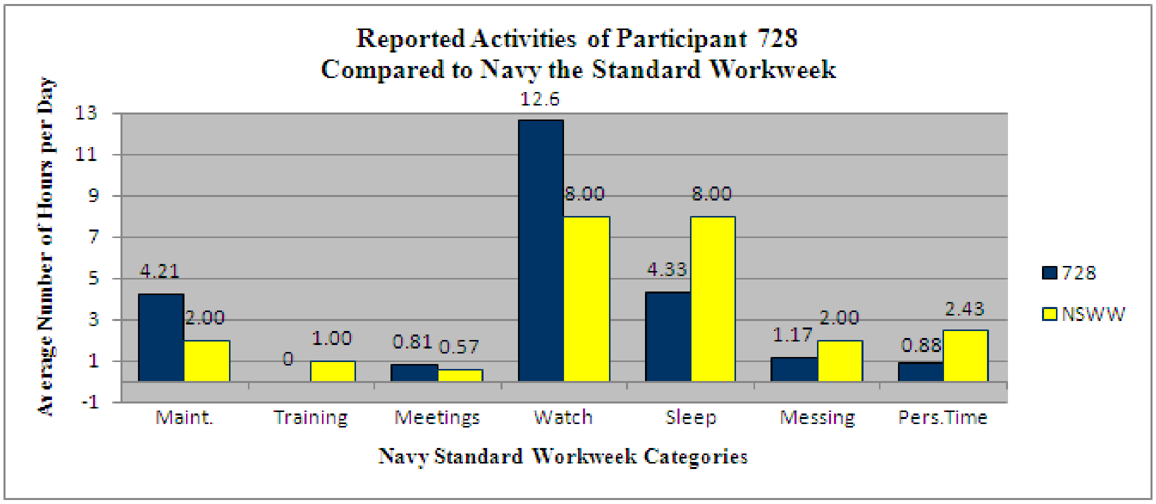


Figure 10. Reported Activities of Participant 728 Compared to the Navy Standard Workweek

Participant 728's reported daily average time training (0.00 hours), messing (1.17 hours), and personal time (0.88 hours) per day were consistently less than the time allocated by the NSWW model. The average time Participant 728 spent sleeping per day was 4.33 hours, 3.67 hours fewer than the allotted time for sleep according to the NSWW model. See Appendix C for each participant's individual self-reported activities compared to the NSWW model.

Figure 11 displays the aggregated difference between participant 728's self-reported activities and the NSWW model. Maintenance and watch exceeded the time allotted by the NSWW model, while the other categories are less than the time allotted by the NSWW model. Based upon a 3-week time period, Participant 728 should receive 168 hours of sleep; however, this particular Sailor received 77 fewer hours of sleep over the 3-week period than set forth in the NSWW model.

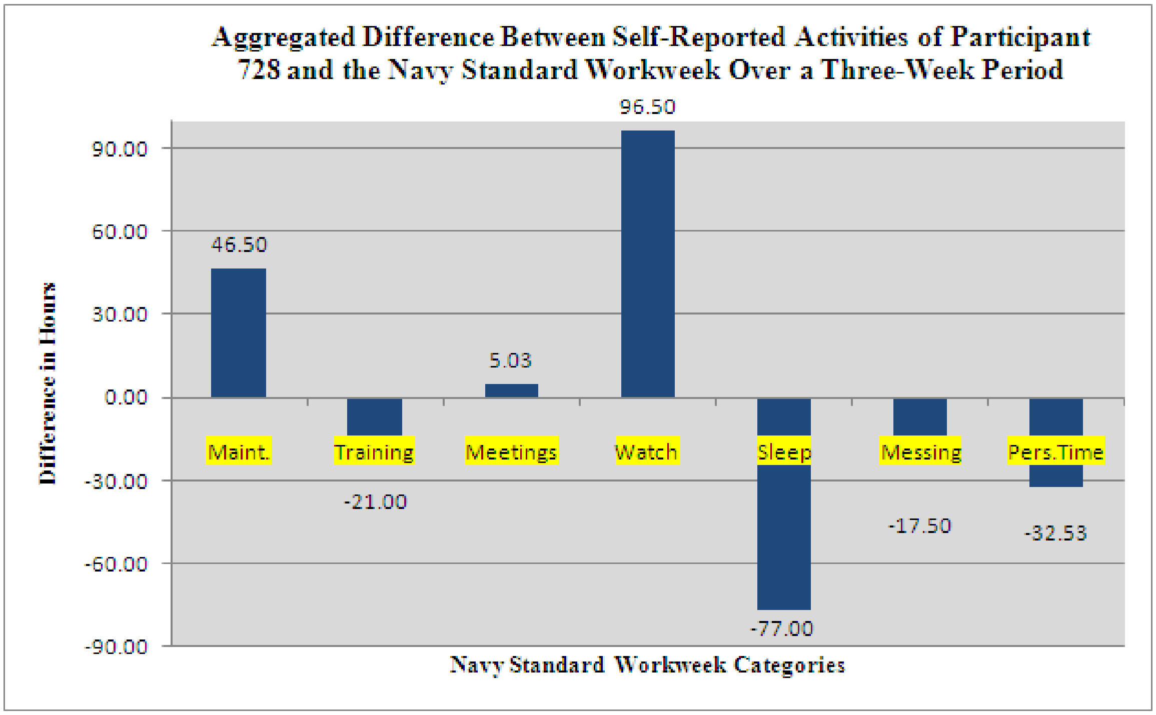


Figure 11. Aggregated Difference Between Self-Reported Activities of Participant 728 and the Navy Standard Workweek Over a Three-Week Period

Over all categories, Participant 728 displayed the greatest deviation from the NSWW model. Figure 12 illustrates the aggregated deviation in absolute value between the self-reported activities of Participant 728 and the NSWW over a 3-week period. NSWW categories of maintenance, sleep, and watch standing display the most deviation. The method used to determine deviation is based upon the following formula:

$$\text{Deviation} = \frac{(\text{Reported} - \text{Allocated})^2}{\text{Allotted}}$$

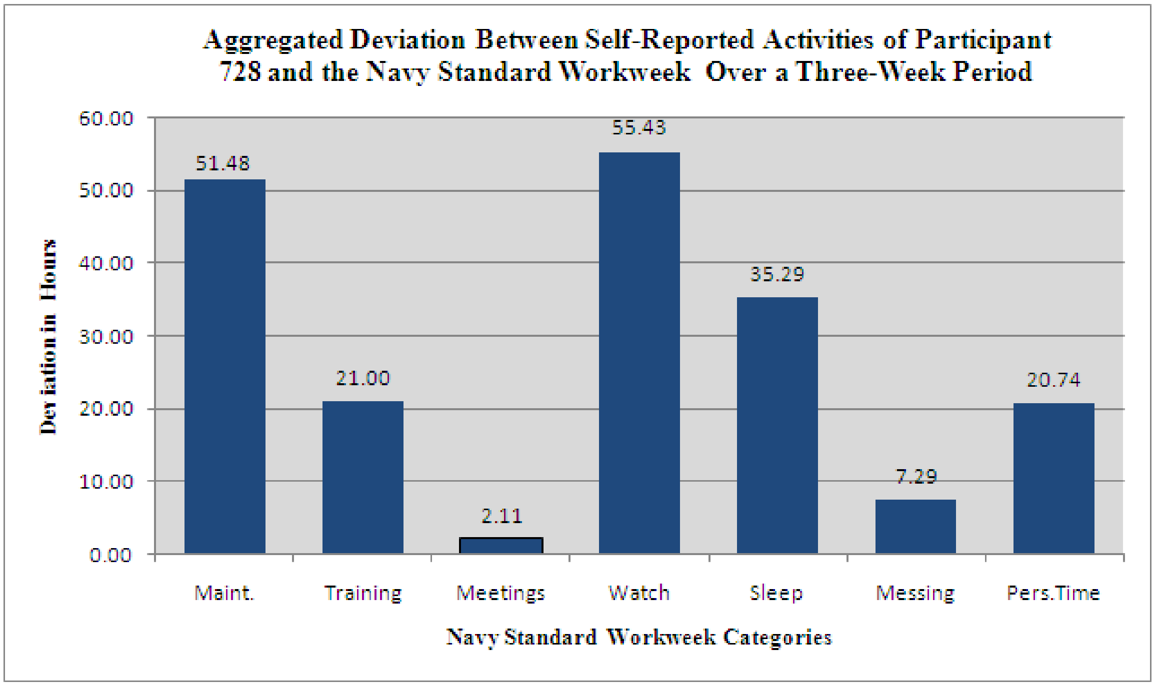


Figure 12. Aggregated Deviation Between Self-Reported Activites of Participant 728 and the Navy Standard Workweek Over a Three-Week Period

C. WORK/REST PATTERNS OF SAILORS BY DEPARTMENT

Figure 13 depicts the mean distribution of Available Time by departments. The Engineering Department's on average, on duty time is 23.04 hours per week more than the Available Time set forth in the NSWW model during the 3-week period. The Operations Department's on average, on duty time is 17.86 hours per week more than the Available Time allotted for in the NSWW. On average, the Supply Department's on duty time was 1.02 hours per week more than the NSWW. Combat Systems and NavAdmin Department's on duty time were fewer hours per week than set forth in the NSWW model. See Appendix D for the average number of hours per week dedicated toward productive work for each participant in their respective departments.

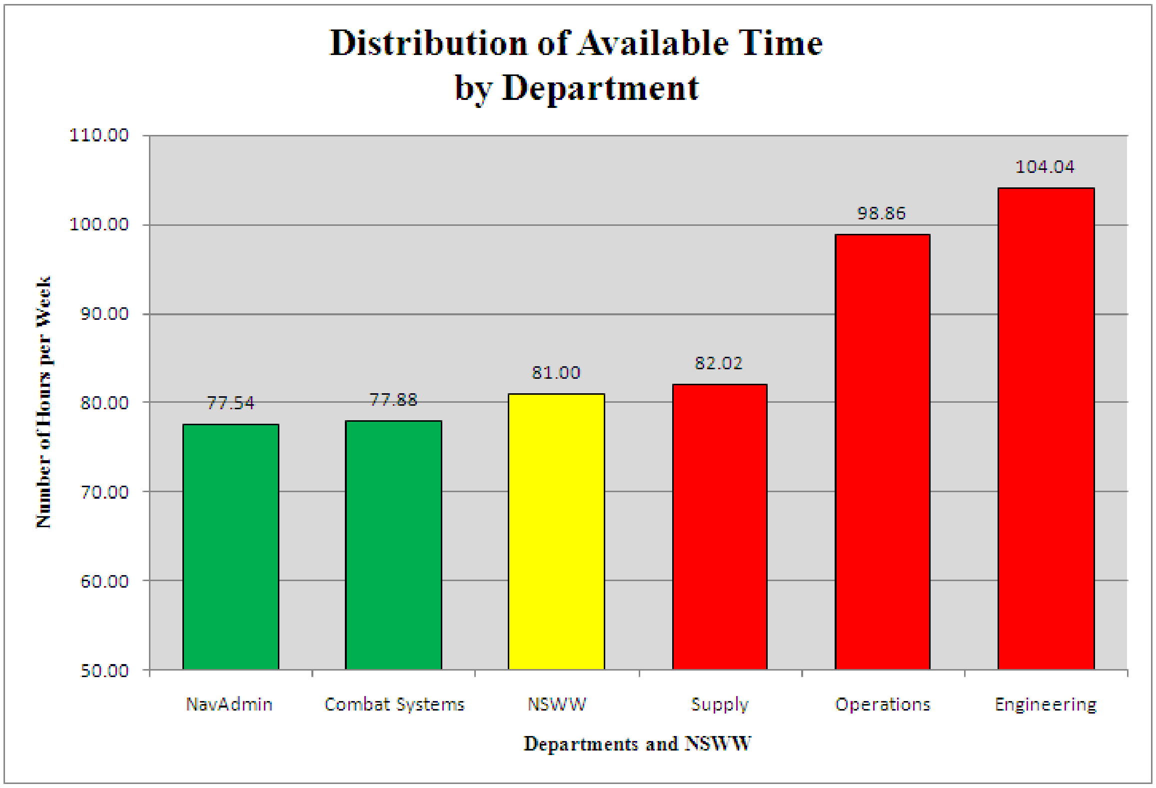


Figure 13. Distribution of Available Time by Department

Figure 14 illustrates a summary of Available Time for the Engineering Department and Figure 15 illustrates the differences in hours for the Engineering Department compared to the NSWW model. The Engineering Department averaged almost three additional hours of maintenance per day. However, the Engineering Department trained 0.27 fewer hours per day than the NSWW model. In reference to service diversion (meetings), the Engineering Department allotted 1.87 hours per day more than the NSWW model. The Engineering Department stood watch 1.14 fewer hours per day than allotted for in the NSWW model. The Engineering Department slept 2.18 hours less per day than allotted for by the NSWW model. Messing by 0.84 hours and personal time by 0.27 hours per day were fewer than allotted for by the NSWW model.

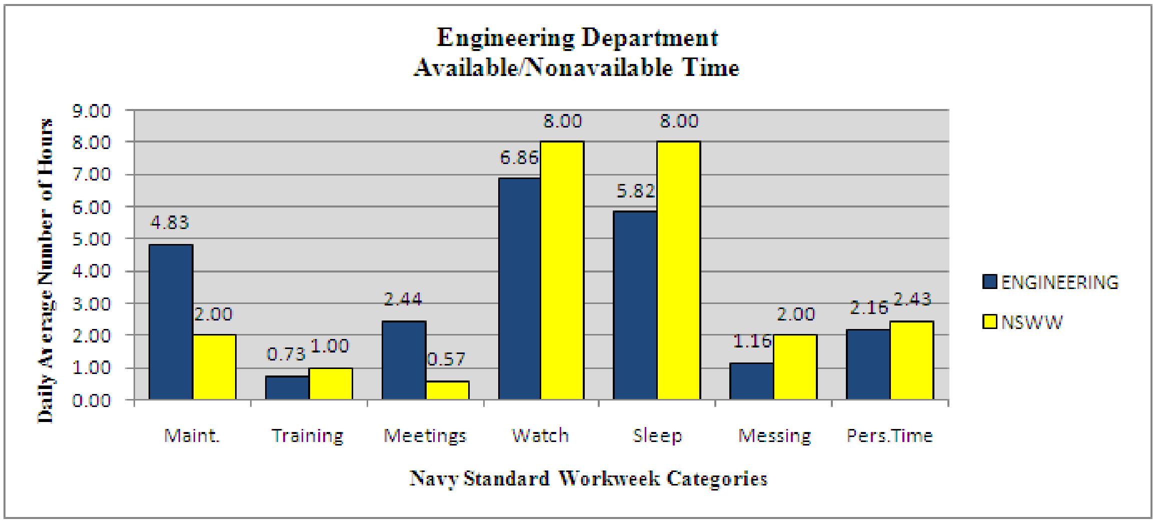


Figure 14. Engineering Department Available/Nonavailable Time

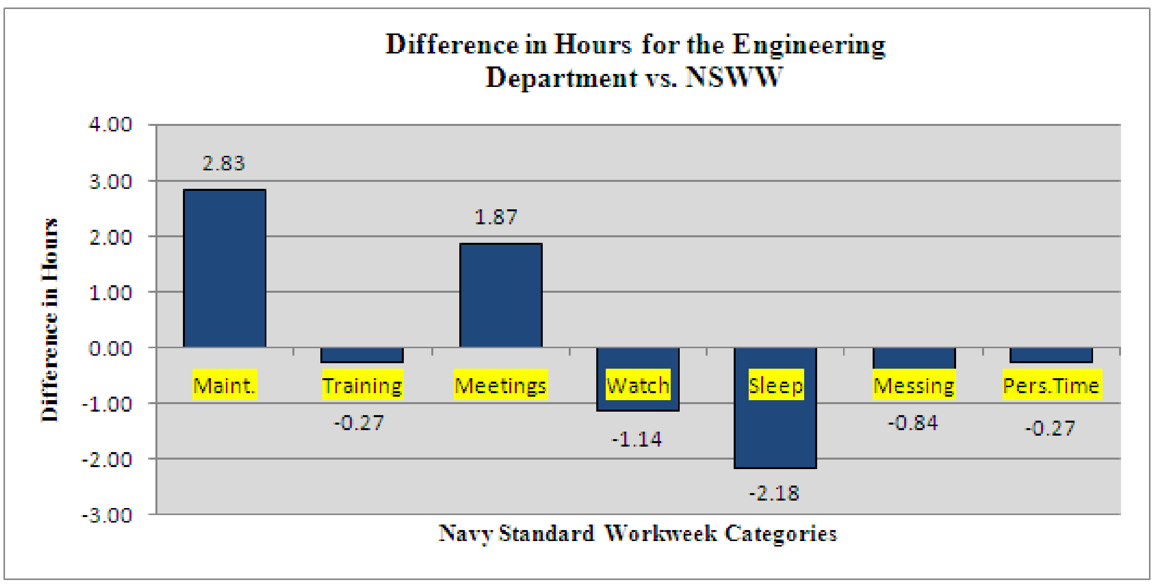


Figure 15. Difference in Hours for the Engineering Department versus the NSWW Model

Figure 16 summarizes Available Time for the Operations Department and Figure 17 illustrates the differences in hours for the Operations Department compared to the NSWW model. The Operations Department averaged more than 3.22 hours of additional time conducting maintenance per day. The Operations Department trained 0.81 hours less per day than provided by the NSWW model. With respect to service diversion, the Operations Department exceeded the one hour set forth in the NSWW model by 0.13 hours. The Operations Department watchstanders stood watch 0.95 hours less per day than the NSWW model. The Operations Department slept 1.36 hours less per day than that allotted for by the NSWW model. Messing per day was 1.17 hours fewer than allotted by the NSWW, while personal time (0.94 hours) exceeded the allotment of NSWW model.

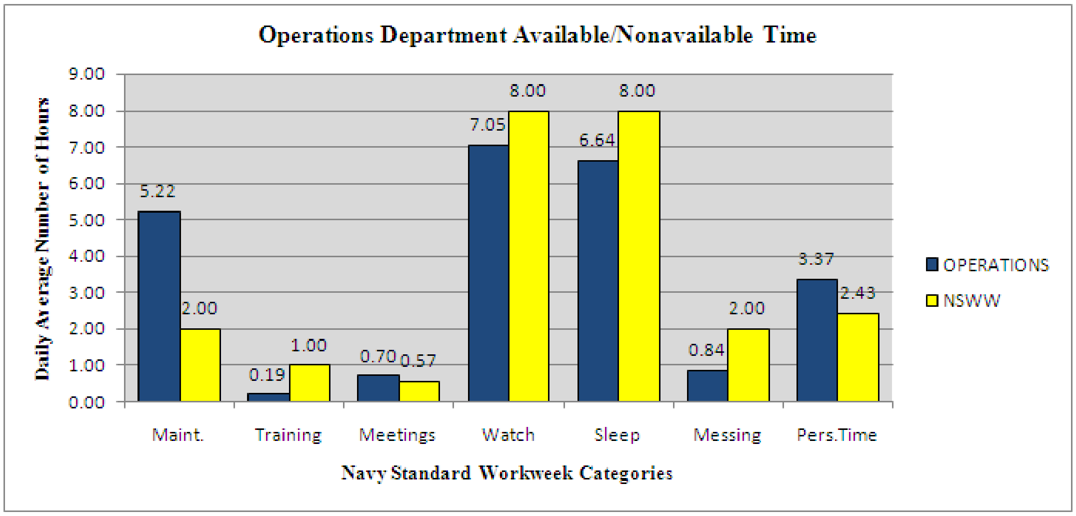


Figure 16. Operations Department Available/Nonavailable Time

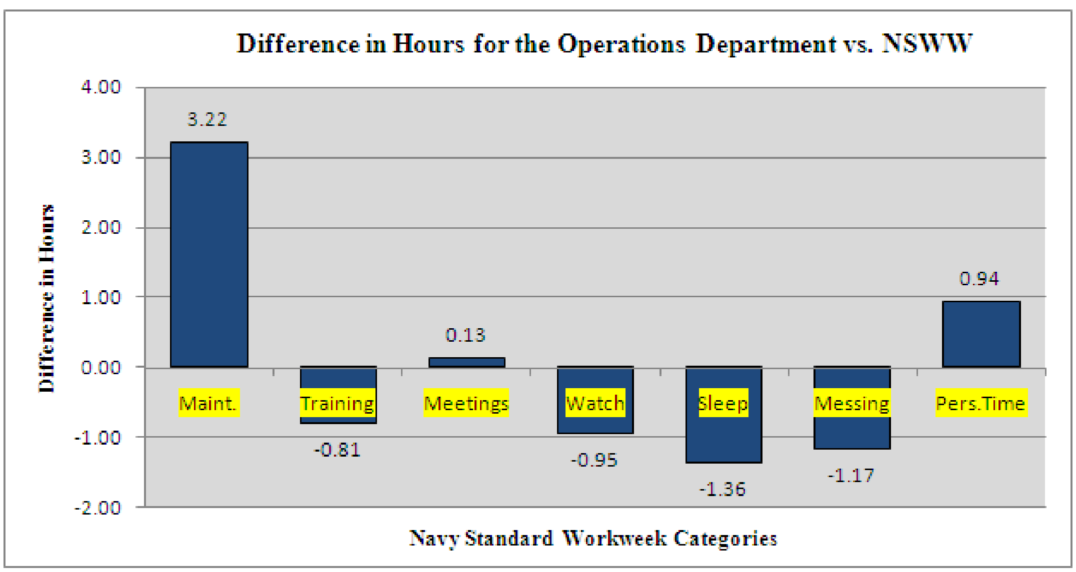


Figure 17. Difference in Hours for the Operations Department Department versus the NSWW Model

Figure 18 illustrates a summary of Available Time for the Combat Systems Department and Figure 19 illustrates a difference in hours for the Combat Systems Department compared to the NSWW model. The Combat Systems Department averaged 2.57 hours of additional time conducting maintenance per day. The Combat Systems Department trained consistently less (0.84 hours) per day than in the NSWW model. With respect to service diversion, the Combat Systems Department exceeded the allotted time by 0.92 hours per day. The Combat Systems Department watchstanders stood watch 3.59 hours per day less than in the NSWW model. Combat Systems Department, per day, slept 1.38 hours less than the NSWW model. The Combat Systems Department spent 0.81 fewer hours per day messing than the NSWW model alloted. Conversely, the Combat Systems Department's personal time exceeded the allotted time per day set forth in the NSWW by 3.13 hours.

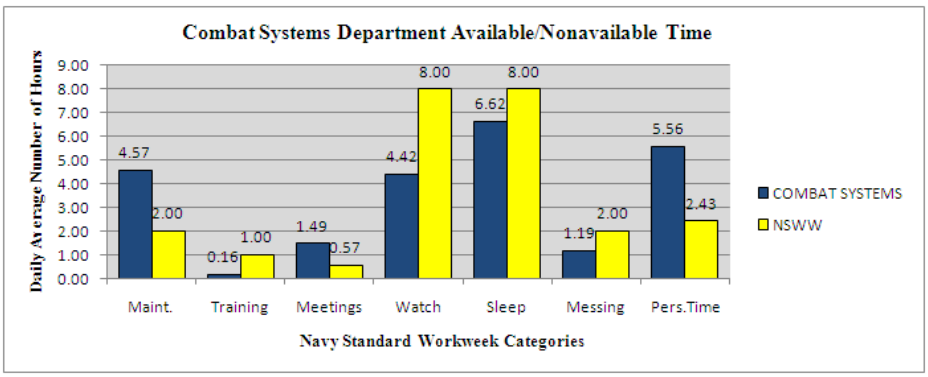


Figure 18. Combat Systems Department Available/Nonavailable Time

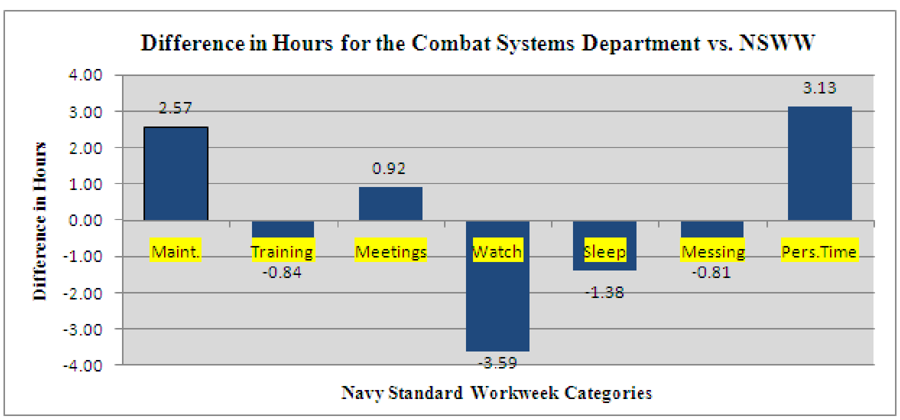


Figure 19. Difference in Hours for the Combat Systems Department versus the NSWW Model

Figure 20 illustrates Available Time for the Supply Department and Figure 21 illustrates a difference in hours for the Supply Department compared to the NSWW model. Supply Department participants, on average per day, conducted 3.15 hours more maintenance than allotted for by the NSWW model. The Supply Department trained 0.65 fewer hours per day than in the NSWW model. With respect to service diversion, the Supply Department spent 0.15 hours less than the time set forth in the NSWW model per day. The Supply Department stood watch 2.20 hours less per day than allotted for by the NSWW model. The Supply Department participants slept 0.29 hours more per day than allotted for in the NSWW model. The Supply Department spent 1.27 fewer hours messing per day than allotted for by the NSWW model. The Supply Department's self-reported personal time was 0.84 hours more than in the NSWW model.

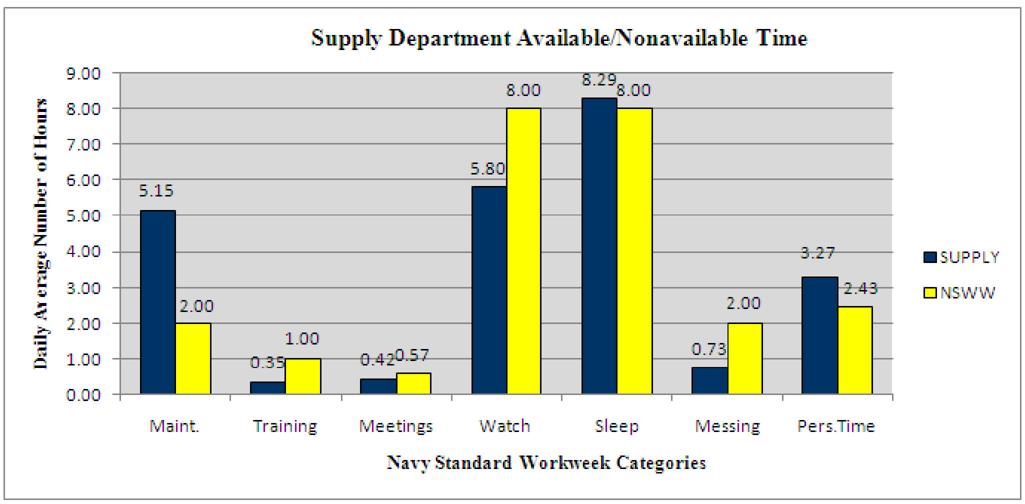


Figure 20. Supply Department Available/Nonavailable Time

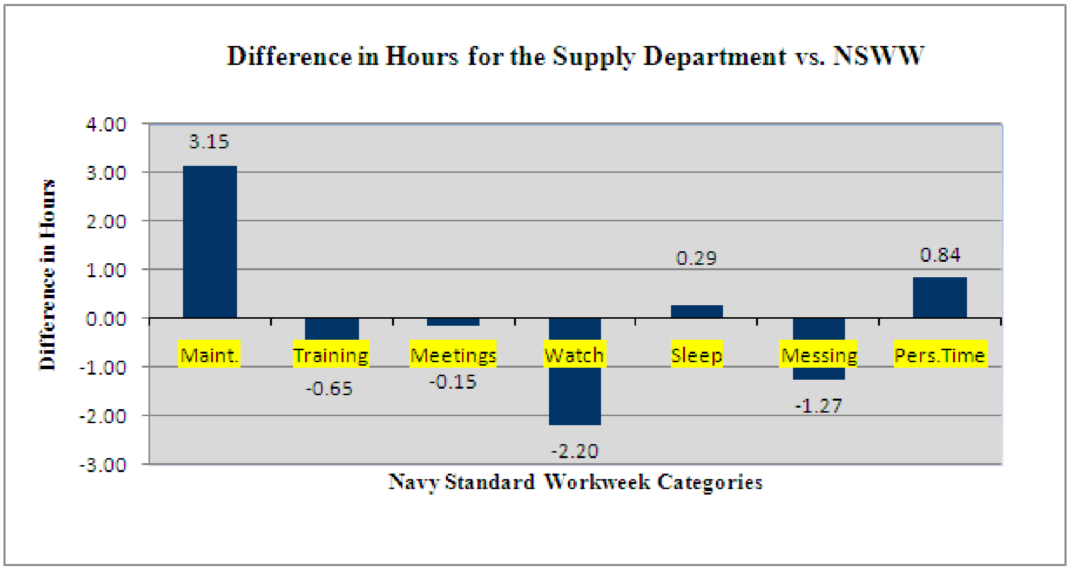


Figure 21. Difference in Hours for the Supply Department versus the NSWW Model

Figure 22 summarizes Available Time for the NavAdmin Department and Figure 23 illustrates the difference in hours for the NavAdmin Department compared to the NSWW model. The NavAdmin Department conducted maintenance 3.93 hours more per day than in the NSWW model. NavAdmin Department participants trained 0.82 fewer hours per day than in the NSWW model. In respect to service diversion, the NavAdmin Department exceeded the time allotted by the NSWW by 2.76 hours per day. The NavAdmin Department stood watch 6.36 hours less per day than the NSWW model allotted. In reference to sleep, the NavAdmin Department slept 1.55 hours less per day than in the NSWW model. On average per day, the NavAdmin Department spent 0.82 fewer hours messing than in the NSWW model. The NavAdmin Department participants exceeded personal time by 2.86 hours per day.

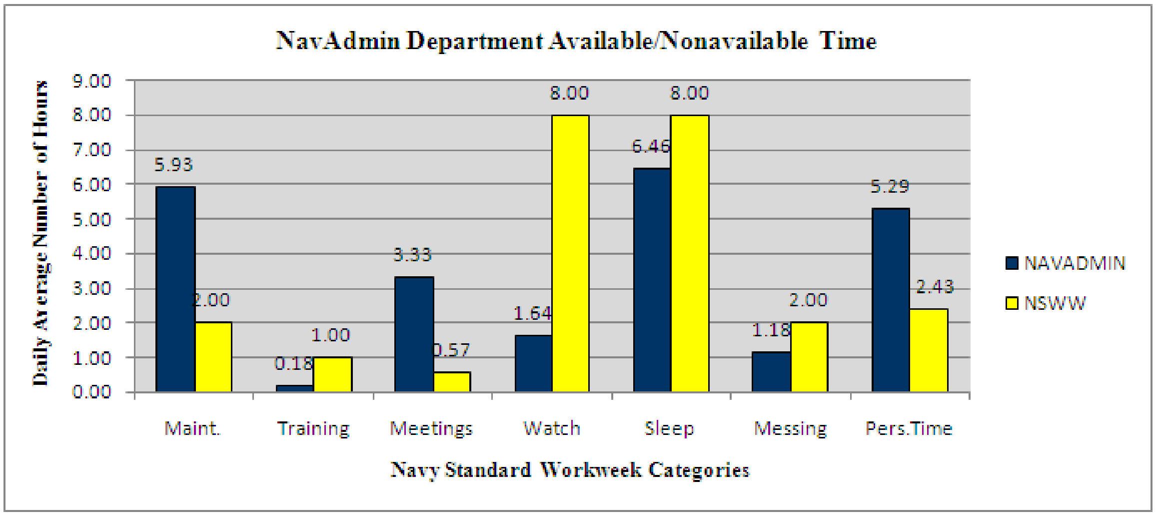


Figure 22. NavAdmin Department Available/Nonavailable Time

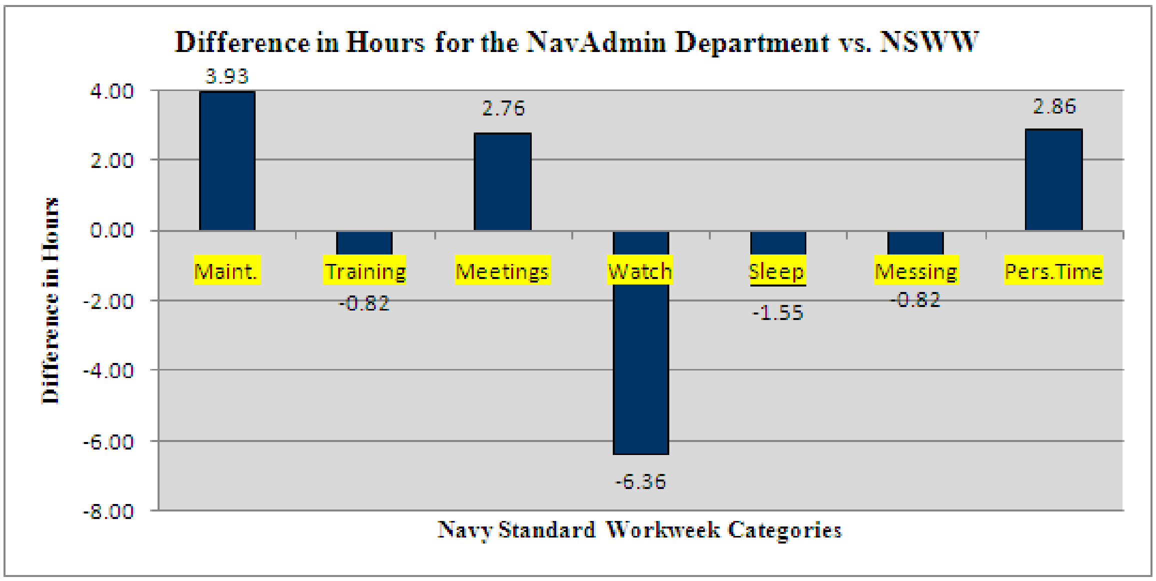


Figure 23. Difference in Hours for the NavAdmin Department versus the NSWW Model

The Combat Systems Department showed the greatest deviation from the NSWW in training and personal time; the NavAdmin Department in maintenance, service diversion and watch; the Engineering Department in sleep; and the Supply Department in messing.

According to the NSWW model, Sailors are allotted eight hours a day to sleep. Figure 24 indicates that, on average, all departments' personnel, excluding supply, slept less than eight hours per day. On average, the Engineering Department slept over two hours less per day than the NSWW model. The Operations, Combat Systems Department, and NavAdmin, on average, slept nearly two hours less per day than the NSWW model allotted.

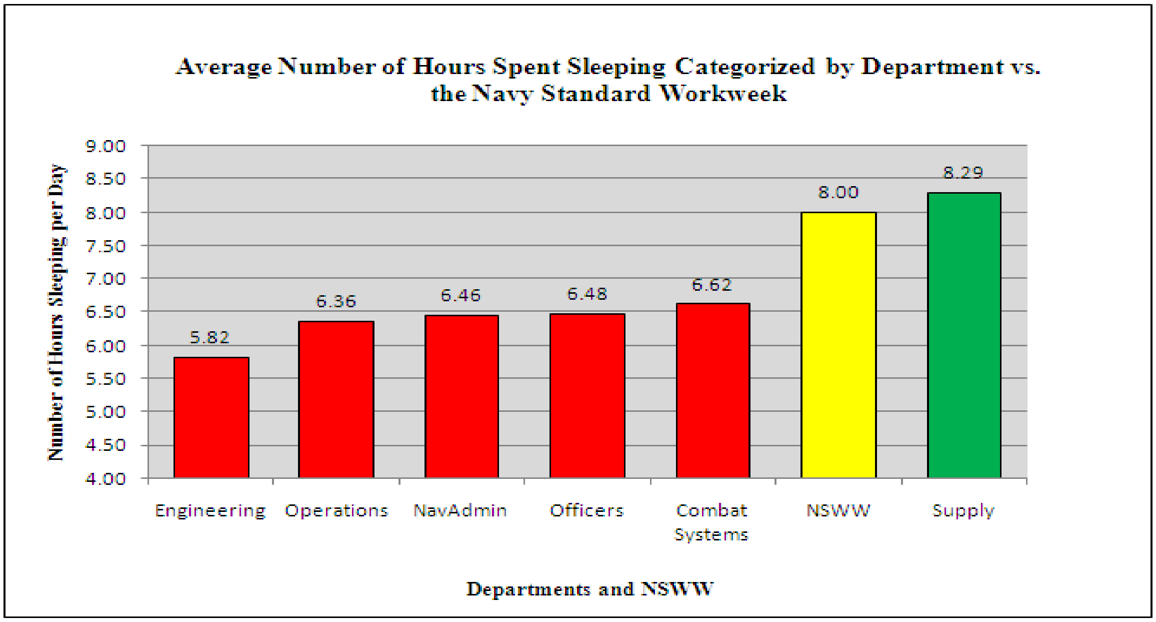


Figure 24. Average Number of Hours Spent Sleeping Categorized by Department versus the Navy Standard Workweek

The relationship between seniority and sleep was also examined by calculating the participants' average sleep per day by pay grade. Figure 25 shows the average number of hours spent sleeping, categorized by pay grade of participants within this study, compared to the NSWW model. The results indicate that the higher-ranked Sailors, with the exception of E-4s, self-reported sleeping fewer hours than those of lower rank.

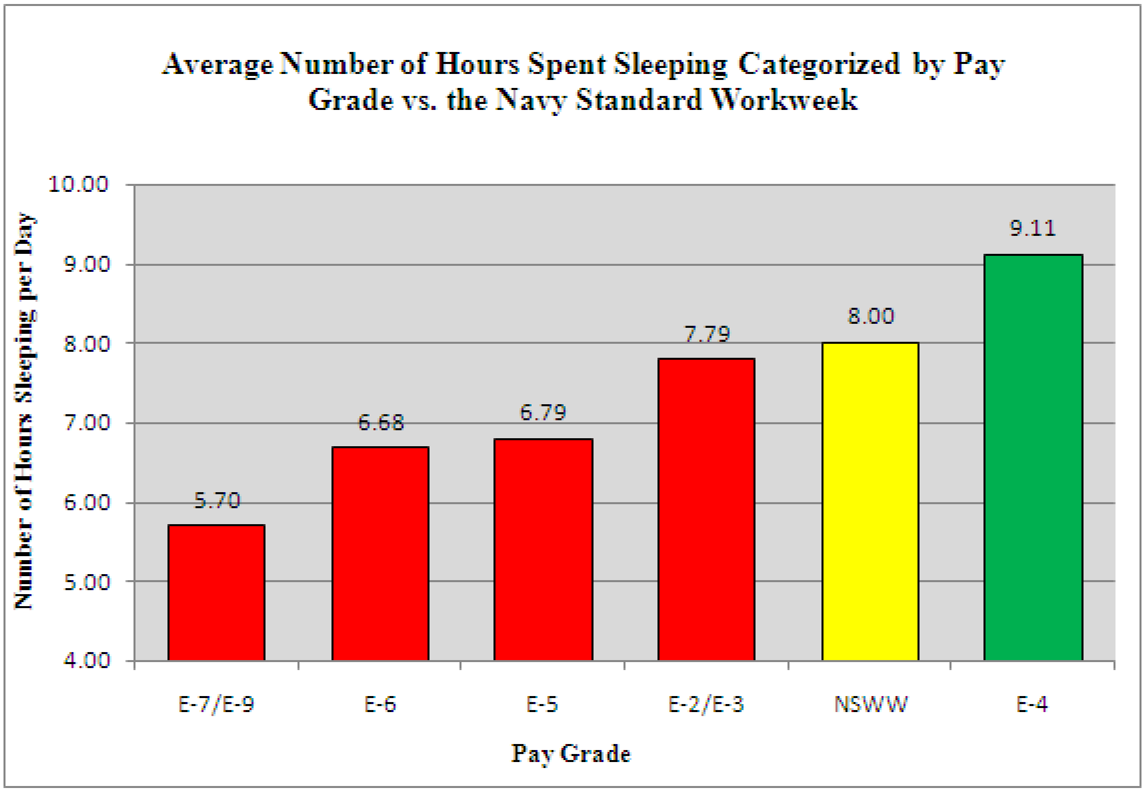


Figure 25. Average Number of Hours Spent Sleeping Categorized by Pay Grade versus the Navy Standard Workweek

D. FAST ANALYSIS

FAST was used to predict Sailors' effectiveness while standing watch and to determine each Sailor's sleep efficiency. The time frame covered by the FAST analysis is from May 11, 2009 at 0800 PST through June 5, 2009 at 0800 PST. Figures 26-28 are graphical representations of Sailors' predicted effectiveness compared to BAE.

Figure 26 illustrates the worst-case analysis of Sailor's predicted effectiveness—Operations Department's Participant 5318, who had an overall effectiveness of 68.76% during the entire study. In one particular case, while standing watch, Participant 5318's predicted effectiveness while awake was 26%. Essentially, during the 48 hours preceding the critical event (standing watch) on May 19, 2009, this participant reported sleeping fewer than 5 hours. However, it is worth noting that Participant 5318's predicted effectiveness increased to 90% following three days of consecutive sleep during the ship's brief return to homeport for refueling. Once the ship returned to sea, following its homeport visit, Participant 5318's sleep time decreased and his predicted effectiveness decreased from 90% to 48%, following five days of being underway.

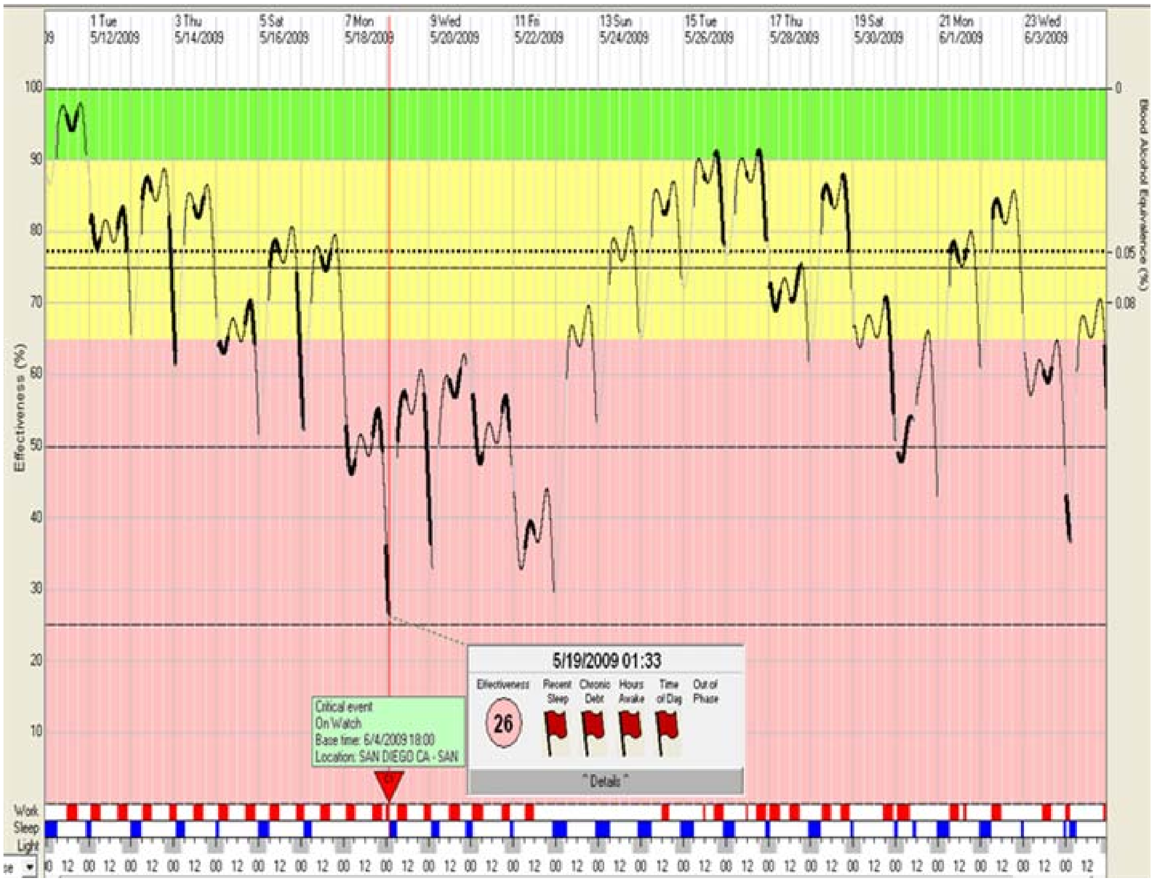


Figure 26. Participant 5318's FAST Analysis

An average case, with respect to predicted effectiveness, is Participant 6188 in the Combat Systems Department. Participant 6188's overall effectiveness while awake was 82.94%. It is worth noting that Participant 6188's predicted effectiveness increased to 89% following three consecutive days of sleep during the ship's return to homeport. In one particular case, while standing watch at 2318 hours, Participant 6188's predicted effectiveness was 43%, which is a BAE level well below 0.08. During the previous 24 hours of standing watch on May 28, 2009, this participant reportedly slept less than three hours. See Figure 27 for a graphical representation of Participant 6188's FAST analysis and average sleep.

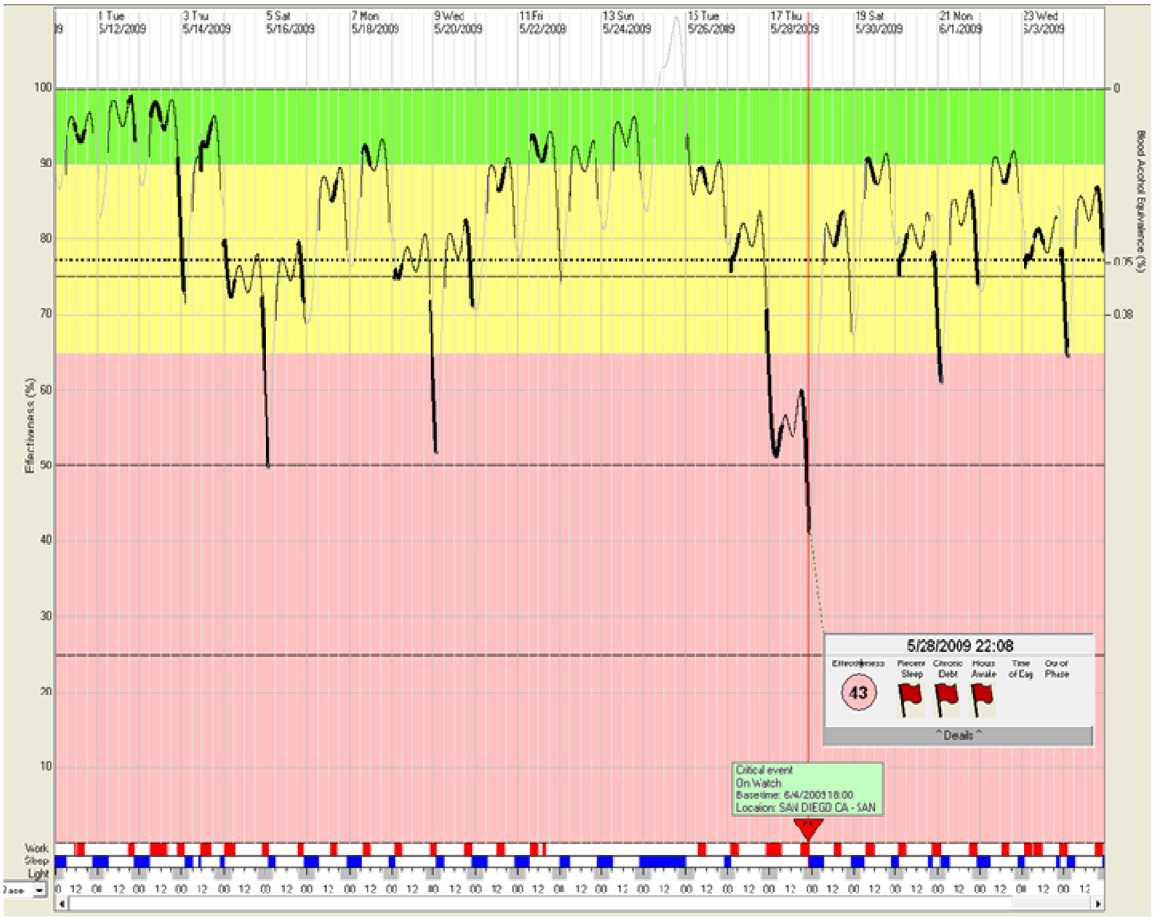


Figure 27. Participant 6188's FAST Analysis

Figure 28 illustrates an optimal-case scenario with respect to predicted effectiveness—Participant 6366 of the Supply Department, whose overall effectiveness while awake was 96.54%. However, keep in mind that this participant did not stand watch as frequently as other participants. In one particular case, while standing watch at 1059 hours, Participant 6366's predicted effectiveness was 99%. During the previous 24 hours, this participant reportedly slept 11 hours.

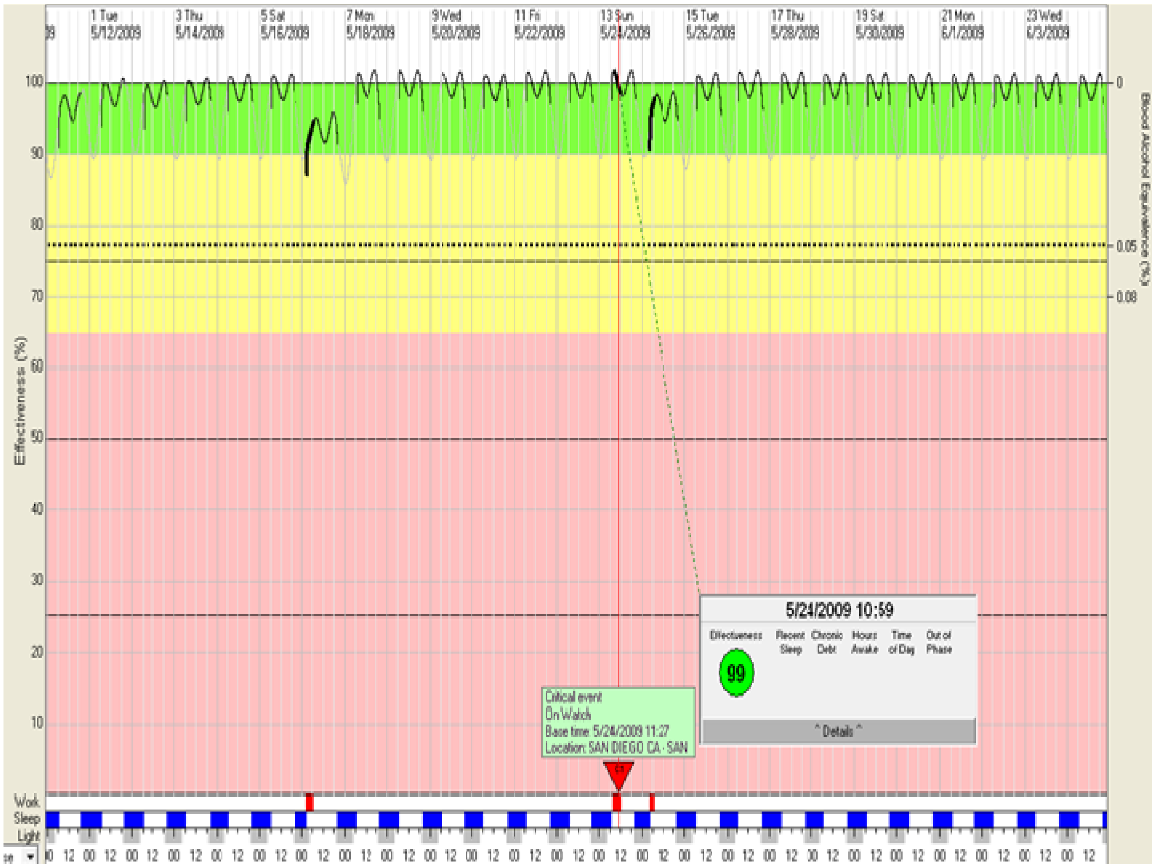


Figure 28. Participant 6366's FAST Analysis

The average overall predicted effectiveness for all participants was 84.21%, whereas sleep efficiency calculated using actigraphy for all participants was 80.78%. See Appendix G for each participant's FAST analysis, Appendix H for a complete list of participants' average sleep efficiency, and Appendix I for a complete list of participants' overall average performance effectiveness.

V. DISCUSSION

As the United States Navy continues to work toward its goal of maintaining an efficient and ever-ready fighting force, adequate measures must be taken to ensure that the tools used to assess manpower requirements onboard frigates and other vessels adequately reflects the physiological needs of their crews (Miller & Firehammer, 2007). There is concern that the current manpower requirements onboard U.S. Navy ships are not accurately reflected in the current NSWW model. This concern centers on the number of hours working and sleeping that today's Sailors receive in order to maintain their required state of readiness aboard ship, to be able to successfully carry out missions. This study was conducted because of concerns about the detrimental effects of fatigue on individual performance; in particular, decreasing alertness, slowing reaction time, decreased work effectiveness and efficiency, and decreased vigilance (Mohler, 1996; Dinges, 1995; National Sleep Foundation, 2006). Previous studies indicate that the NSWW does not accurately reflect current Sailors' work/rest patterns (Miller et al., 2007, Haynes, 2007; Mason, 2009). The purpose of this research was to (1) determine the actual work/rest patterns of Sailors aboard U.S. Navy frigates; (2) determine if the NSWW (afloat) accurately estimates the total number of hours Sailors worked each week aboard U.S. Navy frigates; (3) determine if work/rest patterns differed among departments aboard U.S. Navy frigates; and (4) recommend whether the NSWW needs to be revised to more accurately reflect Sailors' actual standard workweek by department. The findings from this study add to a growing body of literature that supports research that the current NSWW model does not accurately reflect Sailors' work/rest patterns aboard various Navy ships. The details and implications of these findings are discussed below.

A. ACTUAL WORK/REST PATTERNS OF SAILORS

When considering the actual work/rest patterns of Sailors aboard U.S. Navy frigates, the results from this study indicate that participants onboard the RENTZ, excluding officers, on a weekly average, worked 20.24 more hours than allotted in the

NSWW model, and slept 8.98 fewer hours than recommended by the NSWW. This means that participants worked 2.89 more hours per day and slept 1.28 fewer hours than allotted by the current NSWW model. Overall, 61% of participants' Available Time (on duty−maintenance, watch, training, and service diversion) exceeded the time allotted for in the NSWW model of 81 hours per week afloat. These findings are consistent with previous studies examining the work/rest patterns of Sailors aboard U.S. Navy cruisers and destroyers (Haynes, 2007; Mason, 2009). Haynes (2007) found that Sailors aboard U.S. Navy destroyers worked 16.95 hours per week, or 2.42 hours per day, more than allotted by the NSWW and slept fewer hours per week. In all, 84% of participants exceeded the 81 hours of Available Time allotted for in the NSWW (Haynes 2007). Mason (2009) found that Sailors aboard U.S. Navy cruisers worked 9.90 hours per week, or 1.41 hours per day more than set forth in the NSWW, and slept approximately 6 hours less per week, or 0.86 hours less per day than set forth in the NSWW. In all, 85% of participants in Mason's study exceeded the 81 hours of Available Time allotted by the NSWW. The additional hours Sailors work in excess of those being allotted for by the current NSWW are being reallocated from Nonavailable Time. Overall, Sailors are being overworked and getting inadequate sleep. Despite evidence showing that current crews are already working in excess of the time allotted in the current NSWW, the Navy is continuing to build more ships, while decreasing crew sizes. A number of studies have found that reducing personnel on ships and working longer hours are primary factors in causing fatigue (Brown, 1989; Smith et al., 2001; Miller, 2005; Houtman et al., 2005; Arendt et al., 2006). Decisions to reduce crew size are currently being justified by the increasing availability of automated systems aboard Navy vessels. These decisions do not take into consideration literature showing automated systems, combined with fatigued operators, inadvertently increases unpredictability in performance (Dinges, 1995). Fatigue slows reaction times of operators interacting with automated systems. Dinges notes that the physical reaction time of a fatigued operator will be slowed by 5% to as much as 25% (1995). What may seem like a justification for reducing crew sizes aboard ships may instead increase the likelihood of mishaps aboard Navy vessels in the future. Additionally, the combination of smaller crew sizes, over-worked Sailors, and Sailors obtaining inadequate sleep may have broader-reaching effects that undermine other Navy operations. For example, these factors can impact the Navy's ability to retain highly skilled Sailors and the ability of Sailors to properly care for their ship (i.e., failing Board of Inspections and Survey) (Smith et al., 2001; Ewing, 2009).

B. VARIATION BY DEPARTMENT AND SHIP TYPE

By department, the distribution of Available Time varied the most among hours allotted for watch, sleep, maintenance, and training. In particular, all participants in the Engineering, Operations, and Supply Department exceeded the weekly Available Time of 81 hours set forth by the NSWW, whereas those in the Combat Systems and NavAdmin Department did not. These findings illustrate the need to consider how work and rest patterns differ across departments aboard Navy vessels. Some departments had small deviations from the NSWW, whereas other departments varied greatly. The difference for departments, on average per day, varied from 2.83 to 3.93 hours in maintenance, –0.84 to –0.27 hours in training, –0.15 to 2.76 hours in service diversion, –6.36 to –0.95 hours in watch, –2.18 to 0.29 hours in sleep, –1.17 hours to –0.81 hours in messing, and –0.27 to 3.13 hours in personal time. In his study, Haynes (2007) found that the Combat Systems Department conducted the most maintenance, while the Operations Department slept the least on U.S. Navy destroyers. Similarly, Mason (2009) found that the Combat Systems Department conducted the most maintenance, while the Operations Department slept the least aboard U.S. Navy cruisers. However, in the current research, the NavAdmin Department was found to have conducted the most maintenance, while the Engineering Department slept the least.

With respect to ship type, Haynes (2007), Mason (2009), and the current study indicated that Sailors were overworked and obtained inadequate sleep. While these studies were conducted on three different types of Navy vessels (cruisers, destroyers, and frigates), they all find that the NSWW does not reflect Sailors' actual work/rest patterns on any of these ship types. These combined results suggest Sailors' work/rest patterns may be dependent upon the department and ship type. Although these three studies (Haynes, 2007; Mason, 2009; and the current study) were consistent in their finding that, overall, Sailors' activities are not accurately reflected by the NSSW, still future studies should remain vigilant about potential variations in work/rest patterns by ship type. Future studies should consider how workloads across departments may affect overall work/rest patterns found onboard Navy vessels. Findings show that variations in work/rest patterns by ship's department and ship type determines Sailors' Available and Nonavailable Time; therefore, a future recommendation suggests that a standardized NSWW model take into consideration variations by ship type and department.

C. HOW PAY GRADE AFFECTS SLEEP

A significant finding in this study was the variation of sleep patterns by rank among participants. With the exception of E-4s, higher-ranking Sailors' self-reports and actigraphy (the monitored reports of Sailors' rest and activity cycle) show that they receive less sleep than lower-ranking Sailors. As Sailors advance in seniority, the requirements to exercise problem-solving and decision-making skills increase, thus, making it even more important for those higher-ranking Sailors to obtain adequate sleep. Higher-ranking Sailors who neglect their sleep could potentially place the ship and its crew in harm's way, leading to catastrophic operational failure (Shay, 1998). In short, lack of sleep may lead to disastrous leadership decisions (Belenky, 1997; Shay, 1998).

D. PREDICTED PERFORMANCE EFFECTIVENESS

The average predicted effectiveness of participants in this study from May 11, 2009 to June 4, 2009, including officers, was 84.21%. Predicted effectiveness refers to an individual's predicted cognitive performance level, especially vigilance, based upon sleep, sleep inertia, and circadian rhythm. This percentage is acceptable considering a fully compliant Sailor has a predicted effectiveness level of 83.25% (Haynes, 2007). Still, 41% of the participants had a predicted effectiveness level below 83.25%. Thirty-three percent of the Sailors in this study had a predicted effectiveness level of 80% or lower, suggesting that these Sailors were chronically fatigued. Haynes (2007) found similar results, as less than half of the Sailors (41%) in his study had a predicted effectiveness level equal to or above 83.25%. The majority (56%) of his participants had a predicted effectiveness level of 80% or lower, suggesting that a majority of Sailors were chronically fatigued and not operating at an optimal level. The finding, which suggests that among a given subsample of Sailors aboard Navy destroyers, less than half are performance-ready is alarming, based upon literature stating that as fatigue develops and worsens, so do mircosleeps and performance lapses (Dinges, 1995). The data in this current study and others suggest that the performance of almost half the Sailors aboard Navy vessels is unreliable and unpredictable. The dangers of having a fatigued workforce leads to increased anxiety, decreased work effectiveness and efficiency, decreased vigilance, increased irritability, decreased attention span, increased susceptibility to error, and increased mishaps (Mohler, 1966; Dinges, 1995; National Sleep Foundation, 2006). These factors are not desirable characteristics of Sailors who are in a high-risk operational environment, where they are required to be constantly vigilant. Furthermore, long-term fatigue can become a medical cost issue to the Navy, as continuous exposure to fatigue may lead to clinical illnesses such as hypertension, peptic ulcer, migrant headache, and cardiovascular disease (Mohler, 1966; Knutsson, 2000).

E. THE IMPORTANCE OF SLEEP EFFICIENCY

Sleep efficiency is an objective measurement, stated in percentage, of the amount of time spent asleep in bed (Medical India Networking for Health, 2009). Sleep efficiency greater than 80% is normal, whereas sleep efficiency of less than 80% indicates insomnia. While the overall sleep efficiency for participants in this research was 80.78%, FAST results from this study indicated that 40% of the participants' predicted sleep efficiency level was less than 80%. Sleep efficiency is an indication of the quality of the sleep that individuals are receiving and is directly linked to an individual's predicted performance. There is a significant difference between the "quantity" of sleep and the "quality" of sleep that an individual receives. While 8 hours of logged sleep seems to quantitatively fulfill Sailors' sleep requirements, it can be rationally assumed that a Sailor's predicted performance after receiving 8 hours of continuous, uninterrupted sleep will differ significantly from that of a Sailor who also logs 8 hours of noncontinuous, interrupted sleep in nonoptimal conditions (Miller et al., 2007). Researchers suggests that higher sleep quality for Sailors can be obtained by eliminating sleep disruption in berthing areas by reducing the ringing of bells, limiting the passing of words, limiting executive officers' berthing inspections while Sailors are sleeping, masking machinery noise from machinery compartments adjacent to berthing, improving air quality, and reducing ambient light (Miller et al., 2007).

F. LIMITATIONS

Notwithstanding the important contributions of this study to the literature evaluating the current NSSW model, there are important methodological and practical considerations that should be taken into account for future studies wishing to expand upon these findings. The limitations confine the extent to which the conclusions presented here can be inferred to larger populations. These limitations include problems with self-reports, sample size, and dropout rate. It is important to note that some allowance is made for human error, in that participants do not accurately estimate times for various activities. Accordingly, the researcher made certain inferences of how time was allocated by comparing Sailors' self-reports against data from their actigraphy. In addition, the forms that participants used to log data did not ask participants to evaluate the quality of sleep that they received. Consequently, quantitative assessments about total hours of sleep, sleep efficiency, and performance effectiveness do not take into consideration qualitative evaluations of these measures. It is important to factor in the small sample size of participants (n=24) who successfully completed this study for the overall research and within each department. Keeping this in mind, no statistical inferences can be made to the entire population of Sailors aboard U.S. Navy frigates. Another factor to note in this study is the dropout rate, which for this study was almost 50%. Such a high dropout rate is of particular importance to this study, as there may be a significant difference in the workloads of those participants who completed the study from those that did not. The process of logging and keeping track of Available Time and Nonavailable Time is a time-consuming one, potentially suggesting that those who were able to complete this study may differ in the amount of Available Time from those who were unable to do so. Those participants who were unable to complete the study, representing almost half of the starting volunteers, may have sleep efficiency, predicted effectiveness levels, and work/rest patterns significantly different than those who successfully completed data collection. Taken into consideration, the missing data from these dropped-out participants might have significantly changed the overall averages presented in this study.

Future studies should consider methodological improvements in observing and collecting data reflecting the work/rest patterns of Sailors that supplement Sailors' self-reports and actigraphy reports. Despite these limitations, the NSWW is a critical driving factor in determining manning aboard ships. Thus, all available measures should be utilized in ensuring that the NSWW more accurately reflects Sailors' actual work/rest patterns afloat.

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VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The NSWW model is used as a tool to assist NAVMAC in determining manpower aboard ships and to assist leaders in properly scheduling Sailors' work and rest schedules. In order for the model to be effective, leaders must be familiar with the model, use the model as a tool to schedule Sailors' workweeks, and ensure that the model accurately reflects Sailors' actual work and rest patterns. The NSWW was last revised in 2001, which led to an increase in productive work (workload) per Sailor; however, the manpower aboard ships did not increase.

Today's Sailors not only prepare for war, but are also called on to conduct Military Operations Other Than War (MOOTW). MOOTW includes, but is not limited to, supporting efforts in resolving conflicts, promoting peace, and assisting in humanitarian efforts and crises, both international and domestic. Consequently, these additional requirements demand additional time from Sailors. The new challenges of today's Navy require more out of Sailors than in the past. The current NSWW model does not reflect these additional requirements, nor does it take into consideration a Sailor's physiological requirements for adequate sleep and rest, as suggested by some researchers (Miller & Firehammer, 2007). The data from this study showed that the NSWW does not accurately reflect Sailors' activities, such as that Sailors work more hours than allotted and obtain inadequate amounts of sleep compared to those amounts set forth in the current NSWW. As a result, almost half of Sailors participating in this study fell below acceptable predicted effectiveness levels and had poor sleep efficiency. In addition, this study found that higher-ranking Sailors slept fewer hours than lower-ranking Sailors. Lastly, the distribution of Available Time varied by department.

The results of this study indicate that the NSWW does not accurately reflect the activities of today's Sailors. Similar results were found on U.S. Navy cruisers and destroyers during studies by Haynes (2007) and Mason (2009). Navy leaders can use information from the FAST analysis to assistance in scheduling Sailors' work/rest patterns and to drive home the fact that performance is linked to sleep. Without adequate sleep, Sailors' performance will be substandard. This study concludes that the NSWW model should be revisited to determine if it accurately reflects the workplace of today's Sailors, who are facing additional challenges and requirements afloat.

The daily operational environment that Sailors encounter while underway, is both physically and mentally demanding. Leaders must ensure that Sailors are fully prepared to carry out their duties and assignments during peace and war. To add to this already demanding situation, overworked and sleep-deprived Sailors will lead to a fatigued workforce. It is important that fatigue onboard ships not be dismissed nor thought of as a necessary evil or part of the Navy's culture. Fifty years of extensive scientific research documents the negative impact of lack of sleep and fatigue. While other remedies, such as changes in staffing, and educating personnel on the effects of fatigue, are instrumental in improving Sailor effectiveness aboard Navy vessels, the only proven remedy to recover from lack of sleep is sleep.

B. RECOMMENDATIONS

The key findings from this study showed that the NSWW does not accurately reflect Sailors' activities, since Sailors work more hours and obtain less sleep compared to those amounts set forth in the current NSWW. As a result, almost half of the Sailors participating in this study fell below acceptable predicted effectiveness levels. In addition, this study found that higher-ranking Sailors slept fewer hours than lower-ranking Sailors. Lastly, variation existed by departments in reference to the distribution of Available Time. Based upon these key findings, the following recommendations should be taken into consideration.

1. Recommendations for Future Studies

While the ship was underway, RENTZ was conducting military exercises; however, the conditions during the exercises were similar to, but not exactly, wartime conditions. As a result, it is highly recommended that researchers wishing to understand the actual work/rest patterns of Sailors repeat the study over a longer time span and in warlike conditions. The recommendation to conduct similar studies over a longer period of time, while in warlike conditions, is supported by various studies (Miller et al., 2007;

Haynes, 2007; Mason, 2009). The direct benefit of expanding the time frame of this study during warlike conditions is to arrive at more accurate estimates of Sailors' workloads in a wartime environment for the NSWW.

It is highly recommended that similar types of research be repeated using a larger sample of the populations (i.e., Sailors and ship type), including officers, aboard additional frigates and other vessel types (i.e., Littoral Combatant Ships and DDG1000 Zumwalt Class). The current study was conducted on one frigate, with a small sample size. It may be difficult to differentiate Sailors' activities that may be unique to one type of ship. Therefore, conducting this study on additional ship types will help to determine if ship types and accompanying departments have unique workloads (Miller et al., 2007). Additionally, conducting this type of study on the DDG1000 Zumwalt smartship, which is more automated, may determine how Sailors' work/rest patterns onboard a ship type whose crew size is reduced by 60%–70% compares to the NSWW.

Despite the fact that the NSWW does not include officers, based upon this study's results showing high-ranking Sailors sleeping fewer hours, particular attention should be focused on officers' sleep regimen. Higher-ranking Sailors, officers in particular, are responsible for leading Sailors, directing Sailors, and making effective decisions. A problem exists when key individuals in charge receive the least amount of sleep.

Research should be conducted in tandem with IMPRINT (Gunzelmann & Gluck, 2008). IMPRINT is a task network modeling tool used to set realistic system requirements based upon system design, and evaluate the capabilities of manpower and personnel, to effectively operate a system under various environmental stressors (e.g., fatigue). The tool allows cognitive effectiveness algorithms from SAFTE to be downloaded into IMPRINT software, allowing cognitive effectiveness predictions. IMPRINT output will allow researchers to develop human performance models to estimate manpower requirements for ship type and department. This tool can be used to complement FAST findings in reference to sleep efficiency and predicted performance, with regard to departmental workloads and even ship type.

Each department aboard a ship has varying requirements and responsibilities, and the NSWW should reflect these variations. Based upon Haynes (2007), Mason (2009), and this study, a departmental NSWW may need to be developed for each respective department and, possibly, each ship type. Haynes found that the Combat Systems Department conducted the most maintenance, while the Operations Department slept the least on U.S. Navy destroyers. Similarly, Mason found that the Combat Systems Department conducted the most maintenance, while the Operations Department slept the least aboard U.S. Navy cruisers. However, in the current research, it was found the NavAdmin Department conducted the most maintenance, while the Engineering Department slept the least. As a result, the NSWW model may not be able to be standardized across all ships and departments.

2. Recommendations for the United States Navy

It is recommended that Sailors in all pay grades be educated on the importance of sleep and the importance of scheduling Sailors' work/rest schedules to minimize the likelihood of Sailors' circadian desynchronization, sleep deprivation, and fatigue (i.e., required General Military Training). Educating Sailors about fatigue and how it impacts human performance may help the Navy guard against and recognize the onset of fatigue (Dinges, 1995). Shay (1998) stated that legitimate self-care (i.e., obtaining adequate sleep) should be taught within the officer corps itself. This suggests that leaders must be educated on self-care so that junior Sailors will emulate their leaders. Some researchers also believe that educating Sailors on the signs of fatigue might make them more alert to its effects, realizing that an adequate amount of sleep is the best solution for countering fatigue.

Accordingly, from findings of this study and other similar studies, it is recommended that the NSWW be revisited to determine if the current model is a good fit for the additional challenges and requirements facing today's Sailors while afloat. Miller et al. (2007) suggest that adjusting the NSWW to allow for 9 hours of sleep per day will reduce the Navy's productive workweek by 7 hours per week. Doing so will increase the afloat staffing requirement and more accurately reflect Sailors' ability to sustain combat capability beyond a couple of days (Miller et al., 2007), as required in Conditions I and II.

3. Recommendations for Follow-On Study

Those planning to conduct a follow-on study of this topic should keep in mind that buy-in from the Commanding Officer, Executive Officer, and Command Master Chief is vital. Buy-in from ship leaders will drive home the importance of the study and Sailors will be more apt to volunteer. The researcher may desire to go one step further and obtain the Commanding Officer superior's buy-in.

Some problems that were encountered during the study include: (1) what department Food Service Attendants (FSA) fall under; (2) participants losing their Daily Activity Logs; (3) participants not logging their sleep quality as excellent, good, or poor; (4) accountability for watches, and (5) participants departing ship to attend school. A participant can be a Yeoman in the NavAdmin Department; however, during their time as an FSA, the Sailor will fall under the Supply Department, not the NavAdmin Department. Numerous participants lost their Daily Activity Log. To overcome this problem, the researcher should provide the ship point of contact with additional hard copies and an electronic copy of Daily Activity Logs to resupply the ones that were lost. All participants' sleep was recorded as excellent, thus impacting predicted sleep efficiency. By Sailors indicating all sleep episodes as excellent, the predicted sleep efficiency may be overstated. Researchers should tell participants to indicate sleep quality on their Daily Activity Logs. The Researcher and Point of Contact aboard ship should maintain a list documenting which Sailors have a watch, to maintain accountability. Lastly, it should be ensured that participants will remain on the ship for the duration of the study.

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APPENDIX A. PARTICIPANT CONSENT FORM

Informed Consent Form

Introduction. You are invited to participate in a research study entitled A COMPARATIVE ANALYSIS BETWEEN THE NAVY STANDARD WORKWEEK AND THE WORK/REST PATTERNS OF SAILORS ABOARD U.S. NAVY FRIGRATES being conducted by the Naval Postgraduate School Operations Research Department.

Procedures. You will be asked to wear a wristwatch data collection device continuously, to include normally scheduled sleep periods. In addition, you will be asked to fill out a daily activity log with specific information related to your schedule, particularly times related to sleep and rest periods. This experiment will take approximately 25 days to complete.

R**isks.** The potential risks of participating in this study does not involve greater than minimal risk and involves no known reasonably foreseeable risks or hazards greater than those encountered in everyday life. A potential risk of participating in this study is a breach of confidentiality. However, this is very unlikely given the only identification factor is a code number.

Benefits. Anticipated benefits from this study are to ensure the NSWW (afloat) model more accurately estimates the standard workweek for Sailors aboard U.S. Navy ships to ensure missions effectiveness, increase human performance, and increase the overall safety of U.S. Navy ships.

Compensation. No tangible compensation will be given. A copy of the research results will be available at the conclusion of the experiment from LT Kim Green (kygreen@nps.edu).

Confidentiality & Privacy Act. Any information that is obtained during this study will be kept confidential to the full extent permitted by law. All efforts, within reason, will be made to keep your personal information in your research record confidential but total confidentiality cannot be guaranteed. No information will be publicly accessible which could identify me as a participant. I will be identified only as a code number on all research forms/data bases. My name on any signed document will not be paired with my code number in order to protect my identity. Only the researchers will have access to the data. However, it is possible that the researcher may be required to divulge information obtained in the course of this research to the subject's chain of command or other legal body.

Voluntary Nature of the Study. Participation in this study is strictly voluntary, and if agreement to participation is given, it can be withdrawn at any time without prejudice.

Points of Contact. It is understood that should any questions or comments arise regarding this project, or a research related injury is received, the Principal Investigator, Dr. Nita L. Miller, 831-656-2281, nlmiller@nps.edu or LT Kim Y. Green, USN, (831) 495-8553, kygreen@nps.edu should be contacted. Any other questions or concerns may be addressed to the Navy Postgraduate School. IRB Chair, LCDR Paul O'Connor , 831-656-3864, peoconno@nps.edu.

Statement of Consent. I have read the information provided above. I have been given the opportunity to ask questions and all the questions have been answered to my satisfaction. I have been provided a copy of this form for my records and I agree to participate in this study. I understand that by agreeing to participate in this research and signing this form, I do not waive any of my legal rights.

____________________________________ ________________

Participant's Signature Date

____________________________________ ________________

Researcher's Signature Date

APPENDIX B. DEMOGRAGPHIC QUESTIONNAIRE

Demographic Questionnaire

Actiwatch # _ _ _ _ _ _ _

1. Watchstation: ____________________

2. Watch Rotation (i.e. Port/Starboard, 3 Section Rotation): __________________

3. Rank: ______________

4. Rate: ______________

5. Age: _______________

6. Race: ______________

7. Male or Female (circle one)

8. Department: _____________

9. Officer or Enlisted (circle one)

10. Time in Service: __________

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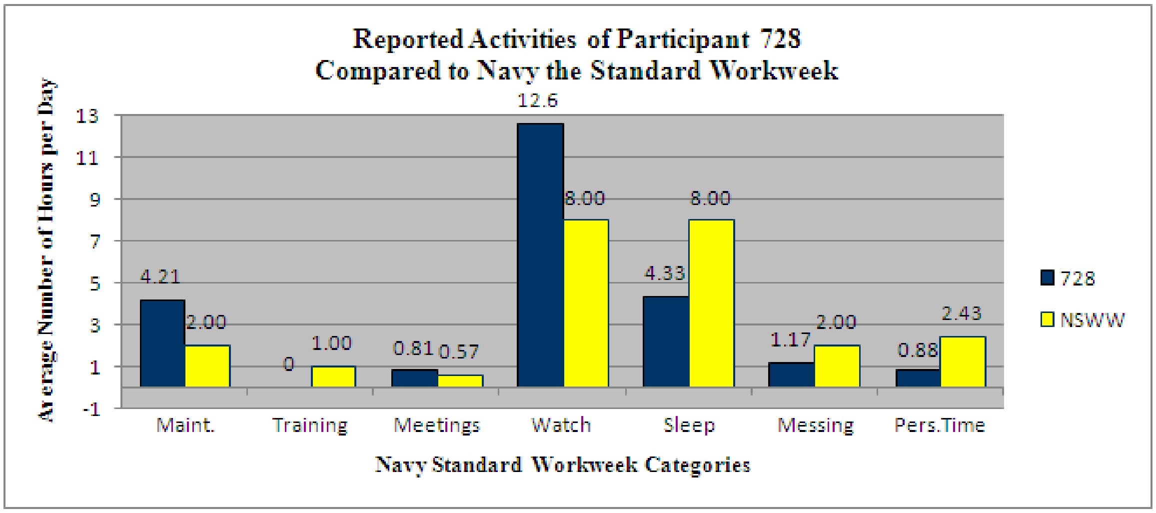
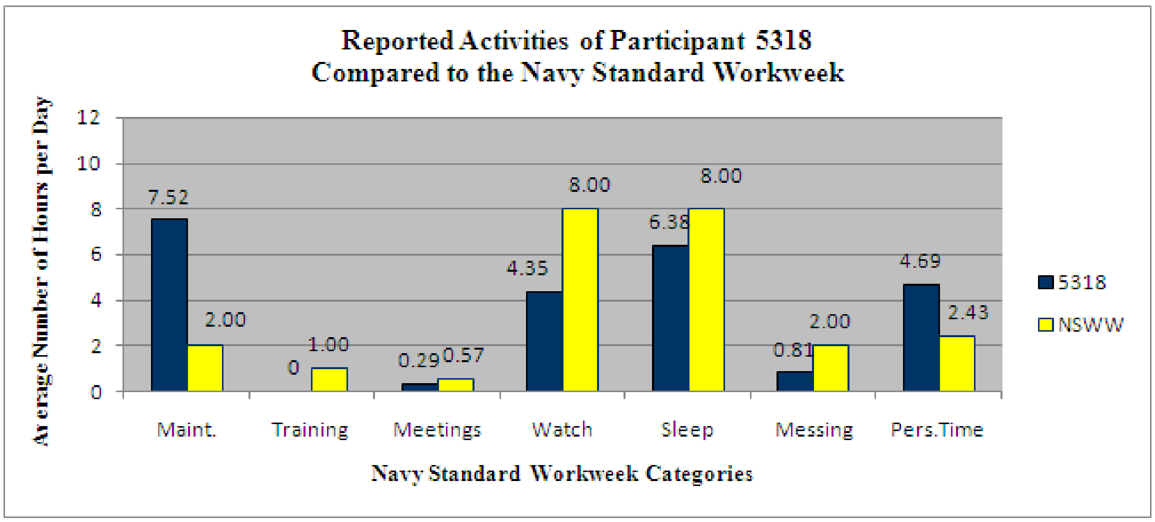
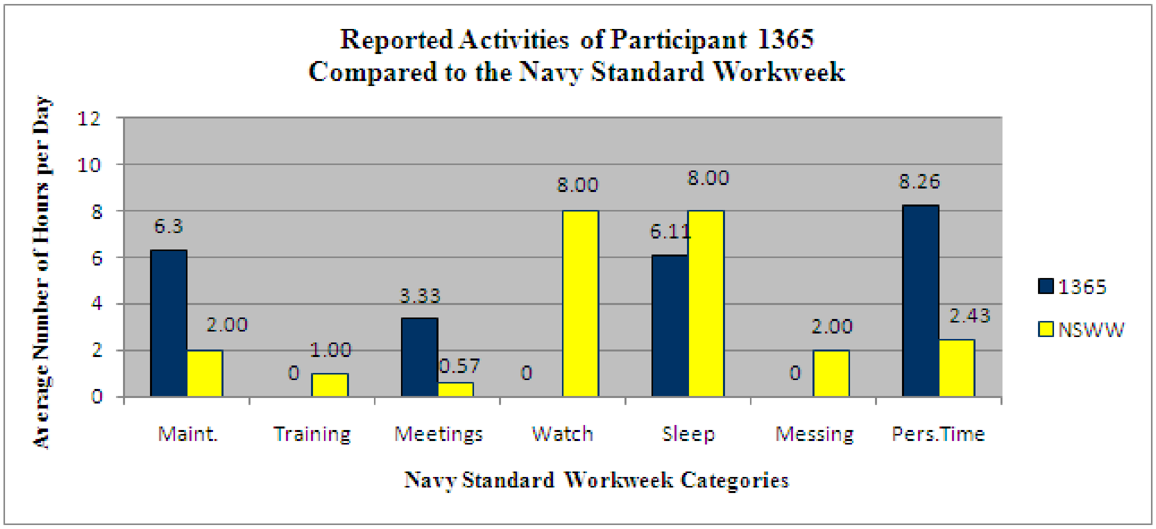
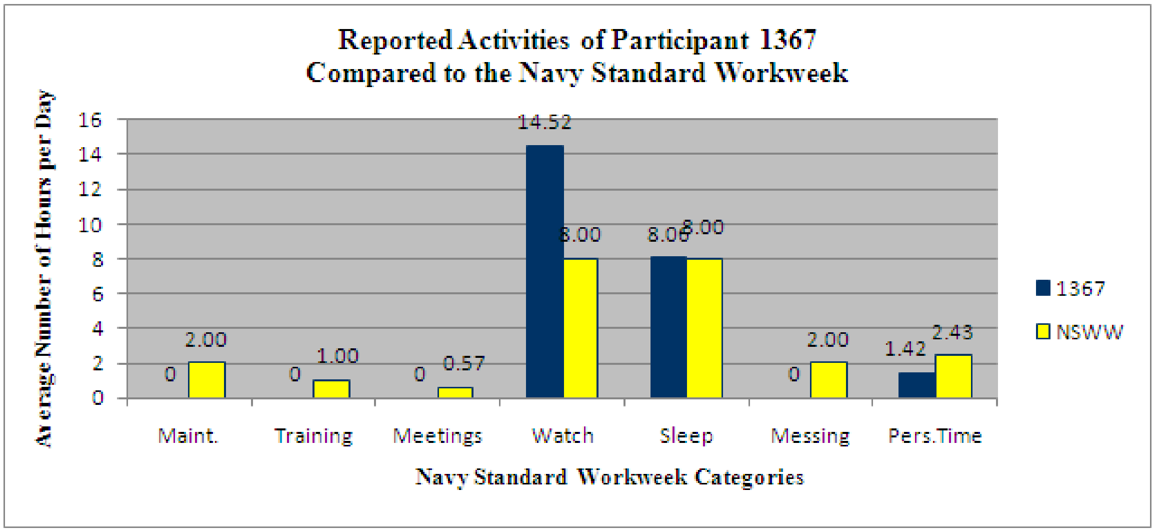
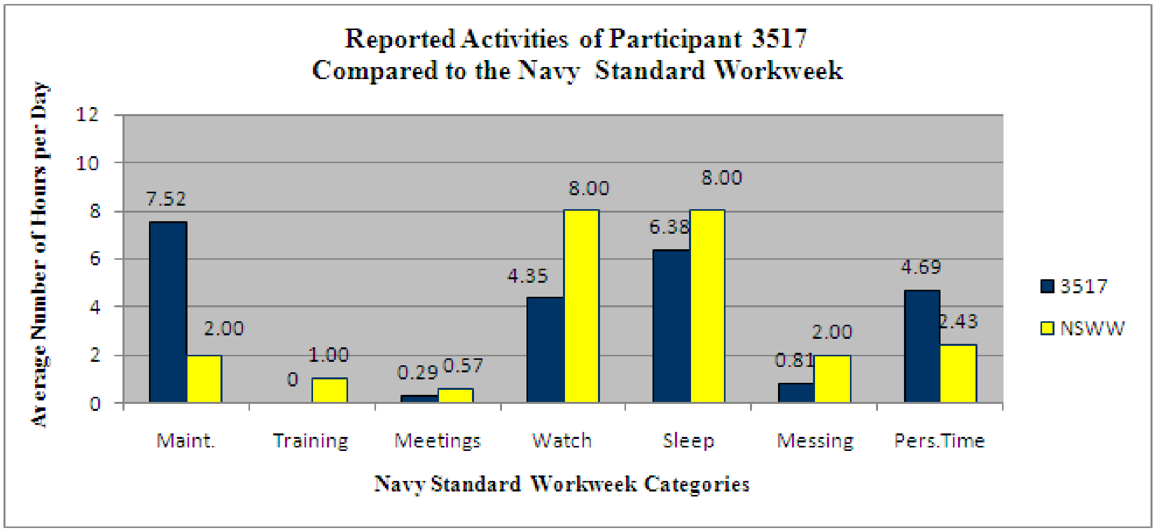
APPENDIX C. DAILY AVERAGE OF SAILORS' SELF-REPORTED AVAILABLE AND NONAVAILABLE TIME VERSUS THE NAVY STANDARD WORKWEEK

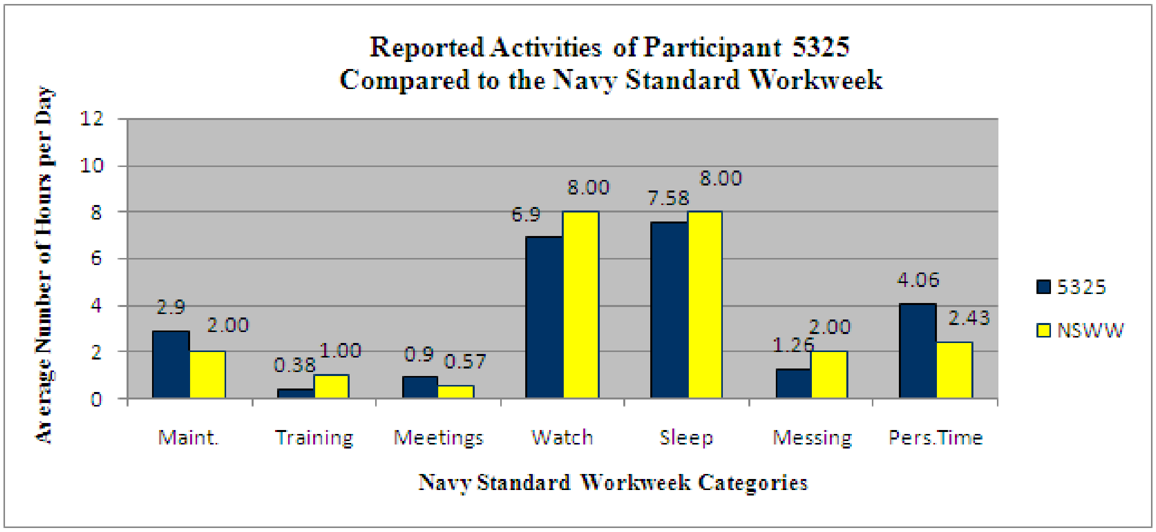




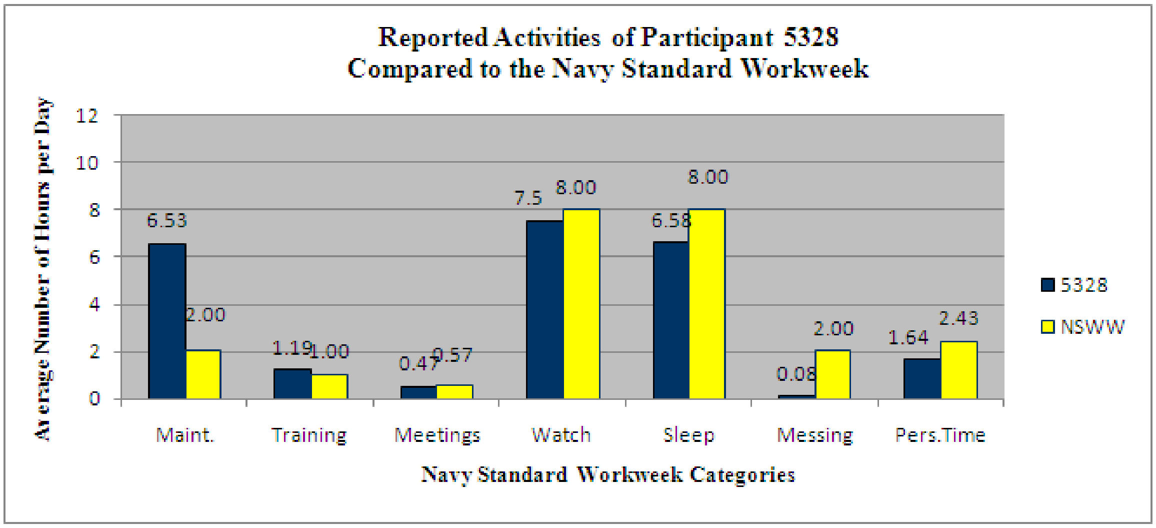

Reported Activities of Participant 1365
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
6.3
2.00
0
1.00
3.33
0.57
0
8.00
6.11
8.00
0
2.00
8.26
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
1365
NSWW


Reported Activities of Participant 1367
Compared to the Navy Standard Workweek
Average Number of Hours per Day
16
14
12
10
8
6
4
2
0
0
2.00
0
1.00
0
0.57
14.52
8.00
8.06
8.00
0
2.00
1.42
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
1367
NSWW

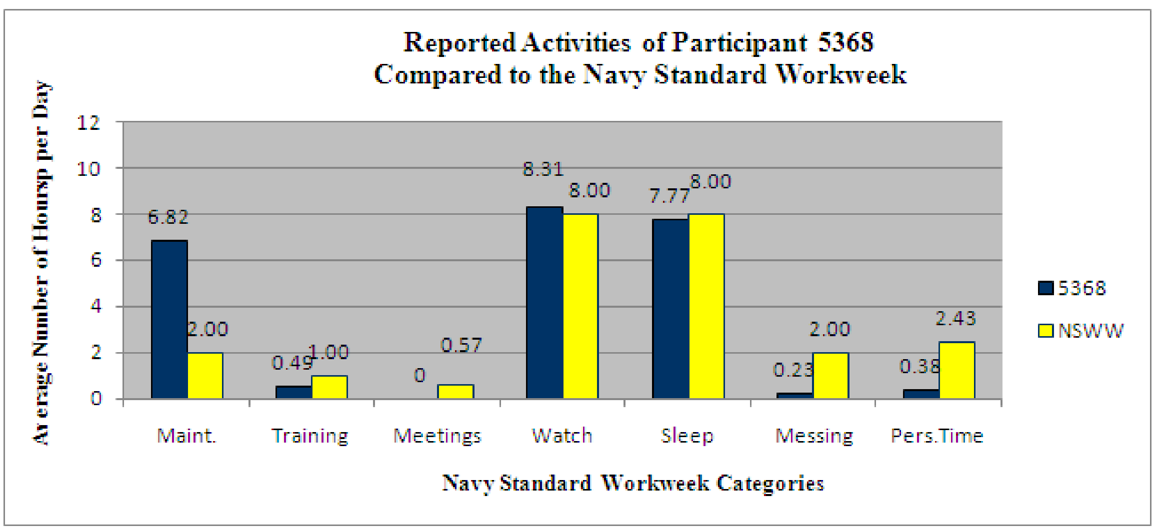

Reported Activities of Participant 3517
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
7.52
2.00
0
1.00
0.29
0.57
4.35
8.00
6.38
8.00
0.81
2.00
4.69
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
3517
NSWW



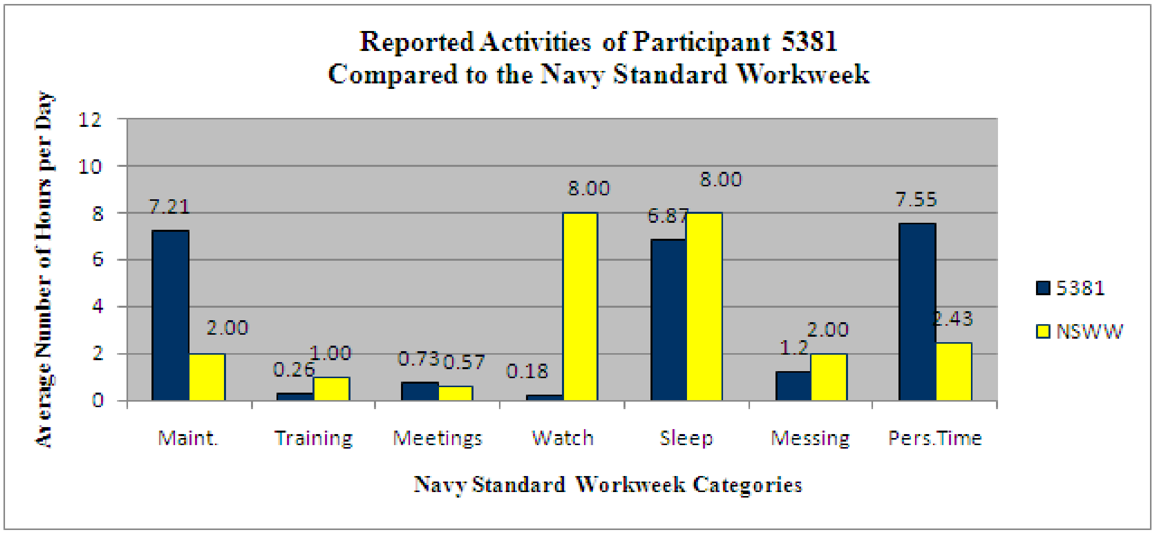
Reported Activities of Participant 5325
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
2.9
2.00
0.38
1.00
0.9
0.57
6.9
8.00
7.58
8.00
1.26
2.00
4.06
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5325
NSWW

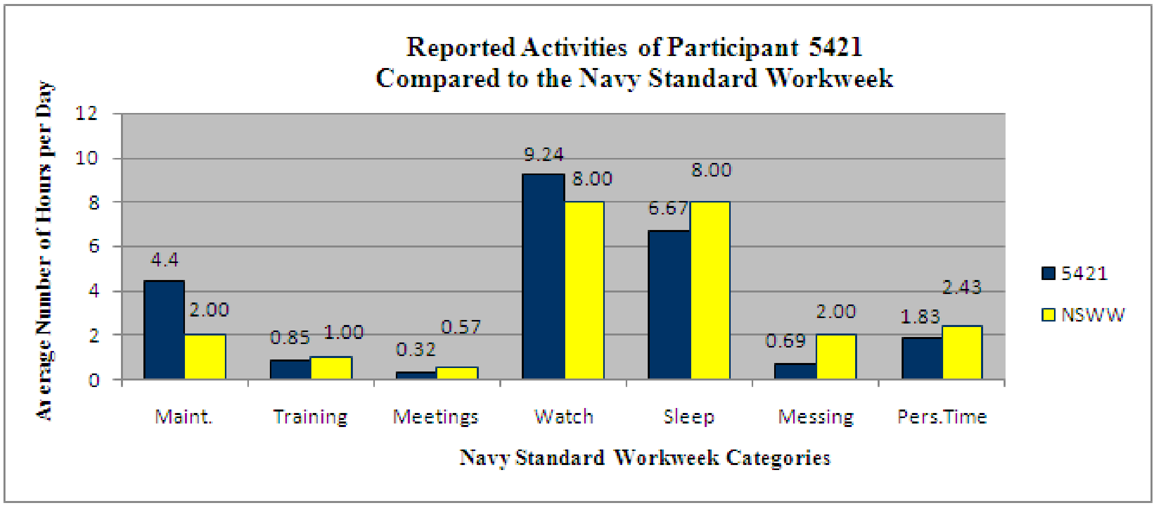


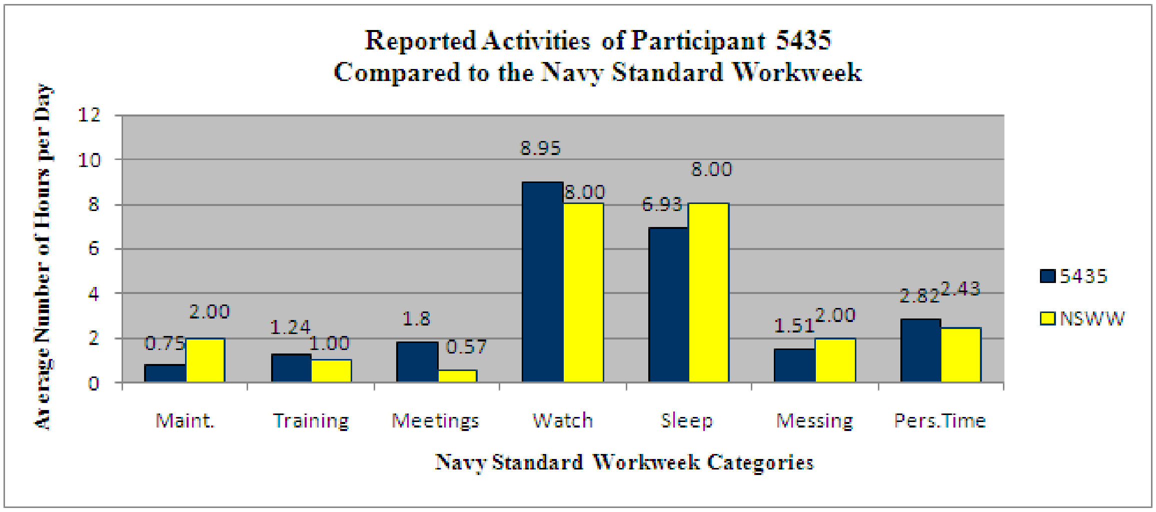
Reported Activities of Participant 5328
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
6.53
2.00
1.19
1.00
0.47
0.57
7.5
8.00
6.58
8.00
0.08
2.00
1.64
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5328
NSWW

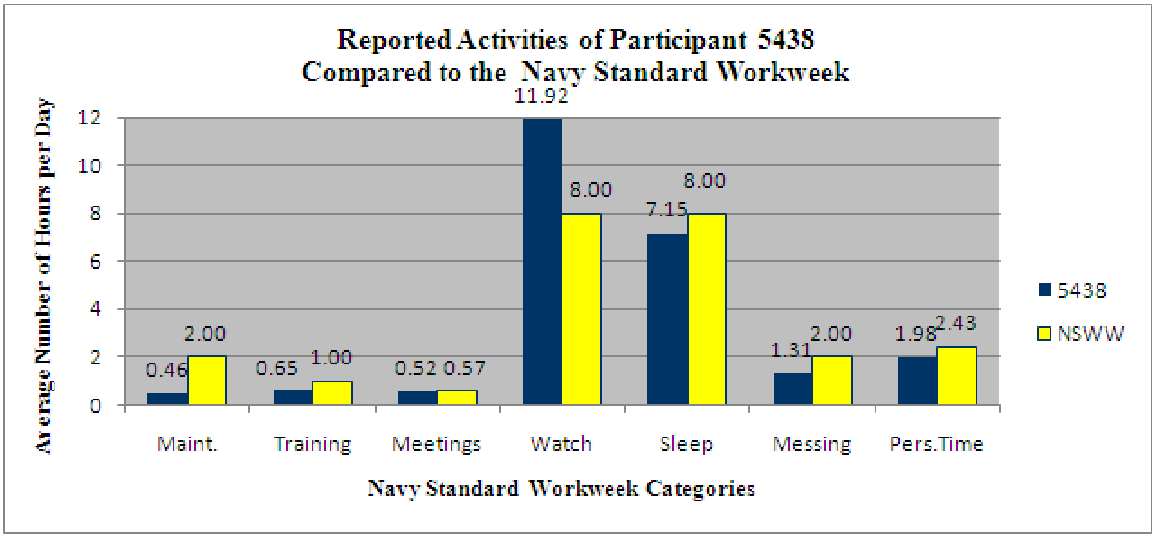


Reported Activities of Participant 5368
Compared to the Navy Standard Workweek
Average Number of Hoursp per Day
12
10
8
6
4
2
0
6.82
2.00
0.49
1.00
0
0.57
8.31
8.00
7.77
8.00
0.23
2.00
0.38
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5368
NSWW

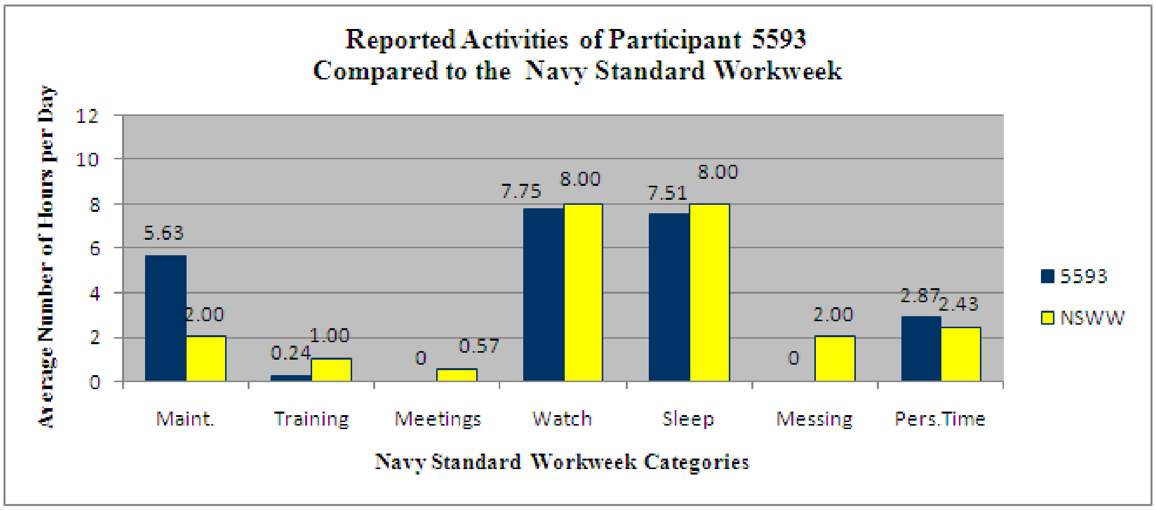

Reported Activities of Participant 5381
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
7.21
2.00
0.26
1.00
0.73
0.57
0.18
8.00
6.87
8.00
1.2
2.00
7.55
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5381
NSWW


Reported Activities of Participant 5421
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
4.4
2.00
0.85
1.00
0.32
0.57
9.24
8.00
6.67
8.00
0.69
2.00
1.83
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5421
NSWW

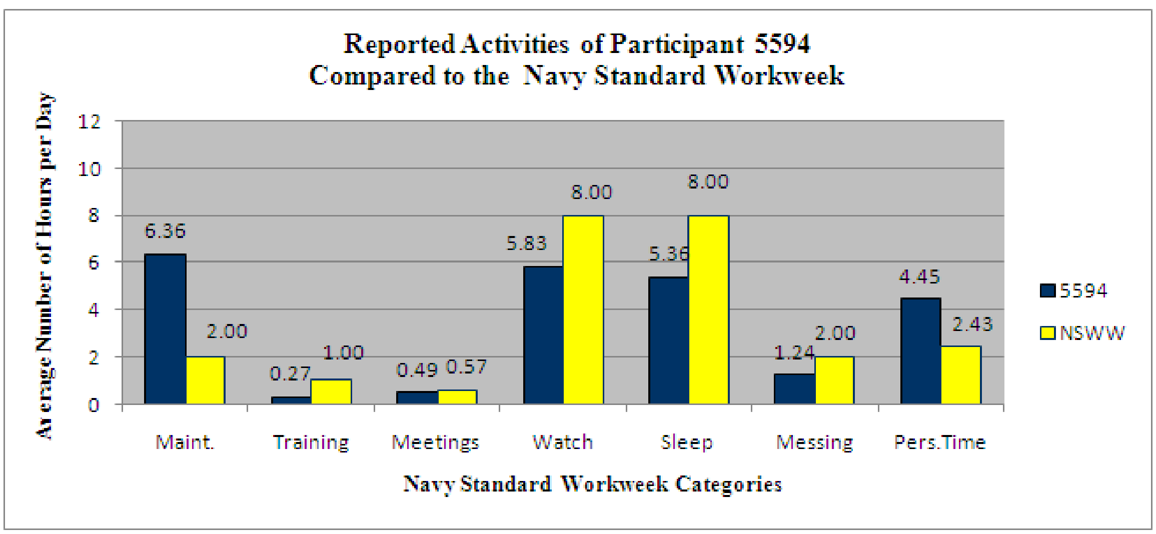

Reported Activities of Participant 5435
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
0.75
2.00
1.24
1.00
1.8
0.57
8.95
8.00
6.93
8.00
1.51
2.00
2.82
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5435
NSWW



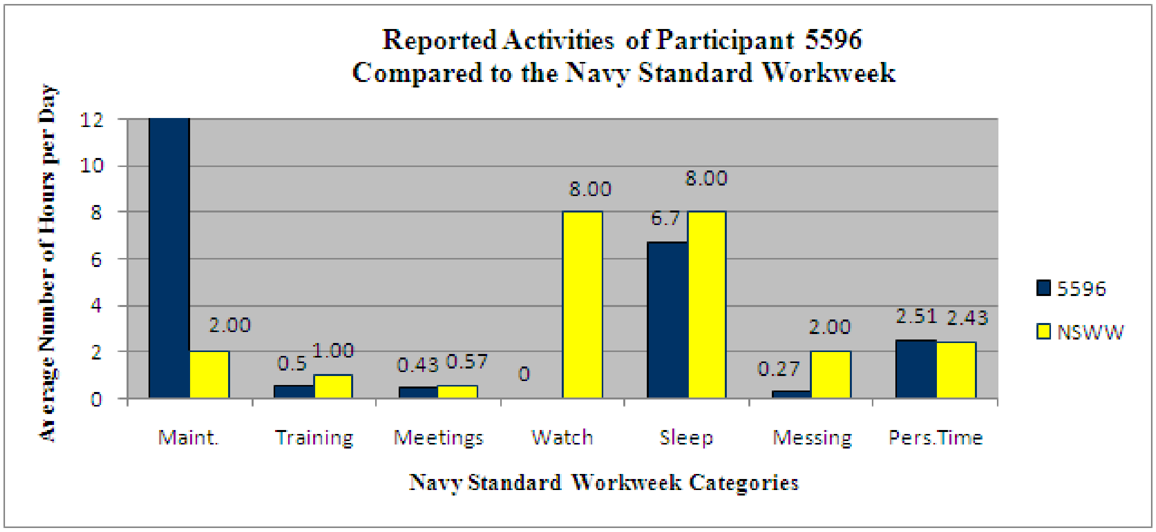
Reported Activities of Participant 5438
Compared to the Navy Standard Workweek
Average Number of Hours per Day
Navy Standard Workweek Categories
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
0.46
2.00
0.65
1.00
0.52
0.57
11.92
8.00
7.15
8.00
1.31
2.00
1.98
2.43
5438
NSWW

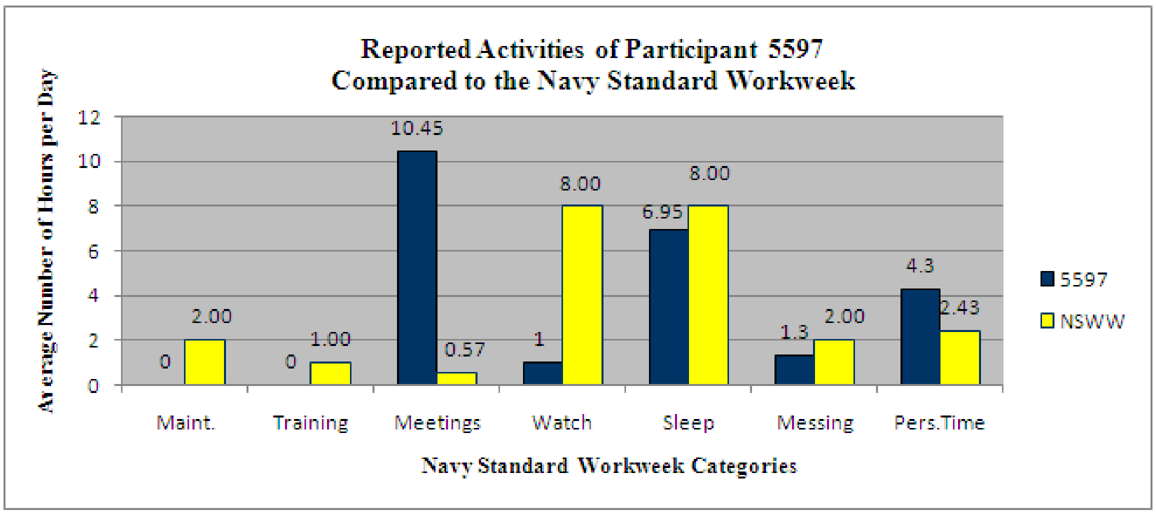


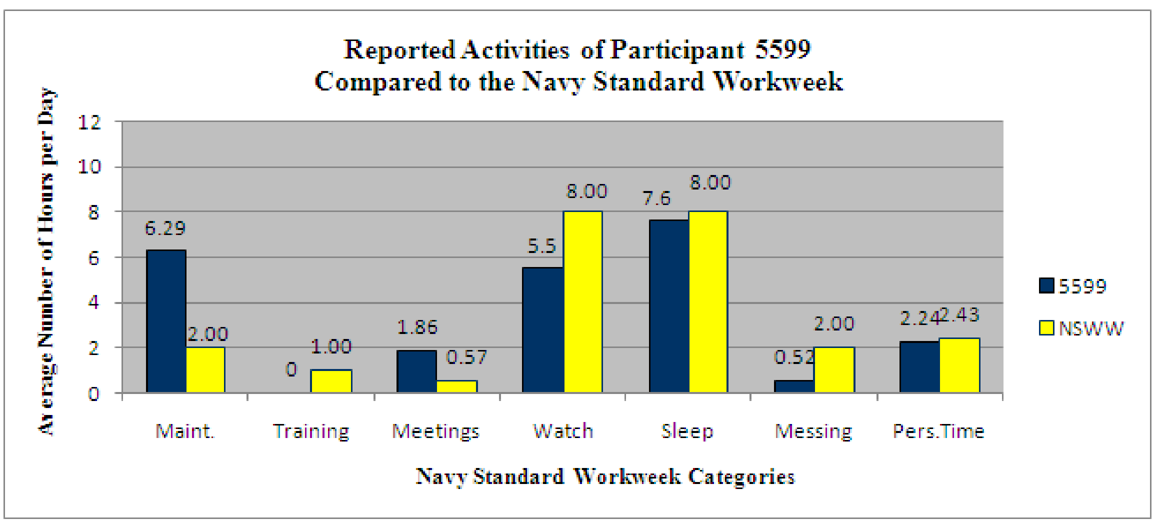
Reported Activities of Participant 5593
Compared to the Navy Standard Workweek
Average Number of Hours per Day
Navy Standard Workweek Categories
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
5.63
2.00
0.24
1.00
0
0.57
7.75
8.00
7.51
8.00
0
2.00
2.87
2.43
5593
NSWW

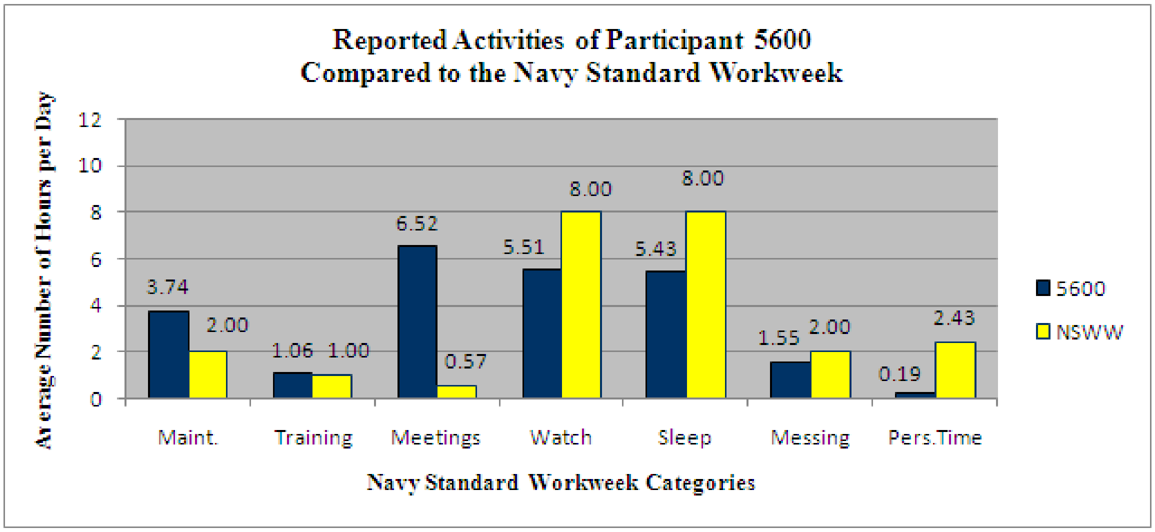


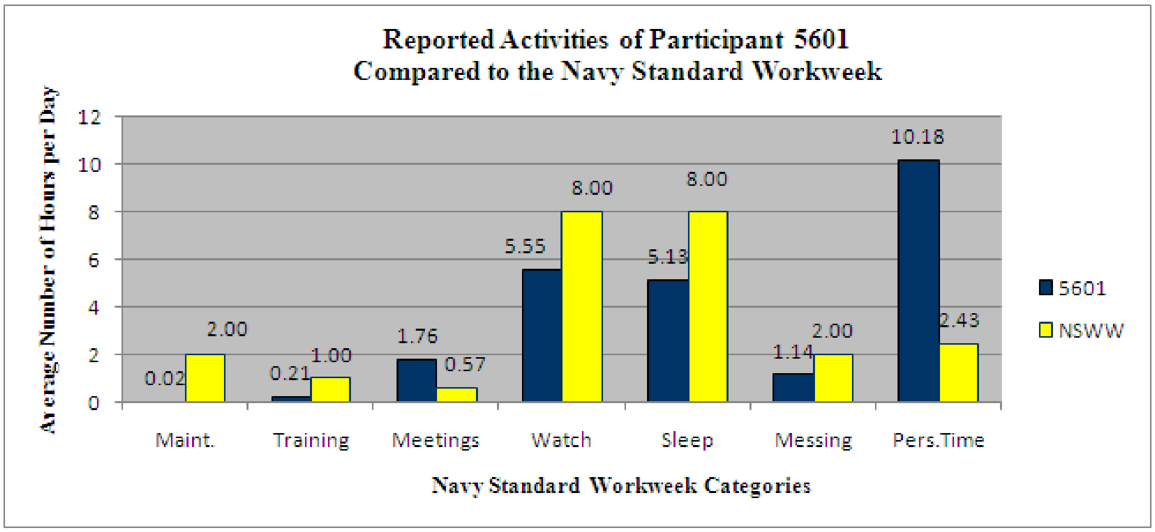
Reported Activities of Participant 5594
Compared to the Navy Standard Workweek
Average Number of Hours per Day
Navy Standard Workweek Categories
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
6.36
2.00
0.27
1.00
0.49
0.57
5.83
8.00
5.36
8.00
1.24
2.00
4.45
2.43
5594
NSWW

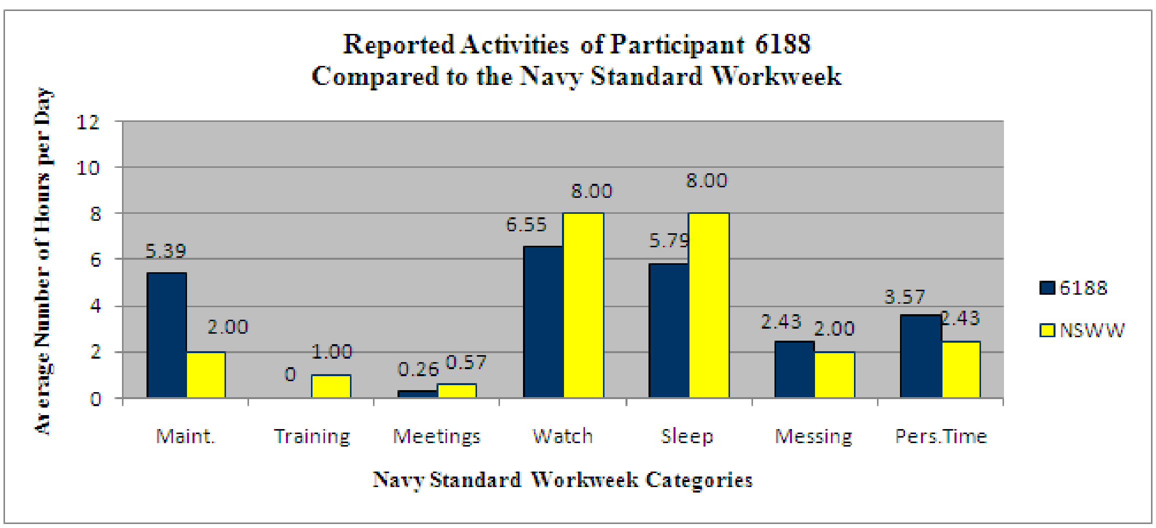

Reported Activities of Participant 5596
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
2.00
0.5
1.00
0.43
0.57
0
8.00
6.7
8.00
0.27
2.00
2.51
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5596
NSWW

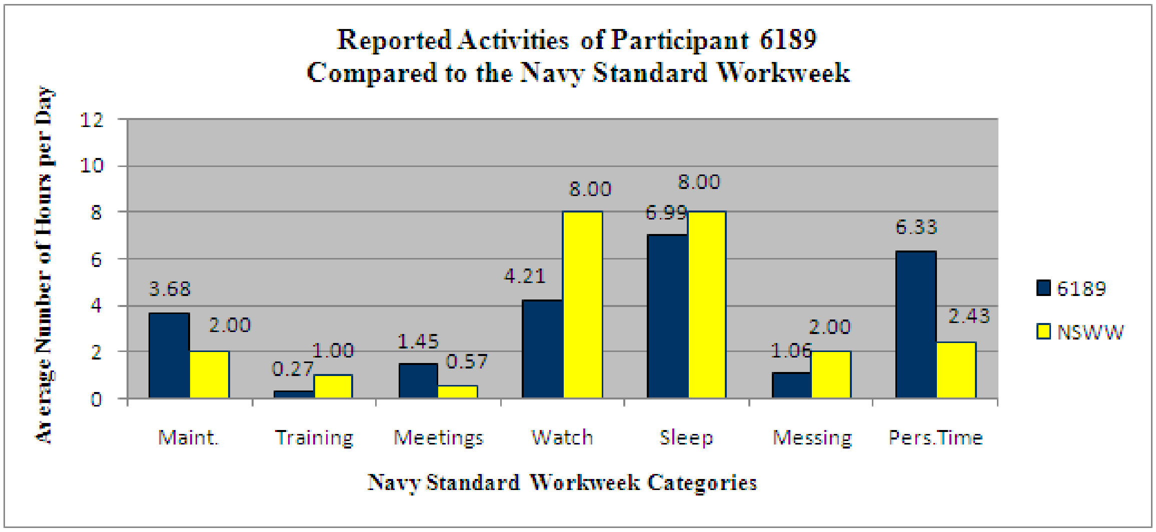

Reported Activities of Participant 5597
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
0
2.00
0
1.00
10.45
0.57
1
8.00
6.95
8.00
1.3
2.00
4.3
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5597
NSWW

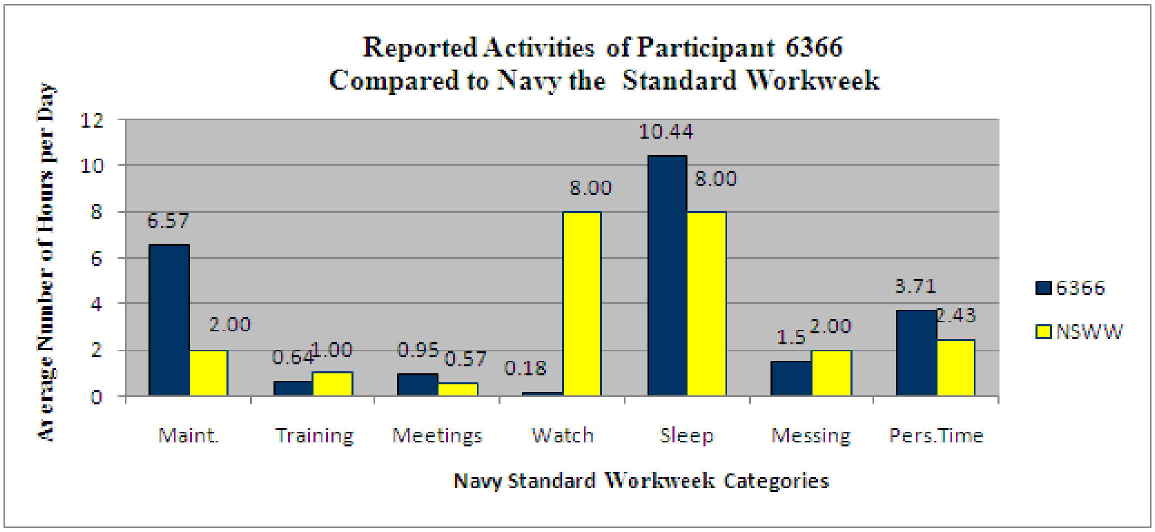

Reported Activities of Participant 5599
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
6.29
2.00
0
1.00
1.86
0.57
5.5
8.00
7.6
8.00
0.52
2.00
2.24
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5599
NSWW

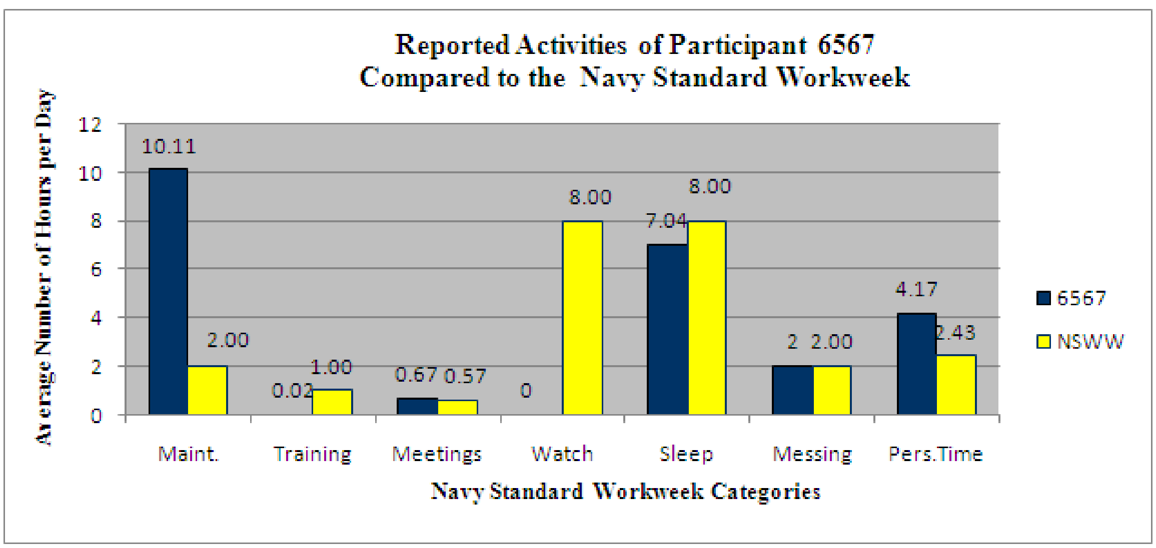

Reported Activities of Participant 5600
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
3.74
2.00
1.06
1.00
6.52
0.57
5.51
8.00
5.43
8.00
1.55
2.00
0.19
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5600
NSWW

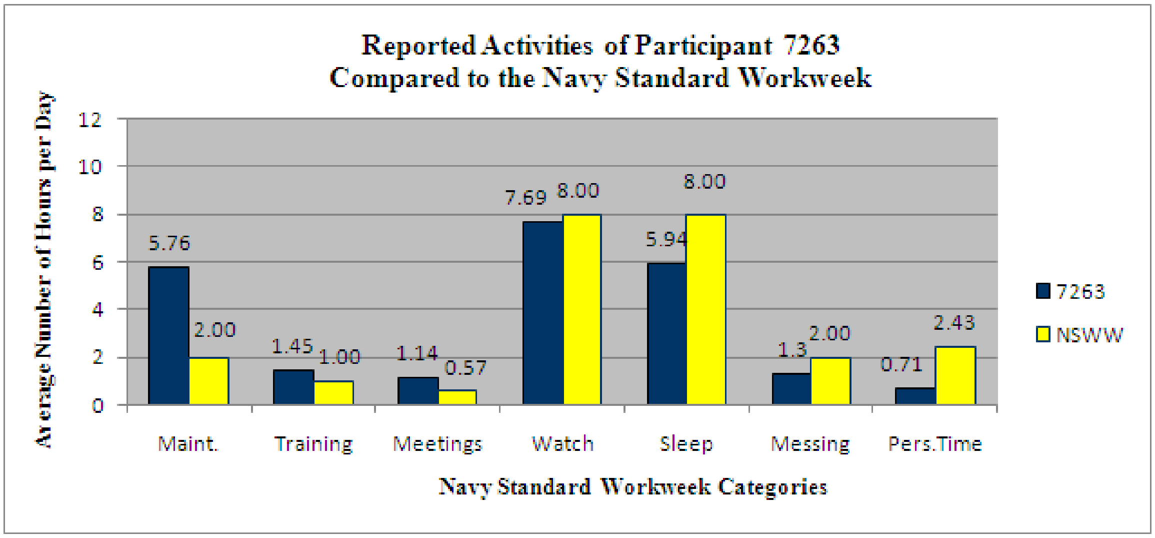

Reported Activities of Participant 5601
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
0.02
2.00
0.21
1.00
1.76
0.57
5.55
8.00
5.13
8.00
1.14
2.00
10.18
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
5601
NSWW


Reported Activities of Participant 6188
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
5.39
2.00
0
1.00
0.26
0.57
6.55
8.00
5.79
8.00
2.43
2.00
3.57
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
6188
NSWW


Reported Activities of Participant 6189
Compared to the Navy Standard Workweek
Average Number of Hours per Day
Navy Standard Workweek Categories
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
3.68
2.00
0.27
1.00
1.45
0.57
4.21
8.00
6.99
8.00
1.06
2.00
6.33
2.43
6189
NSWW


Reported Activities of Participant 6366
Compared to Navy the Standard Workweek
Average Number of Hours per Day
Navy Standard Workweek Categories
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
6.57
2.00
0.64
1.00
0.95
0.57
0.18
8.00
10.44
8.00
1.5
2.00
3.71
2.43
6366
NSWW


Reported Activities of Participant 6567
Compared to the Navy Standard Workweek
Average Number of Hours per Day
Navy Standard Workweek Categories
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
10.11
2.00
0.02
1.00
0.67
0.57
0
8.00
7.04
8.00
2
2.00
4.17
2.43
6567
NSWW


Reported Activities of Participant 7263
Compared to the Navy Standard Workweek
Average Number of Hours per Day
12
10
8
6
4
2
0
5.76
2.00
1.45
1.00
1.14
0.57
7.69
8.00
5.94
8.00
1.3
2.00
0.71
2.43
Maint.
Training
Meetings
Watch
Sleep
Messing
Pers.Time
Navy Standard Workweek Categories
7263
NSWW

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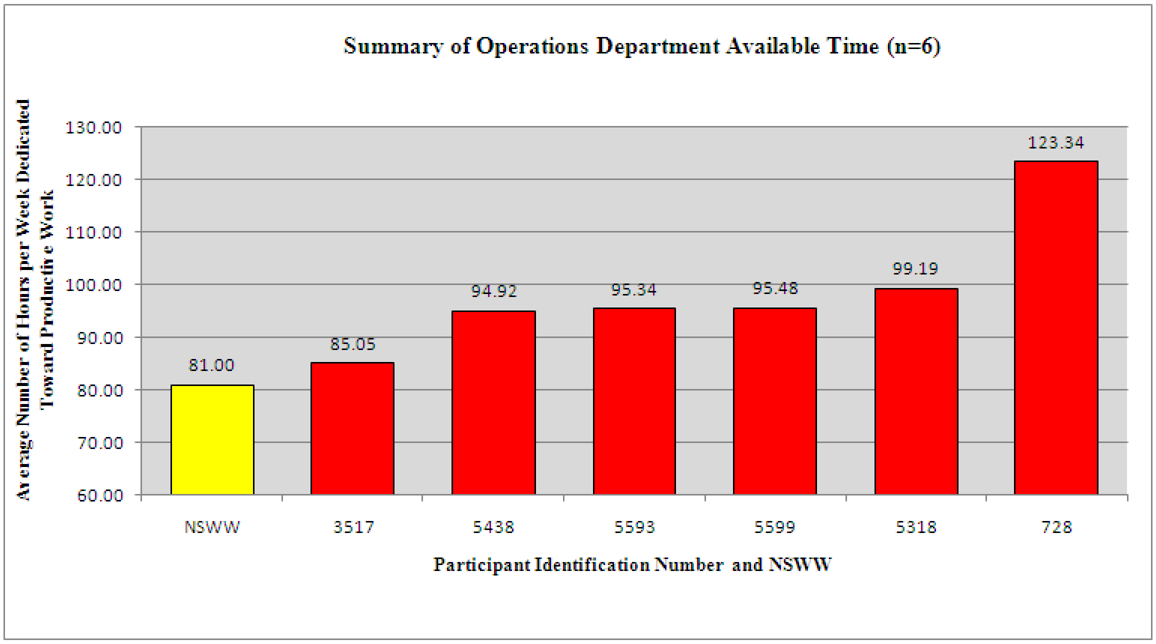
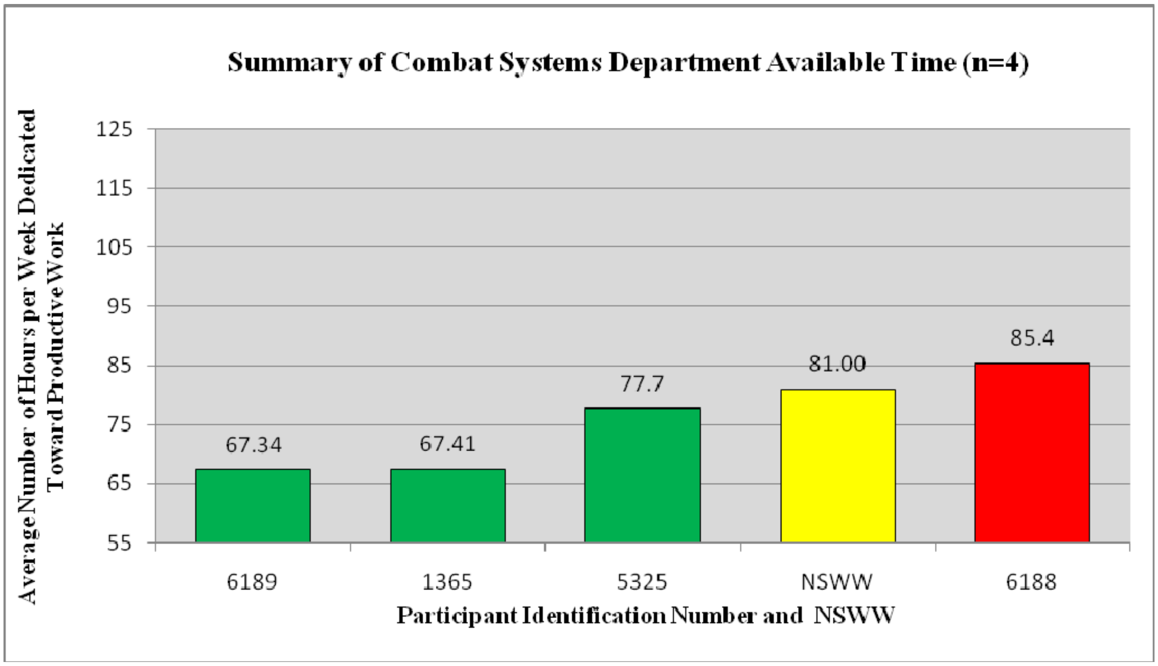
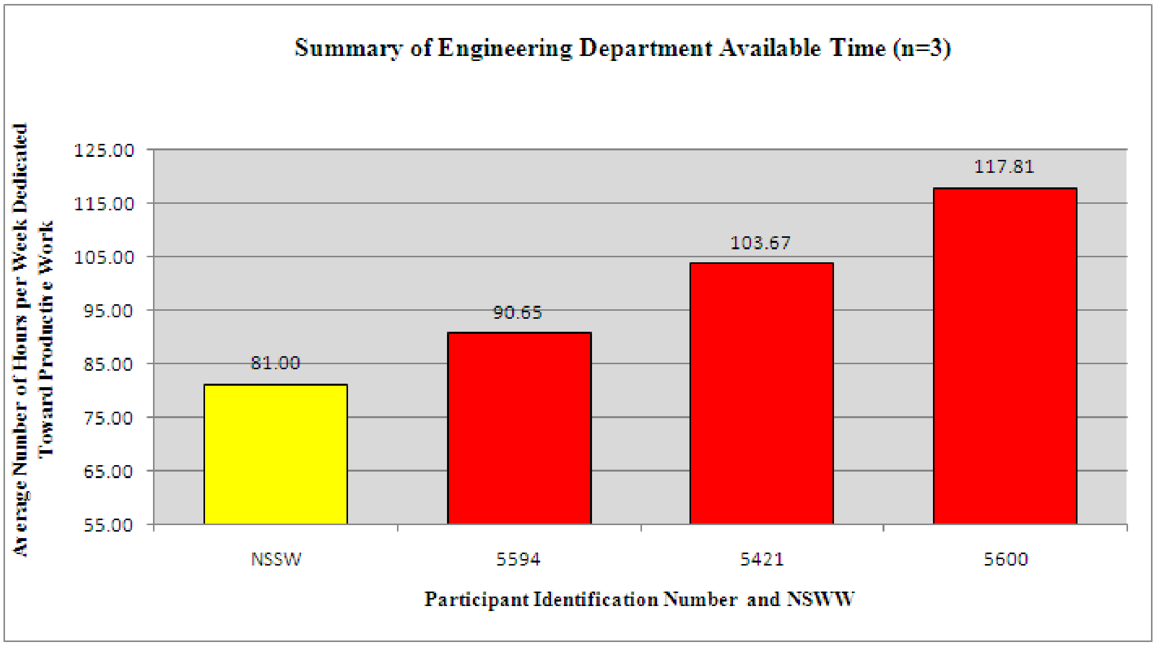
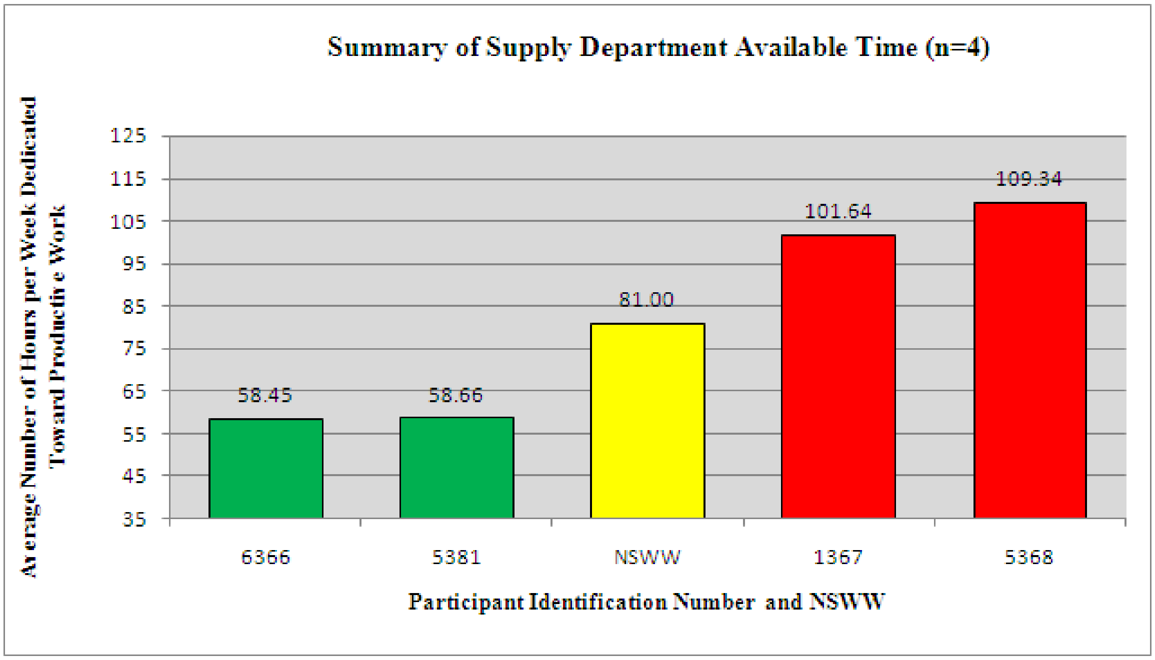
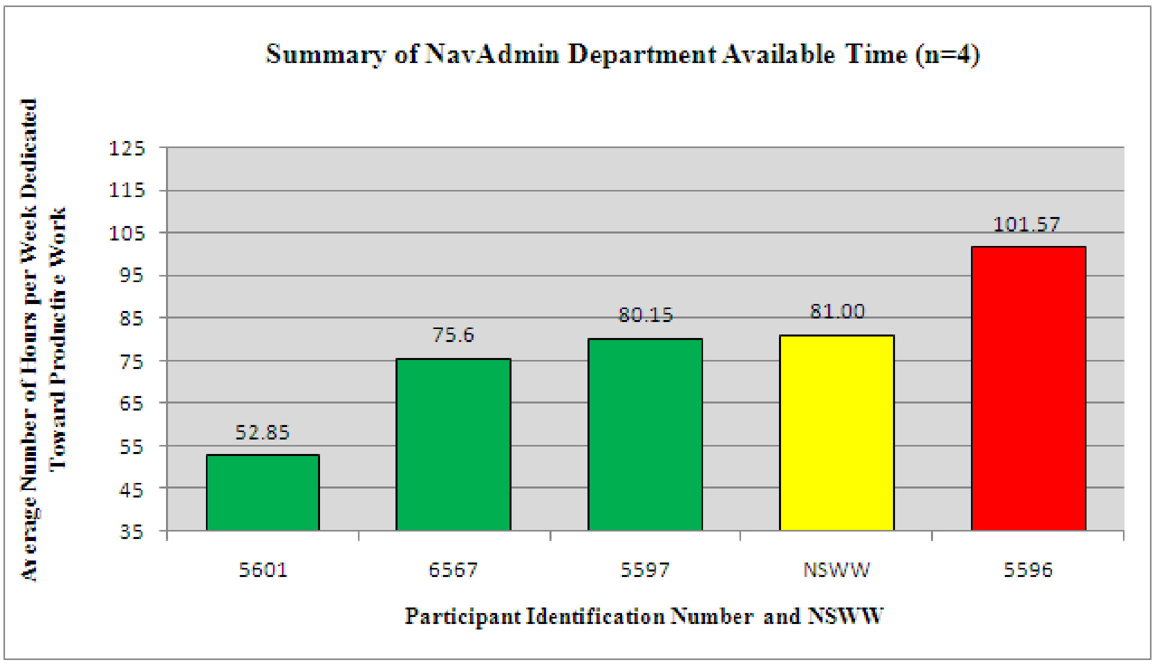
APPENDIX D. SUMMARY OF DEPARTMENTS' AVAILABLE TIME






Summary of Engineering Department Available Time (n=3)
Average Number of Hours per Week Dedicated Toward Productive Work
125.00
115.00
105.00
95.00
85.00
75.00
65.00
55.00
81.00
90.65
103.67
117.81
NSSW
5594
5421
5600
Participant Identification Number and NSWW


Summary of Supply Department Available Time (n=4)
Average Number of Hours per Week Dedicated Toward Productive Work
125
115
105
95
85
75
65
55
45
35
58.45
58.66
81.00
101.64
109.34
6366
5381
NSWW
1367
5368
Participant Identification Number and NSWW


Summary of NavAdmin Department Available Time (n=4)
Average Number of Hours per Week Dedicated Toward Productive Work
125
115
105
95
85
75
65
55
45
35
52.85
75.6
80.15
81.00
101.57
5601
6567
5597
NSWW
5596
Participant Identification Number and NSWW

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APPENDIX E. WEEKLY AVERAGE OF REPORTED AVAILABLE AND NONAVAILABLE TIME FOR USS RENTZ VERSUS NSWW MODEL (INCLUDING OFFICERS)

RENTZ AVERAGE NUMBER OF HOURS SPENT PER WEEK (INCLUDING OFFICERS)							
Participant	Maintenance	Training	Meetings	Watch	Sleep	Messing	Personal Time
NSWW	14	7	4	56	56	14	17
728	29.47	0	5.67	88.2	30.31	8.19	6.16
1365	44.1	0	23.31	0	42.77	0	57.82
1367	0	0	0	101.64	56.42	0	9.94
3517	52.64	0	2.03	30.45	44.66	5.67	32.83
5318	10.64	2.73	28.28	57.61	36.33	9.45	23.03
5325	20.3	2.66	6.3	48.3	53.06	8.82	28.42
5368	47.74	3.43	0	58.17	54.39	1.61	2.66
5381	50.47	1.82	5.11	1.26	48.09	8.4	52.85
5421	30.8	5.95	2.24	64.68	46.69	4.83	12.81
5438	3.22	4.55	3.64	83.44	50.05	9.17	13.86
5593	39.41	1.68	0	54.25	52.57	0	20.09
5594	44.52	1.89	3.43	40.81	37.52	8.68	31.15
5596	95.06	3.5	3.01	0	46.9	1.89	17.57
5597	0	0	73.15	7	48.65	9.1	30.1
5599	44.03	0	13.02	38.5	53.2	3.64	15.68
5600	26.18	7.42	45.64	38.57	38.01	10.85	1.33
5601	0.14	1.47	12.32	38.85	35.91	7.98	71.26
6188	37.73	0	1.82	45.85	40.53	17.01	24.99
6189	25.76	1.89	10.15	29.47	48.93	7.42	44.31
6366	45.99	4.48	6.65	1.26	73.08	10.5	25.97
6567	70.77	0.14	4.69	0	49.28	14	29.19
5328	45.71	8.33	3.29	52.5	46.06	0.56	11.48
5435	5.25	8.68	12.6	62.65	48.51	10.57	19.74
7263	40.32	10.15	7.98	53.83	41.58	9.1	4.97
Average	33.76	2.95	11.43	41.55	46.81	6.98	24.51
Std. Deviation	23.49	3.12	16.82	29.09	8.69	4.57	17.71

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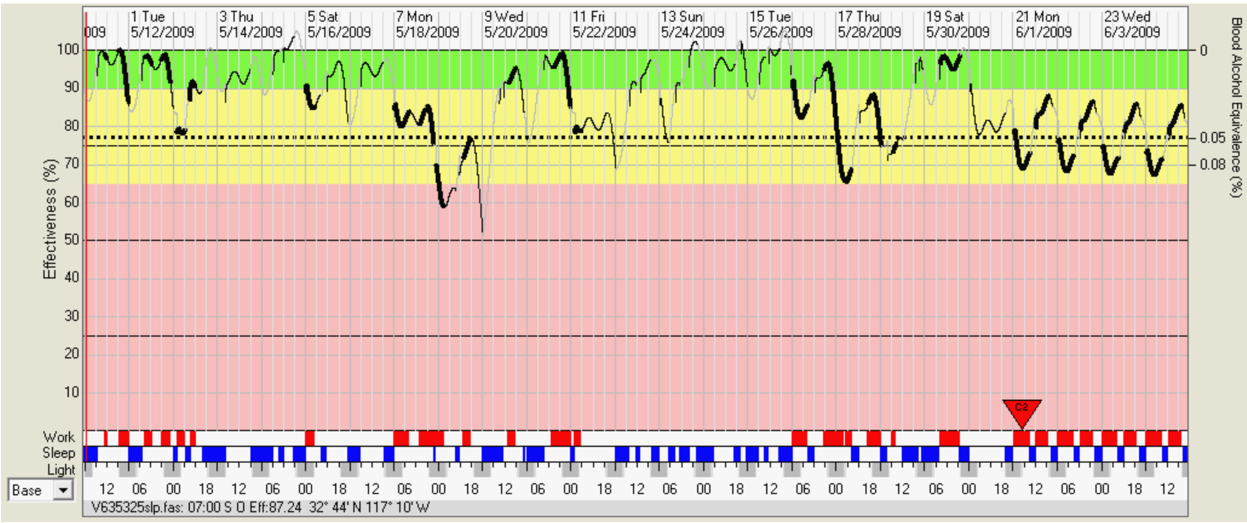
APPENDIX F. SUMMARY TABLE OF INDIVIDUAL SAILORS REPORTED AVAILABLE AND NONAVAILABLE TIME

Reported			
NSWW		AVAILABLE TIME	NON-AVAILABLE TIME
PARTICIPANT	DEPARTMENT	81 HOURS	87 HOURS
728	OPERATIONS	123.34	44.66
1365	COMBAT SYSTEMS	67.41	100.59
1367	SUPPLY	101.64	66.36
3517	OPERATIONS	85.05	82.95
5238	OFFICER	99.19	68.81
5318	OPERATIONS	77.7	90.3
5368	SUPPLY	109.34	58.66
5381	SUPPLY	58.66	109.34
5421	ENGINEERING	103.67	64.33
5438	OPERATIONS	94.92	73.08
5593	OPERATIONS	95.34	72.66
5594	ENGINEERING	90.65	77.35
5596	NAVADMIN	101.57	66.43
5597	NAVADMIN	80.15	87.85
5599	OPERATIONS	95.48	72.52
5600	ENGINEERING	117.81	50.19
5601	NAVADMIN	52.85	115.15
6188	COMBAT SYSTEMS	85.4	82.6
6189	COMBAT SYSTEMS	67.34	100.66
6366	SUPPLY	58.45	109.55
6567	NAVADMIN	75.6	92.4
	AVERAGE	87.69	80.31
	MEDIAN	90.65	77.35
	STD. DEVIATION	19.56	19.56

Reported (Including Officers)			
NSWW		AVAILABLE TIME	NON-AVAILABLE TIME
PARTICIPANT	DEPARTMENT	81 HOURS	87 HOURS
728	OPERATIONS	123.34	44.66
1365	COMBAT SYSTEMS	67.41	100.59
1367	SUPPLY	101.64	66.36
3517	OPERATIONS	85.05	82.95
5238	OFFICER	99.19	68.81
5318	OPERATIONS	77.7	90.3
5325	COMBAT SYSTEMS	109.83	58.17
5368	SUPPLY	109.34	58.66
5381	SUPPLY	58.66	109.34
5421	ENGINEERING	103.67	64.33
5435	OFFICER	89.18	78.82
5438	OPERATIONS	94.92	73.08
5593	OPERATIONS	95.34	72.66
5594	ENGINEERING	90.65	77.35
5596	NAVADMIN	101.57	66.43
5597	NAVADMIN	80.15	87.85
5599	OPERATIONS	95.48	72.52
5600	ENGINEERING	117.81	50.19
5601	NAVADMIN	52.85	115.15
6188	COMBAT SYSTEMS	85.4	82.6
6189	COMBAT SYSTEMS	67.34	100.66
6366	SUPPLY	58.45	109.55
6567	NAVADMIN	75.6	92.4
7263	OFFICER	112.35	55.65
	AVERAGE	89.71	78.30
	MEDIAN	92.79	75.22
	STD. DEVIATION	19.40	19.40

APPENDIX G. FAST ANALYSIS

*The triangle on FAST chart represents a critical event (i.e., watch or maintenance).



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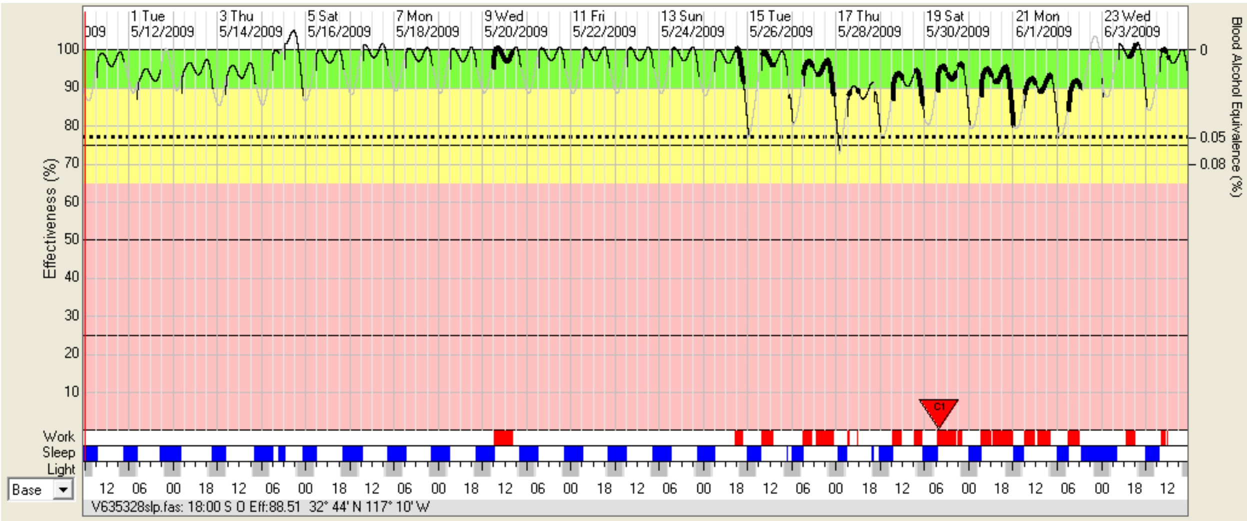

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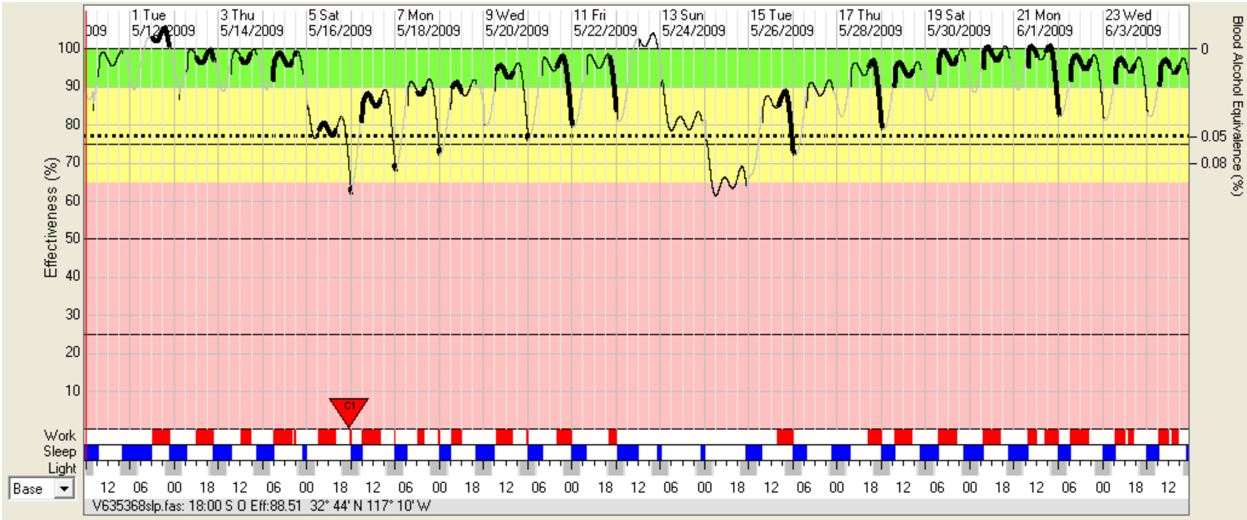
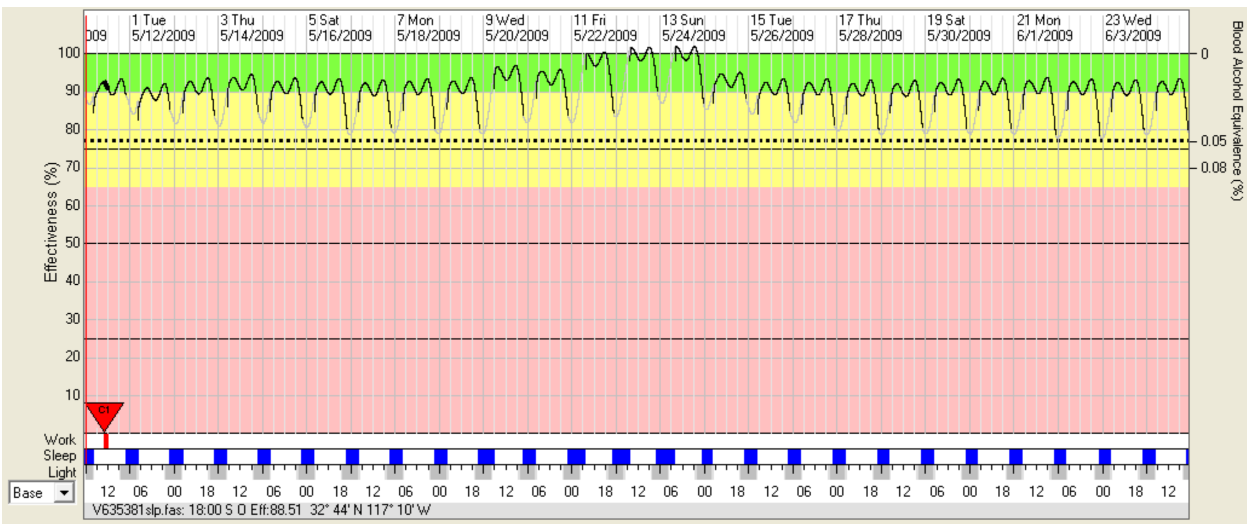


Effectiveness (%)
Blood Alcohol Equivalence (%)
0
0.05
0.08
100
90
80
70
60
50
40
30
20
10
Work
Sleep
Light
Base
1 Tue 5/12/2009
3 Thu 5/14/2009
5 Sat 5/16/2009
7 Mon 5/18/2009
9 Wed 5/20/2009
11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
12 06 00 18 12 06 00 18 12 06 00 18 12 06 00 18 12 06 00 18 12 06 00 18 12 06 00 18 12
V635368slp.fas: 18:00 S 0 Eff:88.51 32° 44' N 117° 10' W

5368



Effectiveness (%)
Blood Alcohol Equivalence (%)
0
0.05
0.08
100
90
80
70
60
50
40
30
20
10
Work
Sleep
Light
Base
1 Tue 5/12/2009
3 Thu 5/14/2009
5 Sat 5/16/2009
7 Mon 5/18/2009
9 Wed 5/20/2009
11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
12 06 00 18 12 06 00 18 12 06 00 18 12 06 00 18 12 06 00 18 12 06 00 18 12 06 00 18 12
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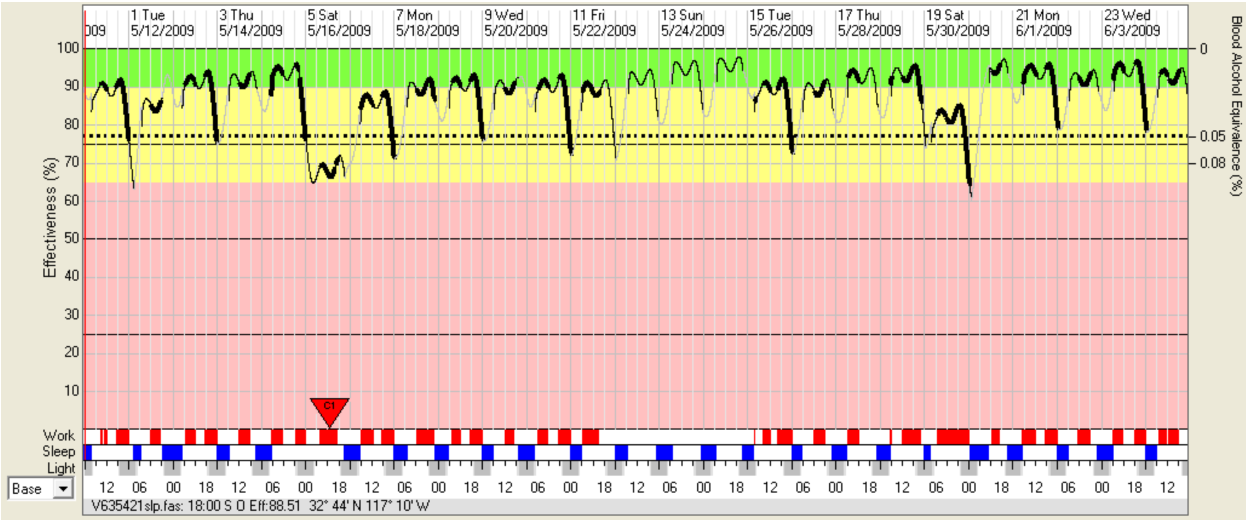
5381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3 Thu 5/14/2009
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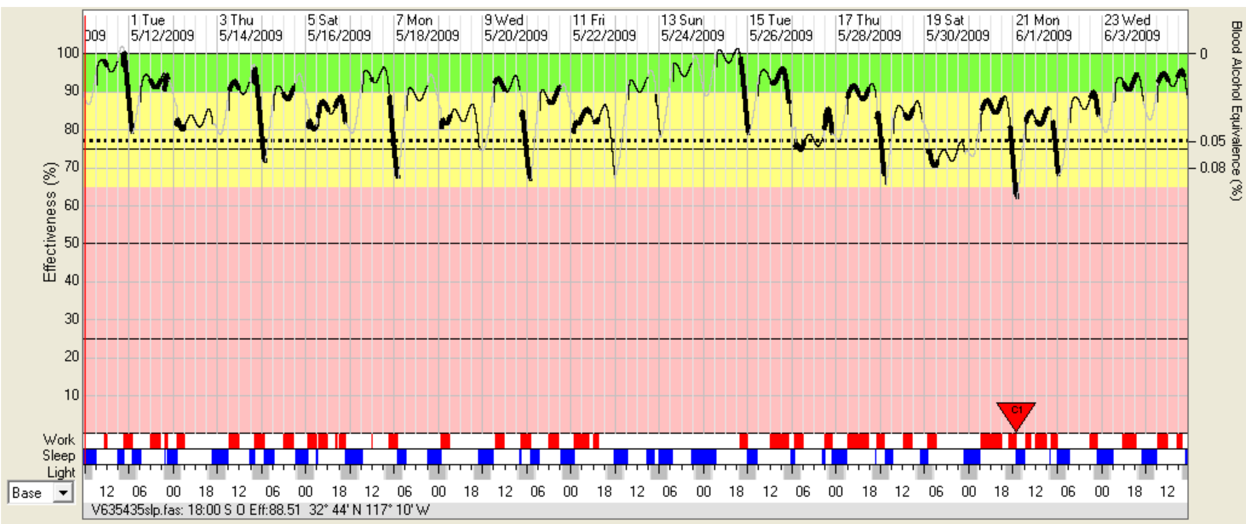
7 Mon 5/18/2009
9 Wed 5/20/2009
11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Effectiveness (%)
Blood Alcohol Equivalence (%)
0.05
0.08
Work
Sleep
Light
Base
V635421slp.fas: 18:00 S O Eff:88.51 32° 44' N 117° 10' W

5421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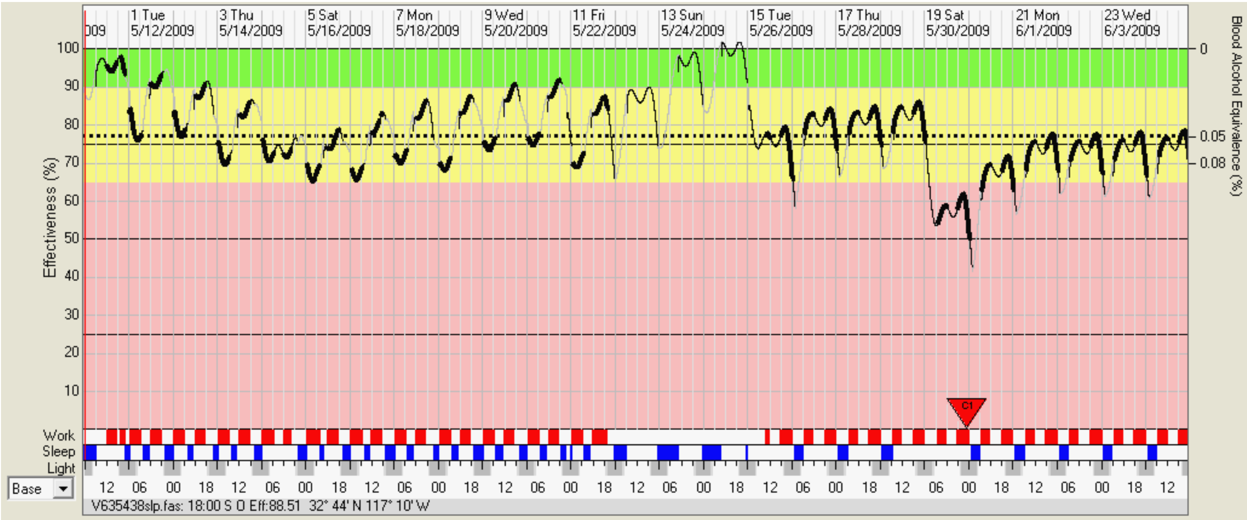
3 Thu 5/14/2009
5 Sat 5/16/2009
7 Mon 5/18/2009
9 Wed 5/20/2009
11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Effectiveness (%)
Blood Alcohol Equivalence (%)
0.05
0.08
Work
Sleep
Light
Base
V635435slp.fas: 18:00 S O Eff:88.51 32° 44' N 117° 10' W

5435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3 Thu 5/14/2009
5 Sat 5/16/2009
7 Mon 5/18/2009
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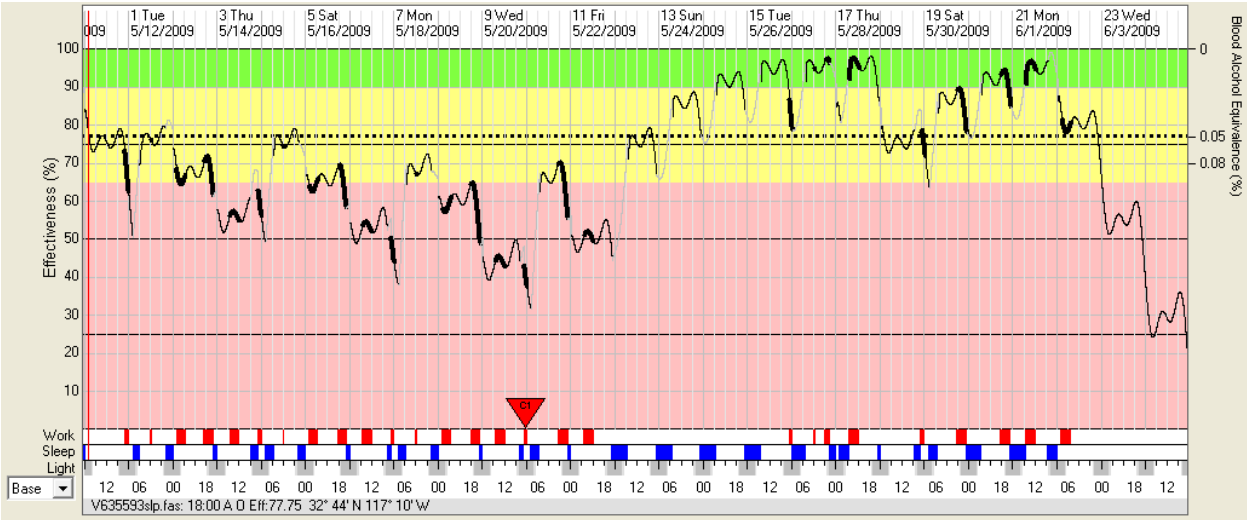
11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Effectiveness (%)
Blood Alcohol Equivalence (%)
0.05
0.08
Work
Sleep
Light
Base
V635438slp.fas: 18:00 S 0 Eff:88.51 32° 44' N 117° 10' W

5438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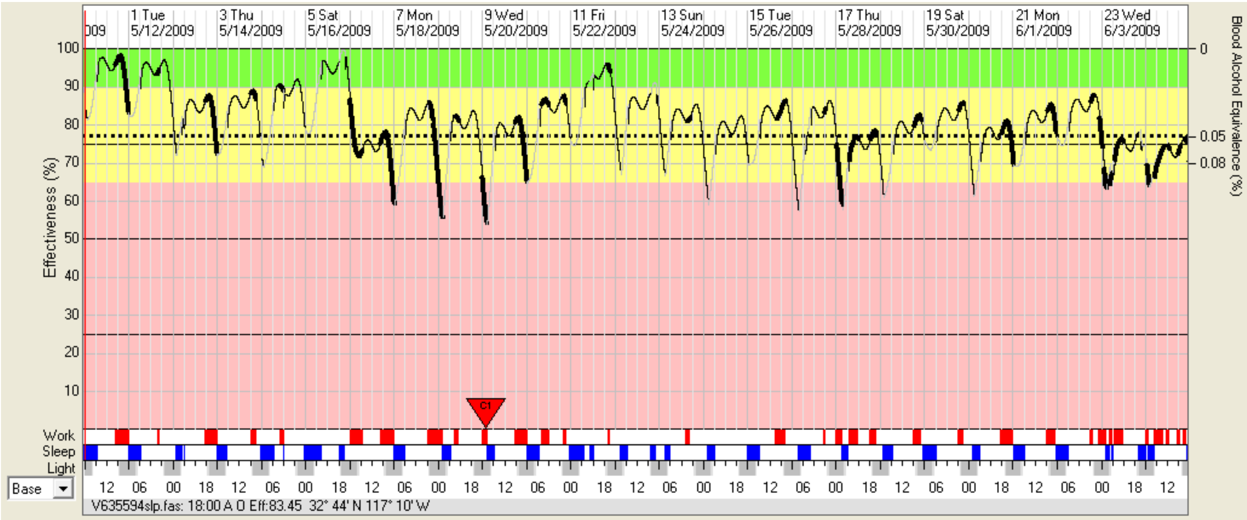
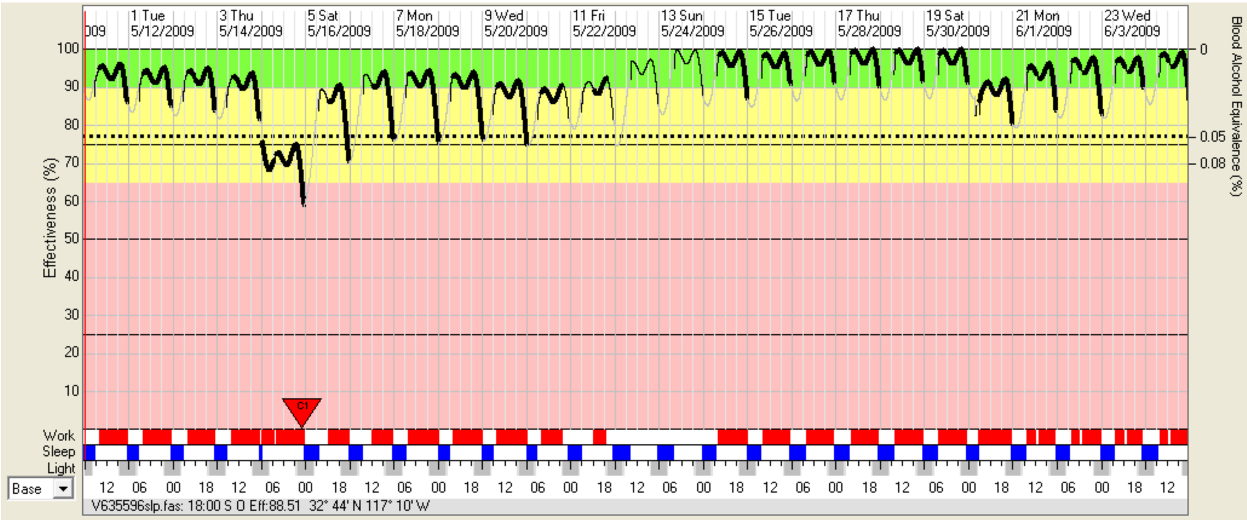
9 Wed 5/20/2009
11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Effectiveness (%)
Blood Alcohol Equivalence (%)
0.05
0.08
Work
Sleep
Light
Base
V635593slp.fas: 18:00 A 0 Eff:77.75 32° 44' N 117° 10' W

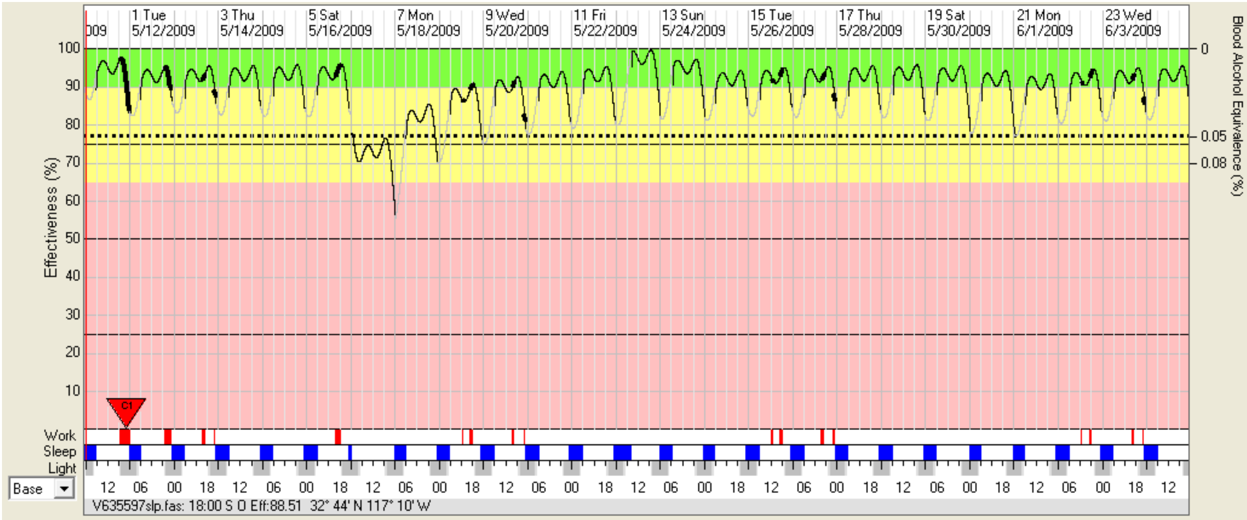
5593


Effectiveness (%)
Blood Alcohol Equivalence (%)
Work
Sleep
Light
Base
V635594slp.fas: 18:00 A O Eff:83.45 32° 44' N 117° 10' W

5594


Effectiveness (%)
Blood Alcohol Equivalence (%)
Work
Sleep
Light
Base
V635596slp.fas: 18:00 S O Eff:88.51 32° 44' N 117° 10' W

5596



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11 Fri 5/22/2009
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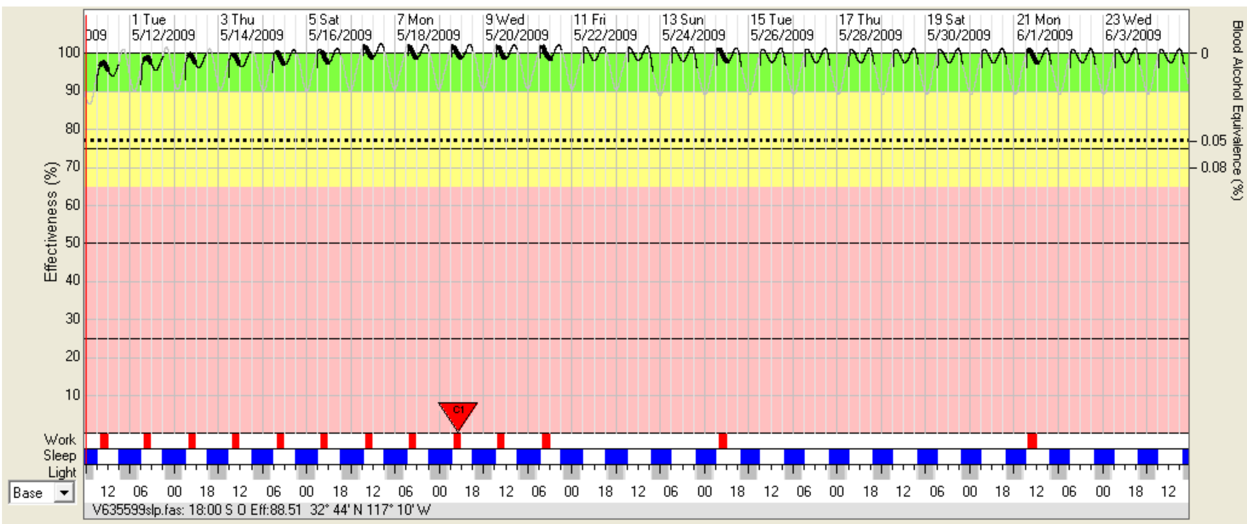
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Effectiveness (%)
Blood Alcohol Equivalence (%)
0.05
0.08
Work
Sleep
Light
Base
V635597slp.fas: 18:00 S O Eff:88.51 32° 44' N 117° 10' W

5597



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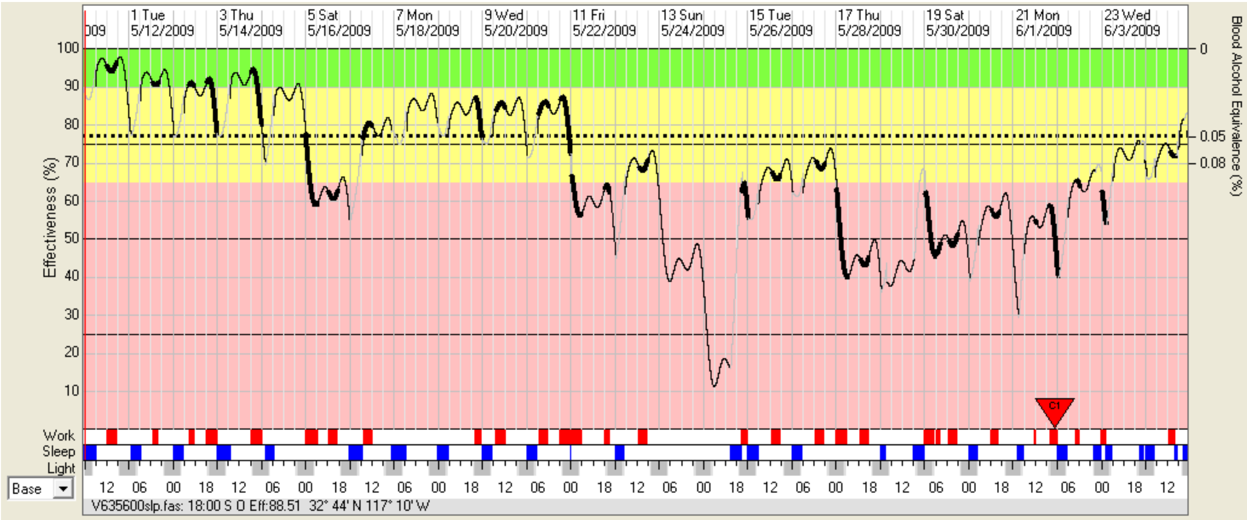
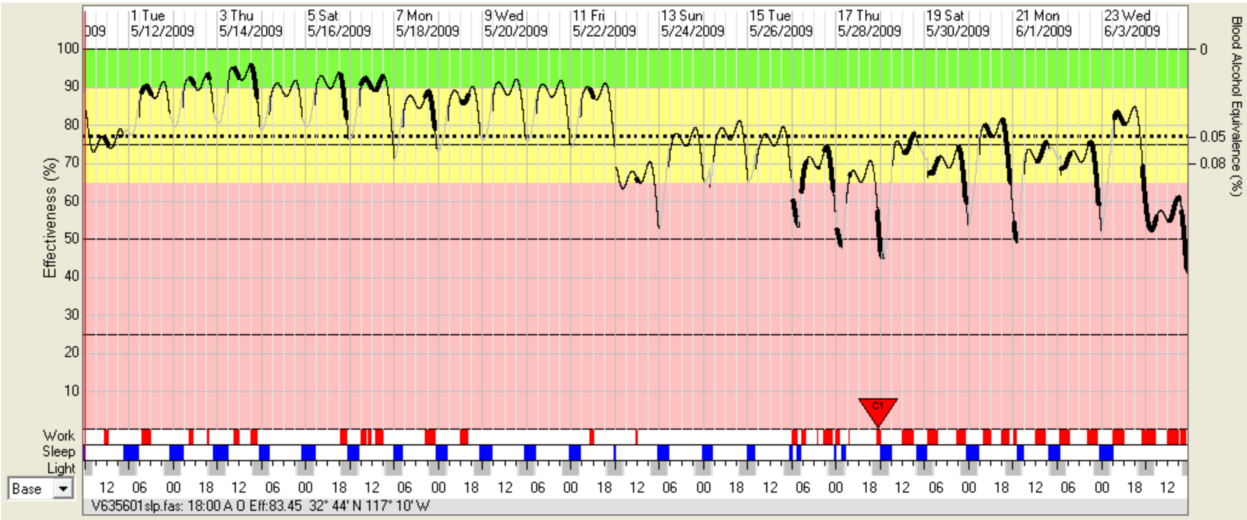
7 Mon 5/18/2009
9 Wed 5/20/2009
11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Effectiveness (%)
Blood Alcohol Equivalence (%)
0.05
0.08
Work
Sleep
Light
Base
V635599slp.fas: 18:00 S O Eff:88.51 32° 44' N 117° 10' W

5599



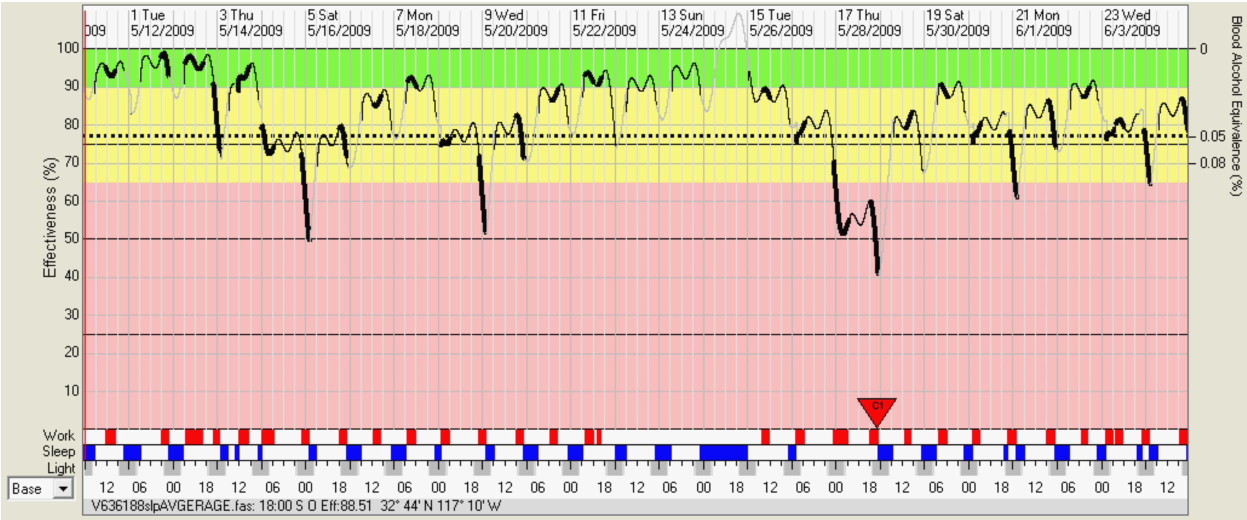
Effectiveness (%)
Blood Alcohol Equivalence (%)
Work
Sleep
Light
Base
V635600slp.fas: 18:00 S 0 Eff:88.51 32° 44' N 117° 10' W

5600

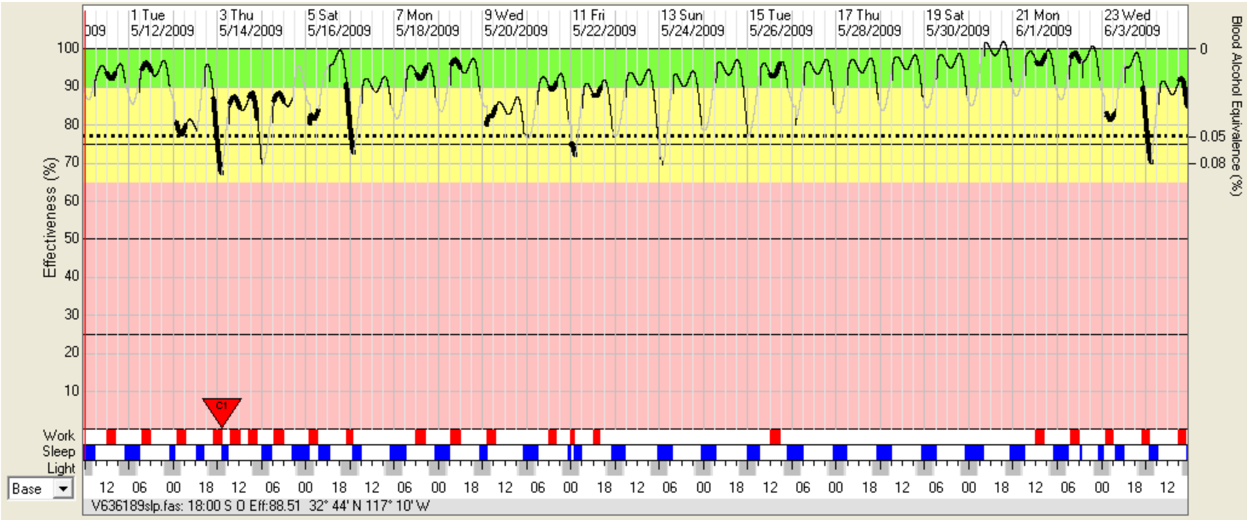


Effectiveness (%)
Blood Alcohol Equivalence (%)
Work
Sleep
Light
Base
V635601slp.fas: 18:00 A 0 Eff:83.45 32° 44' N 117° 10' W

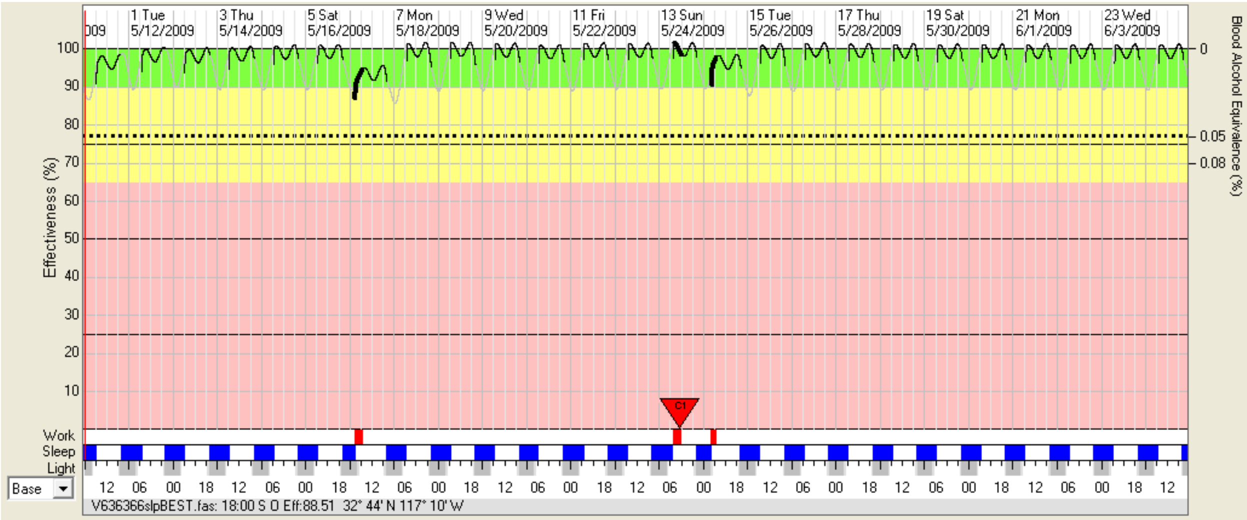
5601


Effectiveness (%)
Blood Alcohol Equivalence (%)
Work
Sleep
Light
Base
V636188slpAVGERAGE.fas: 18:00 S O Eff:88.51 32° 44' N 117° 10' W

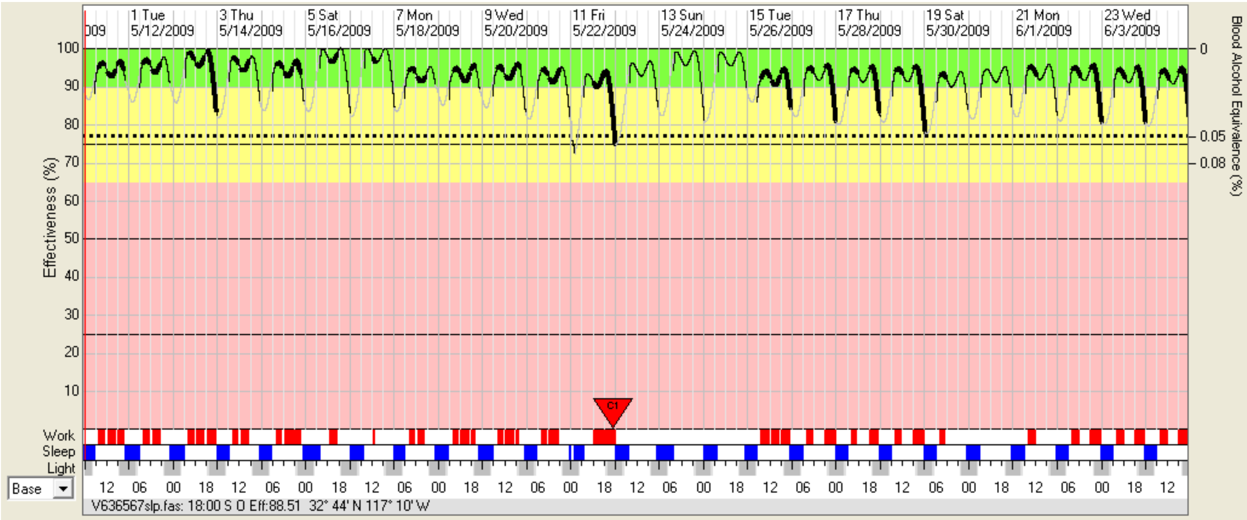
6188


Effectiveness (%)
Blood Alcohol Equivalence (%)
Work
Sleep
Light
Base
V636189slp.fas: 18:00 S O Eff:88.51 32° 44' N 117° 10' W

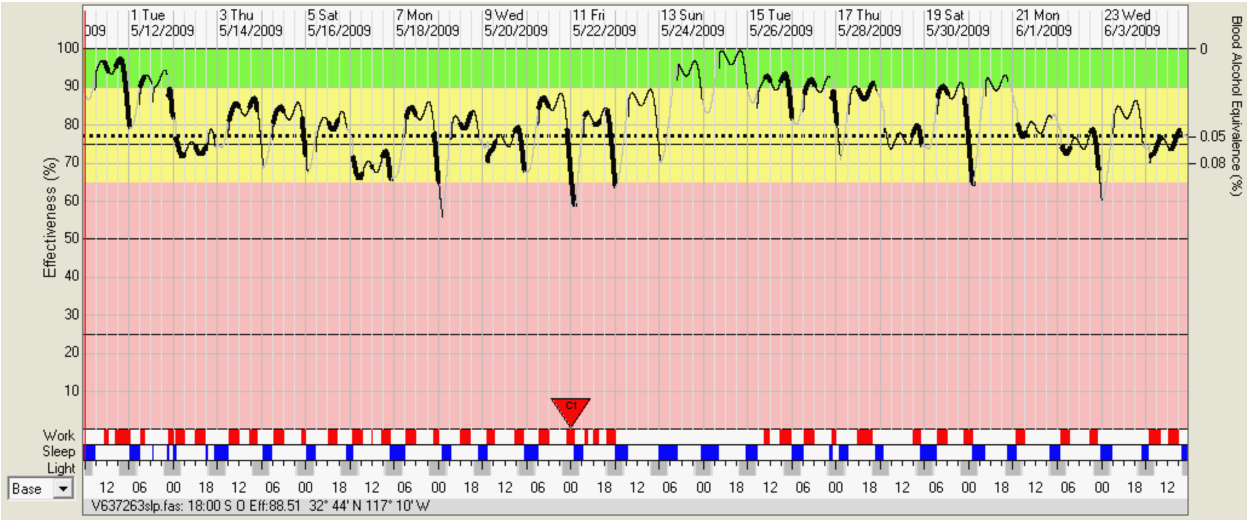
6189


Effectiveness (%)
Blood Alcohol Equivalence (%)
1 Tue 5/12/2009
3 Thu 5/14/2009
5 Sat 5/16/2009
7 Mon 5/18/2009
9 Wed 5/20/2009
11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Work
Sleep
Light
Base
V636366slpBEST.fas: 18:00 S O Eff:88.51 32° 44' N 117° 10' W

6366


Effectiveness (%)
Blood Alcohol Equivalence (%)
1 Tue 5/12/2009
3 Thu 5/14/2009
5 Sat 5/16/2009
7 Mon 5/18/2009
9 Wed 5/20/2009
11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Work
Sleep
Light
Base
V636567slp.fas: 18:00 S O Eff:88.51 32° 44' N 117° 10' W

6567


Effectiveness (%)
Blood Alcohol Equivalence (%)
Work
Sleep
Light
Base
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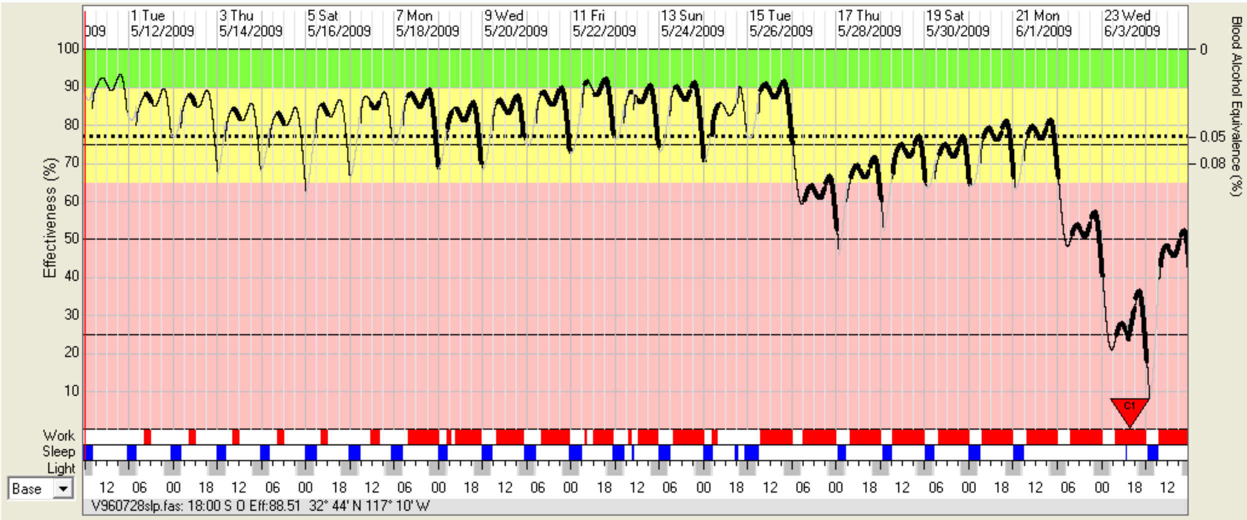
7263


Effectiveness (%)
Blood Alcohol Equivalence (%)
Work
Sleep
Light
Base
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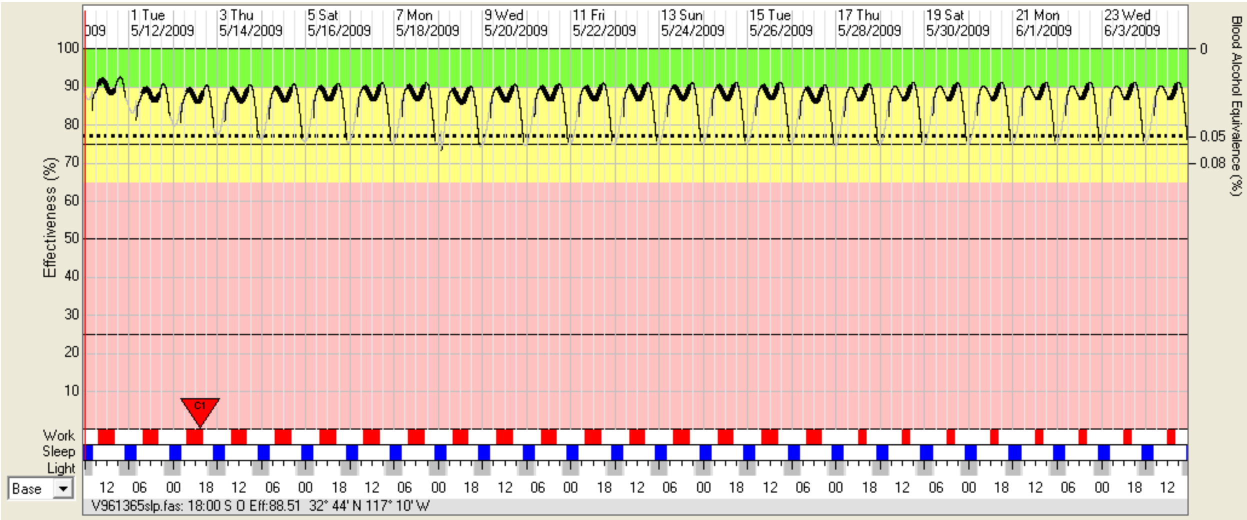
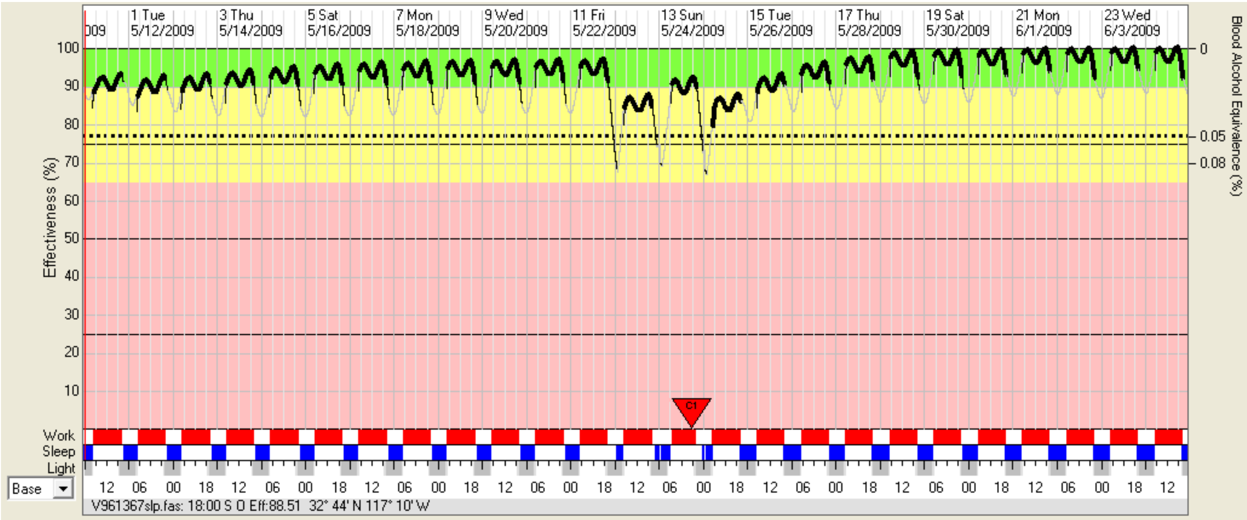
728



1 Tue 5/12/2009
3 Thu 5/14/2009
5 Sat 5/16/2009
7 Mon 5/18/2009
9 Wed 5/20/2009
11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Effectiveness (%)
Blood Alcohol Equivalence (%)
0.05
0.08
Work
Sleep
Light
Base
V961365slp.fas: 18:00 S 0 Eff:88.51 32° 44' N 117° 10' W

1365



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11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Effectiveness (%)
Blood Alcohol Equivalence (%)
0.05
0.08
Work
Sleep
Light
Base
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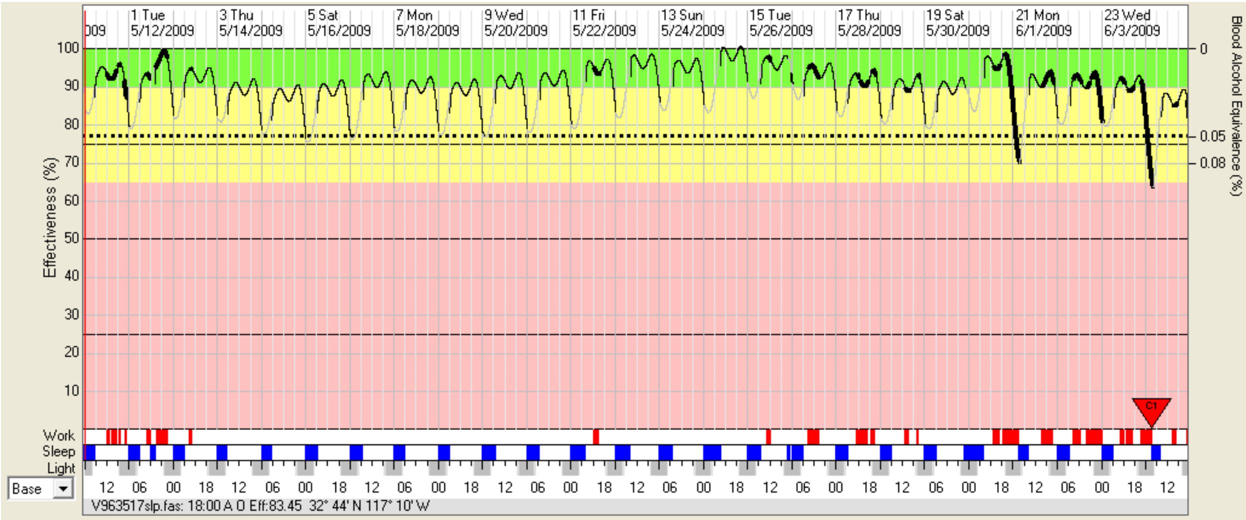
1367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11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Effectiveness (%)
Blood Alcohol Equivalence (%)
0.05
0.08
Work
Sleep
Light
Base
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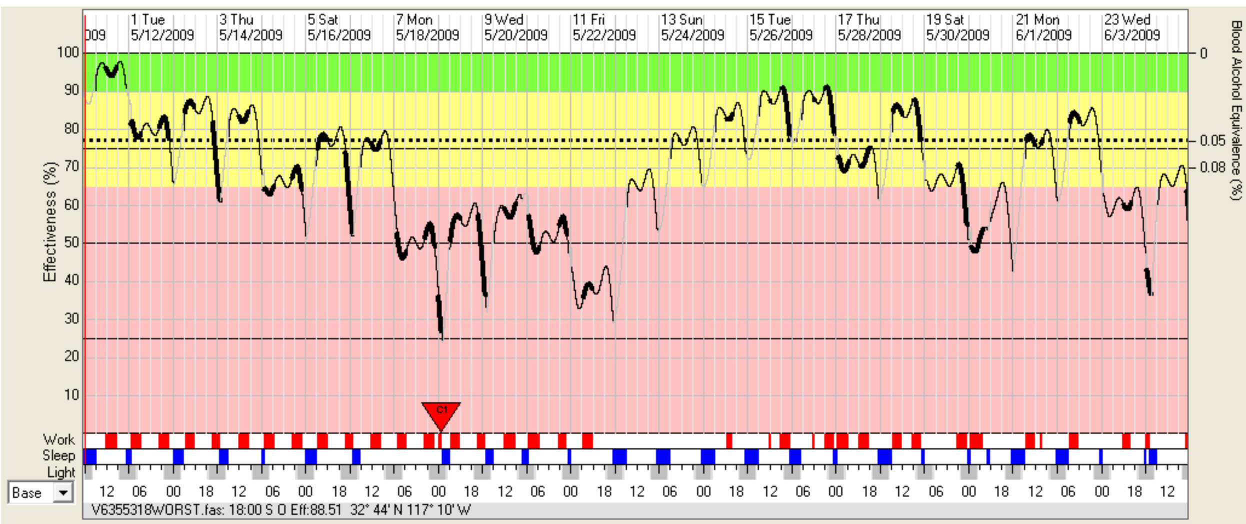
3517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11 Fri 5/22/2009
13 Sun 5/24/2009
15 Tue 5/26/2009
17 Thu 5/28/2009
19 Sat 5/30/2009
21 Mon 6/1/2009
23 Wed 6/3/2009
Effectiveness (%)
Blood Alcohol Equivalence (%)
0.05
0.08
Work
Sleep
Light
Base
V6355318WORST.fas: 18:00 S O Eff:88.51 32° 44' N 117° 10' W

5318

APPENDIX H. FAST OVERALL PREDICTED AVERAGE SLEEP EFFICIENCY

Participant	Sleep Efficiency
728	71.1
1365	79.01
1367	86.72
3517	83.99
5318	63.93
5325	88.55
5328	90.41
5368	87.52
5381	84.34
5421	83.17
5435	84.18
5438	77.65
5593	74.24
5594	75.61
5596	84.92
5597	83.15
5599	75.61
5600	66.25
5601	73.62
6188	81.6
6189	85.9
6366	93.4
6567	85.84
7263	78.04
Overall Predicted Average Sleep Efficiency	80.78

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APPENDIX I. FAST OVERALL PREDICTED AVERAGE PERFORMANCE EFFECTIVENESS

Participant	Performance Effectiveness
728	75.04
1365	85.7
1367	91.32
3517	89.44
5318	68.76
5325	86.83
5328	93.9
5368	90.02
5381	89.68
5421	87.44
5435	86.75
5438	78.48
5593	70.43
5594	80.38
5596	90
5597	88.87
5599	80.38
5600	67.93
5601	77.2
6188	82.94
6189	89.94
6366	96.54
6567	91.43
7263	81.7
Overall Perdicted Average Performance Effectiveness	84.21

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