NPS-OR-15-003

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

SLEEP PATTERNS, MOOD, PSYCHOMOTOR VIGILANCE PERFORMANCE, AND COMMAND RESILIENCE OF WATCHSTANDERS ON THE "FIVE AND DIME" WATCHBILL

by

Nita Lewis Shattuck, Panagiotis Matsangas, and Edward H. Powley

February 2015

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Prepared for: Twenty-First Century Sailor Office, N 171; 5720 Integrity Drive, Millington, TN 38055 and
Advanced Medical Development Program; Naval Medical Research Center; 503 Robert Grant Avenue, Silver Spring, MD 20910

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
28-02-2015

2. REPORT TYPE
Technical Report

3. DATES COVERED *(From-To)*
June 2014 – December 2014

4. TITLE: SLEEP PATTERNS, MOOD, PSYCHOMOTOR VIGILANCE PERFORMANCE, AND COMMAND RESILIENCE OF WATCHSTANDERS ON THE “FIVE AND DIME” WATCHBILL

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S): Nita Lewis Shattuck, Panagiotis Matsangas, and Edward H. Powley

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES):
Operations Research Department, Naval Postgraduate School; Monterey, CA 93943

8. PERFORMING ORGANIZATION REPORT NUMBER
NPS-OR-15-003

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES):
Twenty-First Century Sailor Office, N 171; 5720 Integrity Drive, Millington, TN 38055
Advanced Medical Development Program; Naval Medical Research Center; 503 Robert Grant Avenue, Silver Spring, MD 20910

10. SPONSOR/MONITOR’S ACRONYM(S)
N 171 and AMD/NMRC

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES
The views expressed in this report are those of the author(s) and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

14. ABSTRACT
This study assesses crew rest and sleep patterns, psychomotor vigilance performance, work demands and rest opportunities, organization commitment, and psychological safety and command resilience of Sailors in the Reactor Department on USS Nimitz (CVN 68) (N = 77) working the 5hrs-on/10hrs-off (5/10) watchstanding schedule. Although crewmembers on the 5/10 received approximately seven hours of sleep per day, they reported experiencing excessive fatigue and dissatisfaction with the schedule. This contradiction is best explained by examining sleep and rest periods over a 72-hour period, during which a crewmember sleeps at three distinctly different time periods each day. On the first day of the cycle, the Sailor typically receives an early-terminated 4-hour sleep episode followed by two periods of sustained wakefulness, 22 and 20 hours. During these periods, daytime napping only partially ameliorates the fatigue and sleep debt accrued during these periods of sustained wakefulness. Given this pattern, it is not surprising that at the end of the underway phase, the crewmembers’ moods had worsened significantly compared to moods at the beginning of the underway period. Psychomotor vigilance performance in the 5/10 is comparable to the performance of Sailors on the 6hrs-on/6hrs-off (6/6) schedule. It is significantly degraded compared to Sailors on the modified 6hrs-on/18hrs-off (6/18) and the 3hrs-on/9hrs-off (3/9) schedules. Specifically, the 5/10 had 21.4% slower PVT reaction times, and 71.5% more lapses plus false starts than the 3/9. Our findings suggest that the 5/10 watch, combined with other work duties, leads to poor sleep hygiene. Crewmembers on the 5/10 suffer from sustained wakefulness because of extended workdays and circadian-misaligned sleep times. In general, the self-reported survey results suggest low degrees of resilience, psychological commitment to the organization, and psychological safety. In terms of organizational commitment, participants report that they do not talk positively about their department and do not view their department as inspiring performance. Conversely, Sailors report a high degree of willingness to put in effort beyond expectations, even though overall results indicate low psychological attachment to the unit as a place for working and completing work tasks. Results also show low levels of psychological safety.

15. SUBJECT TERMS
Watch schedules, sleep, psychomotor vigilance performance, command resilience

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			
Unclassified	Unclassified	Unclassified	Unclassified	70	Nita Lewis Shattuck
					19b. TELEPHONE NUMBER (831) 656-2281

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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NAVAL POSTGRADUATE SCHOOL
Monterey, California 93943-5000

Ronald A. Route President	Douglas Hensler Provost

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Paul J. Nicholas
Operations Research Analyst

ALDERSON.DAVID.L.JR.1292960294 Digitally signed by ALDERSON.DAVID.L.JR.1292960294 DN: c=US, o=U.S. Government, ou=DoD, ou=PKI, ou=USN, cn=ALDERSON.DAVID.L.JR.1292960294 Date: 2015.01.15 10:41:32 -08'00'

David L. Alderson
Associate Professor of Operations Research

Reviewed by:

Johannes O. Royset
Associate Chairman for Research
Department of Operations Research

Robert F. Dell
Chairman
Department of Operations Research

Released by:

Jeffrey D. Paduan
Vice President and
Dean of Research

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ABSTRACT

This study assesses crew rest and sleep patterns, psychomotor vigilance performance, work demands and rest opportunities, organization commitment, and psychological safety and command resilience of Sailors in the Reactor Department on USS Nimitz (CVN 68) (N = 77) working the 5hrs-on/10hrs-off (5/10) watchstanding schedule. Although crewmembers on the 5/10 received approximately seven hours of sleep per day, they reported experiencing excessive fatigue and dissatisfaction with the schedule. This contradiction is best explained by examining sleep and rest periods over a 72-hour period, during which a crewmember sleeps at three distinctly different time periods each day. On the first day of the cycle, the Sailor typically receives an early-terminated 4-hour sleep episode followed by two periods of sustained wakefulness, 22 and 20 hours. During these periods, daytime napping only partially ameliorates the fatigue and sleep debt accrued during these periods of sustained wakefulness. Given this pattern, it is not surprising that at the end of the underway phase, the crewmembers' moods had worsened significantly compared to moods at the beginning of the underway period. Psychomotor vigilance performance in the 5/10 is comparable to the performance of Sailors on the 6hrs-on/6hrs-off (6/6) schedule. It is significantly degraded compared to Sailors on the modified 6hrs-on/18hrs-off (6/18) and the 3hrs-on/9hrs-off (3/9) schedules. Specifically, the 5/10 had 21.4% slower PVT reaction times, and 71.5% more lapses plus false starts than the 3/9. Our findings suggest that the 5/10 watch, combined with other work duties, leads to poor sleep hygiene. Crewmembers on the 5/10 suffer from sustained wakefulness because of extended workdays and circadian-misaligned sleep times. In general, the self-reported survey results suggest low degrees of resilience, psychological commitment to the organization, and psychological safety. In terms of organizational commitment, participants report that they do not talk positively about their department and do not view their department as inspiring performance. Conversely, Sailors report a high degree of willingness to put in effort beyond expectations, even though overall results indicate low psychological attachment to the unit as a place for working and completing work tasks. Results also show low levels of psychological safety.

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I. INTRODUCTION

Researchers from the Naval Postgraduate School were contacted by the Commanding Officer, USS Nimitz (CVN 68), to assess the fatigue levels of USS Nimitz crewmembers while conducting underway operations. The primary focus of the assessment was the Reactor (RX) Department, although individuals from other departments on the ship were also encouraged to participate.

A. SCOPE

Based on a sample of USS Nimitz RX Department crewmembers, this study focused on the 5hrs-on/10hrs-off (5/10) watchstanding schedule in terms of:

- Sleep quantity and quality, daytime sleepiness, sleep conditions;
- Workload and compliance to the Navy Standard Workweek (NSWW) model;
- Psychomotor vigilance performance;
- Fatigue Avoidance Scheduling Tool (FAST) predicted effectiveness; and
- Assessment of organization commitment, psychological safety, and command resilience in the RX Department.

Beyond the RX Department's crewmembers on the 5/10 watchstanding schedule, the following information is also included:

- Appendix: This appendix focuses on the Command Resilience Questionnaire (CRQ) and the associations between the CRQ, demographic information, sleep, Epworth Sleepiness Scale (ESS), Profile of Mood States (POMS), the Organizational Commitment Questionnaire (OCQ) scores, and the Psychological Safety Questionnaire (PSQ) scores.

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II. METHODS

A. EXPERIMENTAL DESIGN

This study was quasi-experimental in nature.

B. PARTICIPANTS

Participants were volunteers from the USS Nimitz aircraft carrier. Although the study focused on crewmembers from the RX Department, a number of crewmembers from two other departments, Supply and Medical, also volunteered to participate.

C. EQUIPMENT AND INSTRUMENTS

1. Surveys

The prestudy survey included demographic information and three standardized questionnaires. Questions included age, gender, rate/rank, department, years on active duty, total months deployed, factors affecting sleep, type and frequency of caffeinated beverage use (e.g., tea, coffee, soft drinks, energy drinks), type and frequency of tobacco product use (e.g., cigarettes, chewing tobacco, nicotine gum or patches, electronic smoke), use of medication (prescribed or over-the-counter), and the type and frequency of an exercise routine.

The ESS was used to assess average daytime sleepiness (Johns, 1991). The individual used a 4-item Likert scale to rate the chance of dozing off or falling asleep in eight different everyday situations. Scoring of the answers was 0 to 3, with 0 being "would never doze," 1 being "slight chance of dozing," 2 being "moderate chance of dozing," and 3 denoting a "high chance of dozing." Respondents were instructed to rate each item according to his/her usual way of life in recent times. Responses were summed to the total score. A sum of 10 or more reflects above normal daytime sleepiness and a need for further evaluation (Johns, 1992). The ESS questionnaire has a high level of internal consistency, as measured by Cronbach's alpha, ranging from 0.73 to 0.88 (Johns, 1992).

To measure mood states and assess changes in mood, participants filled out the POMS (McNair, Lorr, & Droppelman, 1971). The POMS is a standardized, 65-item inventory originally developed to assess mood state in psychiatric populations. The questionnaire assesses the dimensions of the mood construct using six subscales: anger - hostility (12 items; range 0-48), confusion - bewilderment (7 items; range 0-28), depression (15 items; range 0-60), fatigue (7 items; range 0-28), tension - anxiety (9 items; range 0-36) and vigor - activity (8 items; range 0-32). Vigor is subtracted and the Total Mood Disturbance (TMD) score is derived by adding the subscales (range 0-200). Normalized scores (T-scores) are based on norms for adults (Nyenhuis, Yamamoto, Luchetta, Terrien, & Parmentier, 1999). The POMS was administered using the instruction set: "Describe how you felt during the past two weeks." Positive mood has been associated with better within-team communication behaviors and enhanced team awareness (Pfaff, 2012).

The posttest survey included the ESS, Pittsburgh Sleep Quality Index (PSQI), POMS, a morningness-eveningness preference scale, and a Command Climate questionnaire. Participants were asked to indicate their watchstanding schedule, the adequacy of their own and their peers' sleep (5-point Likert scale: "Much less than needed"; "Less than needed"; "About right"; "More than needed"; "Much more than needed"), and to compare their workload during the data collection period with their normal workload underway (5-point Likert scale: "Much less than usual," "Less than usual"; "About the same"; "More than usual"; "Much more than usual"). The posttest survey also included two open-ended questions ("What did you like most about your current watch schedule?" and "What did you like least about your current watch schedule?").

The self-administered morningness-eveningness questionnaire (MEQ-SA) (Terman, Rifkin, Jacobs, & White, 2001) was used to assess participants' chronotype, an attribute of human beings related to their preference for waking earlier or later in the day. The scale includes 19 multiple-choice questions. Scores range from 16 to 86, with scores less than 42 corresponding to evening chronotypes and scores higher than 58 indicating morning chronotypes. Although based on the Horne and Östberg (1976) original MEQ scale, the MQE-SA has some stem questions and item choices rephrased to conform with spoken American English. Discrete item choices have been substituted for continuous graphic scales.

Participants' sleep history was assessed using the PSQI (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), which includes 18 questions that yield seven component scores (sleep quality, sleep latency, duration, sleep efficiency, sleep disturbances, sleep medication use, and daytime dysfunction) rated from 0 (better) to 3 (worse). The total score, ranging from 0 (better) to 21 (worse), is the summation of the component scores. Individuals with a PSQI total score of ≤ 5 are characterized as good sleepers, whereas scores >5 are associated with poor sleep quality. The PSQI has a sensitivity of 89.6%, a specificity of 86.5% ($\kappa = 0.75$, $p < 0.001$), and an internal consistency $\alpha = 0.83$ (Buysse et al., 1989).

The Organizational Commitment Questionnaire (OCQ) was used to assess organizational commitment (Brockner et al., 2004), which refers to an individual's psychological attachment to the organization, and is differentiated from job satisfaction or feelings about one's job (Dirani & Kuchinke, 2011), and organizational identification or the degree to which someone experiences a "sense of oneness" with the organization (Riketta, 2005). In the 3-item OCQ, individuals rate their commitment to their immediate organizational unit ("I talk up my department as a great place to work"; "I am willing to put in effort beyond what is normally expected"; "My department really inspires the very best in me in the way of job performance"). Based on a 5-point Likert scale, the responses in the three questions are scored from 1 (strongly disagree) to 5 (strongly agree). The OCQ score is the average of the responses for the three items, ranging from 1 (least favorable) to 5 (most favorable).

The PSQ was used to assess an individual's tolerance for interpersonal risk taking (Edmondson, 1999). At the department level, psychological safety centers on whether members feel respected, accepted, and valued. It is associated with learning at the team level (Edmondson, 2003). The PSQ is a 6-item tool ("Members of this department value and respect each other's contributions"; "In this department, people are sometimes rejected for being different"; "In this department it is easy to discuss difficult issues and problems"; "It is completely safe to take a risk in this department"; "It is difficult to ask other members of this department for help"; "When someone makes a mistake in this department it is often held against him or her"). Based on a 5-point Likert scale, the responses in each question are scored from 1 (strongly disagree) to 5 (strongly agree), except for three reverse-scored questions. The PSQ score is the average of the responses in the six items ranging from 1 (least favorable) to 5 (most favorable).

The Command Resilience Questionnaire (CRQ) was used to obtain perceptions of unit-level resilience. The profile has been in development for use in military commands (Powley & Lopes, 2011), and as in the case of this report, the profile was administered at the department level. The CRQ includes four underlying factors: leadership, recovery, learning orientation, and mutual support, measured by 14 items. Leadership refers to the ability to see and understand challenges and the vision to work through them, and includes 3 items ("Our immediate supervisor establishes a clear vision"; "Our immediate supervisor looks out for our best interests"; "Our immediate supervisor cares about our future well-being"). Recovery refers to the agility and flexibility for recovery from challenging situations, and includes 3 items ("We usually manage difficulties one way or another at work"; "We recover from challenges that affect our day-to-day operations"; "We push forward despite setbacks"). Learning orientation refers to the ability to learn from mistakes and setbacks, and to locate information to help learn from stress and challenges; the measure includes 5 items ("We often take time to figure out ways to improve our work processes"; "We try to discover assumptions or basic beliefs about issues under discussion"; "We discuss how we could have prevented unexpected challenges"; "We take time to discuss challenges with others outside our department"; "We seek insights from those outside our department"). Mutual support denotes the ability to develop positive relationships, and to know how to draw on those relationships when stresses arise, and includes 3 items ("We help members of our department get help"; "We look after and support each other"; "We turn toward each other for support and help").

The command resilience profile attempts to understand resilience at the command level and begins with a prompt whereby participants are instructed to consider times when the department or work center faced setbacks or significant challenges. That is, as participants responded to the items, they did so while thinking about difficulties and setbacks within their department. Based on a 5-point Likert scale, the responses in each question are scored from 1 (strongly disagree) to 5 (strongly agree), except from the three reverse-scored questions. The score of each factor (leadership, learning, mutual support, recover) is the average of the responses in the corresponding items. The CRQ score is the average of the four factor scores. All scores range from 1 (least favorable) to 5 (most favorable).

2. Actiwatches

Two actigraphs were used, the Motionlogger Watch (Ambulatory Monitoring, Inc. [AMI]; Ardsley, New York), and the Spectrum (Philips-Respironics [PR]; Bend, Oregon) actiwatch. Data for both devices were collected in 1-minute epochs. AMI data (collected in the Zero-Crossing Mode) were scored using Action W version 2.7.2155 software. The Cole-Kripke algorithm with rescoring rules was used. Criterion for sleep and wake episodes was five minutes. The sleep latency criterion was no more than one minute awake in a 20-minute period (all values are default for this software). PR data were scored using Actiware software version 6.0.0 (Phillips Respironics; Bend, Oregon). The medium sensitivity threshold (40 counts per epoch) was used, with 10 immobile minutes the criterion for sleep onset and sleep end (all values are default for this software). Previous research has shown that AMI data analyzed with Cole-Kripke and PR data analyzed with medium sensitivity parameters assess total sleep time for an approximately 8-hour night sleep episode with 3-minute precision (average results compared to polysomnography derived 436 minutes of sleep) (Meltzer, Walsh, Traylor, & Westin, 2012). There were no differences in daily time in bed (TIB) or total sleep time (TST) for RX Department participants wearing the AMI and PR actiwatches (Wilcoxon Rank Sum test for all differences $p > 0.500$).

3. Activity Logs

All participants were asked to complete an activity log, documenting their daily routine in accordance with NSWW categories. The activity logs covered a 24-hour period in 15-minute intervals.

4. Psychomotor Vigilance Test (PVT)

Performance data were collected using the PVT (Dinges & Powell, 1985). PVT performance is not only affected by sleep loss, but it has also been shown to be sensitive to circadian rhythmicity (Dinges et al., 1997; Doran, Van Dongen, & Dinges, 2001;

Durmer & Dinges, 2005; Jewett, Dijk, Kronauer, & Dinges, 1999; Wyatt et al., 1997). The PVT is a simple reaction time test where participants are required to press a button in response to a visual stimulus. Because of its simplicity, the PVT has very minor learning effects, which can be reached in one to three trials (Dinges et al., 1997; Jewett et al., 1999; Kribbs & Dinges, 1994; Rosekind et al., 1994). The PVT nominal inter-stimulus interval (ISI), defined as the period between the last response and the appearance of the next stimulus, randomly ranges from 2 to 10 seconds. The original version of the PVT has a duration of 10 minutes (Loh, Lamond, Dorrian, Roach, & Dawson, 2004); however, shortened versions have also recently been validated to assess sleep deprivation effects (Basner & Dinges, 2011; Loh et al., 2004). Operational demands precluded the use of the 10-minute version in this study; therefore, we used a 3-minute version of PVT included on the AMI actigraphs, with ISI ranging from 2 to 10 seconds. A red backlight appeared for one second and the letters "PUSH" were used as visual stimuli; the response time was then displayed in milliseconds.

5. The Fatigue Avoidance Scheduling Tool (FAST)

FAST is based on the Sleep and Fatigue, Task Effectiveness (SAFTE) model, and was developed for the U.S. Department of Defense. The Naval Safety Center has recently determined that SAFTE/FAST will be a mandatory requirement in all mishap investigations (Department of the Navy, 2014). SAFTE/FAST has been validated using actual aircrew performance and provides a tool for assessing and mitigating fatigue in shiftwork environments and aviation duty schedules.

The SAFTE/FAST model has been used to assess predicted effectiveness, a measure of cognitive performance, ranging from 100% (best) to 0% (worst) (Hursh et al., 2004). According to the FAST manual, normal daytime performance following an 8-hour period of excellent sleep at night yields a predicted effectiveness that ranges between 90% and 100%, which is the green zone on the FAST graph. Predicted effectiveness between 65% and 90%, the yellow zone on the FAST graph, is the range of performance observed during the 24-hour period after missing one night of sleep. Predicted effectiveness below 65%, the red zone on the FAST graph, indicates performance that is well below the level acceptable for operations. The red zone represents performance of two full days and a night of sleep deprivation. Reaction times for individuals in the red zone are more than twice their normal level.

D. PROCEDURES

The study protocol was approved by the Naval Postgraduate School Institutional Review Board. Data collection on USS Nimitz was from June 10 to June 27, 2014. The ship was in port from 10 to 15 June, with a brief underway during the daytime hours on 13 June. The ship was at sea from 15 to 27 June. During the entire study period, however, the RX Department was in a simulated underway environment due to reactor plant startup-shutdown and run procedures.

RX Department personnel were briefed on the research protocol and study procedures over three separate presentations. Personnel wishing to volunteer signed consent forms and received further training prior to being issued equipment for the study. The participants filled out the prestudy surveys upon receipt of their sleep watches and activity logbooks. All participants were instructed to fill out their activity logs daily and, at a minimum, complete a PVT prior to and after their watchstanding period. Upon completion of the study, the participants returned their equipment and filled out an end-of-study survey.

E. ANALYTICAL APPROACH

1. Actigraphy Data Cleaning and Reduction Procedures

The preparation of the actigraphy data for analysis included three steps. First, we evaluated the number of days of data available for each participant. Participants with fewer than five days of data were excluded from this analysis.

Next, we compared the actigraphy data with the activity logs. The primary source for the sleep analysis was the actigraphy data, but sleep logs assisted in the determination of start and end times of sleep intervals. Based on this comparison, we manually identified the start and end times of sleep episodes in the actigraphy data. The criteria used to determine whether we could use the data or whether imputation was required included the quality of the actigraphy data, the consistency of activity patterns over consecutive days, the amount of missing data, whether the participant was a watch-stander, and the accuracy of the sleep log. Imputation was applied only when: (a) there was a gap in actigraphy data within which the sleep log showed a sleep interval, and (b) the pattern of actigraphy data, assisted by the activity logs, was such to assure a confidence in the interpolation of a sleep interval.

Based on the actigraphy data, an initial database of sleep intervals was developed. Analysis included actigraphy data from June 10 to June 27, 2014. From the 2,391 rest intervals, 71 (2.97%) were imputed. From the rest/in-bed intervals (identified as DOWN in the AMI software, and REST in Phillips) the time in-bed (TIB) was calculated. Within each rest interval, the actigraphically-assessed sleep was calculated.

2. PVT Data Cleaning and Reduction Procedures

Psychomotor vigilance performance data were collected using the PVT version included in the AMI Motionloggers. PVT data were not available for participants wearing the Respironics actiwatches. The duration of each PVT trial was 3 minutes, with a minimum interstimulus interval (ISIMin) of 2 seconds, and a maximum interstimulus interval (ISIMax) of 10 seconds. PVT analysis was based on 1,861 trials. All PVT responses were aggregated first by trial and then by participant. PVT performance metrics were analyzed between participants. No imputation was used with the PVT data.

PVT data were analyzed based on the metrics proposed by Basner and Dinges (2011) for individuals with chronic sleep deprivation. Responses without a stimulus or with RTs < 100 milliseconds (ms) were identified as false starts. Lapses were defined as RTs equal to, or greater than, 355 ms, 500 ms. 600 ms, and 750 ms.

This data set, however, included some outlying values with reaction times of 10 seconds or more. Given that the PVT was not performed in controlled conditions, we postulate that these responses may be attributed to distracting environmental factors, such as noise or crewmember distractions, rather than excessive fatigue. For this reason, we omitted those responses with RT ≥ 10 seconds from RT calculations, although we still counted them as lapses and included them in the calculation of lapses ($n = 71$ responses). With the settings used, approximately 18-24 PVT responses were expected in a 3-minute PVT. Trials with fewer than 10 responses were omitted from analysis ($n = 137$). One trial was also omitted from the analysis because it included 38 false starts.

3. Sleep Log Data Cleaning and Reduction Procedures

Activity logs were used to analyze work and rest patterns in the actigraphy data. Workload analysis was focused on the crewmembers of the RX Department in the 5/10 watch schedule. Sleep log data were entered into a spreadsheet and screened for completeness and accuracy. Specifically, we looked for missing activity information or instances of noncompliance with the sleep log instructions (e.g., adding activity codes not included in the instruction set).

When deemed appropriate, days with missing activity were interpolated. The criteria for interpolation were the accuracy of the sleep log, the pattern of activities over consecutive days, the length of missing data, whether the participant was a watchstander, and the existence of actigraphy data. Some logs were evaluated as inaccurate for purposes of interpolation because their information did not correlate well with the actigraphy data. The pattern of activities was a critical criterion; if the participant did not have a consistent daily pattern of activities, then it was difficult to infer activities for missing days. Actigraphy assisted in evaluating the actual sleep periods and, hence, deduct the watch period when integrating information from the posttest questionnaire, where participants reported their predominant watch schedule. Overall, we attempted to interpolate as little as possible given the utility and accuracy of the available information sources.

4. Analysis Roadmap

Statistical analysis was conducted with a statistical software package (JMP Pro 9; SAS Institute; Cary, North Carolina). Data are presented as mean (M) ± standard deviation (SD) or median (MD), as appropriately needed. Significance level was set at $p < 0.05$. Nonparametric methods were used; Wilcoxon Rank Sum test, and for multiple comparisons, the Dunn method for joint ranks. Correlation analysis was performed using the nonparametric Spearman's *rho*.

First, all variables underwent descriptive statistical analysis to describe our population in terms of demographic characteristics and ESS scores. Next, analysis focused on daily rest and sleep; a comparison was conducted between the RX Department results with three earlier datasets, participants on a modified 6hrs-on/18hrs-off (6/18) watch schedule, a 3hrs-on/9hrs-off (3/9) watch schedule, and participants on a 6hrs-on/6hrs-off (6/6) watch schedule. Based on activity logs, workload and sleep pattern analysis was compared to the criteria specified in the NSWW model.

Next, a correlational analysis was conducted among mood states, daily rest and sleep duration, and ESS scores. One comparison identified changes in POMS scores between the beginning and end of the study. PVT metrics were calculated for each participant and compared with earlier results. Comparisons were conducted using the nonparametric Wilcoxon Rank Sum test; multiple comparisons were conducted with the nonparametric Dunn method for joint ranking accounting for family-wise error. Correlational analysis was based on the nonparametric Spearman's *rho*. Sleep patterns for a typical 3-day rotation cycle of the 5/10 watch schedule were input in FAST to assess predicted effectiveness.

Although not the main focus of this report, we also assessed the association between poststudy ESS scores, daily rest/sleep duration, and 11 PVT metrics. Initially, a correlational analysis was conducted between the poststudy ESS scores, daily rest/sleep duration, and the 11 PVT metrics. Then, a comparison of mean values and variability (using Levene's test) was made between two groups: participants with Epworth scores less than or equal to10 (referred to as the Normal Group) and participants with Epworth scores greater than 10 (referred to as the Elevated Group).

Next, analysis focused on command resilience. In the main body of this report, we have included the descriptive analysis of the RX Department command resilience. However, a detailed analysis of command resilience, based on the entire data set (N = 131), follows in the Appendix.

III. RESULTS

A. BASIC INFORMATION

Overall, 131 crewmembers volunteered to participate in the study (Reactor = 110, Medical = 9, Supply = 12). All participants from the Supply Department were Culinary Specialists. The nine members from the Medical Department had varied ranks and ratings. Table 1 shows participants' demographic information by ship's department.

Table 1. Demographic information.

Demographics	Reactor Dept. (n = 110)	Reactor Dept. on 5/10 (n = 77)	Medical Dept. (n = 9)	Supply Dept. (n = 12)
Age (Years)	26.0 ± 4.01	25.3 ± 3.17	29.7 ± 9.31	30 ± 9.26
Gender	22 F, 88 M	14 F, 63 M	3 F, 6 M	3 F, 9 M
Rank				
Officers	2	1	2	–
Enlisted	108	76	7	12
Active Duty (Years)	5.24 ± 3.49	4.87 ± 2.65	9.82 ± 7.38	8.52 ± 7.06
Total Deployment (Months)	13.4 ± 14.8	13.8 ± 13.2	18.4 ± 10.2	22.3 ± 23.1
PSQI Global Score	9.58 ± 2.91	9.73 ± 2.89	8.89 ± 4.73	8.82 ± 2.32
"Poor" Sleepers [a]	91%	95%	78%	100%
ME Preference Score [b]	51.0 ± 8.06	51.9 ± 8.31	52.1 ± 11.2	53.3 ± 6.85
ME Preference Type [b]				
Definitely Morning	1	1	1	
Moderately Morning	21	19	1	3
Intermediate	74	48	6	9
Moderately Evening	13	9	1	
Definitely Evening				

[a] PSQI score > 5; [b] ME denotes Morningness-Eveningness

Our analysis (see Figures 1, 2, and 3) focused solely on the participants of the RX Department, who were working the 5/10 watch schedule. The most frequent factor Sailors reported to affect their sleep was inadequate time to sleep (88%), followed by noise (73%), and temperature (56%) in the berthing compartment. Ship's motion was the least common factor cited by Sailors on the Nimitz, which is not surprising due to reduced motion resulting from the size of the aircraft carrier. The reported sources of noise were noise from inside and outside the berthing compartment, other people and noise from 1 Main Circuit (1MC).

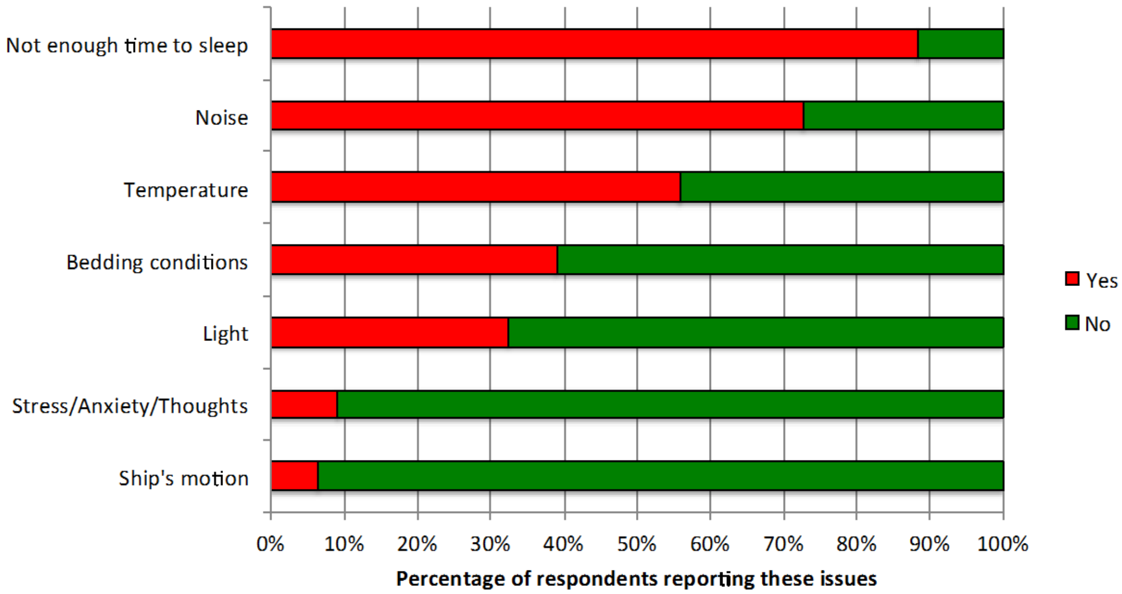

Figure 1. Factors affecting sleep.

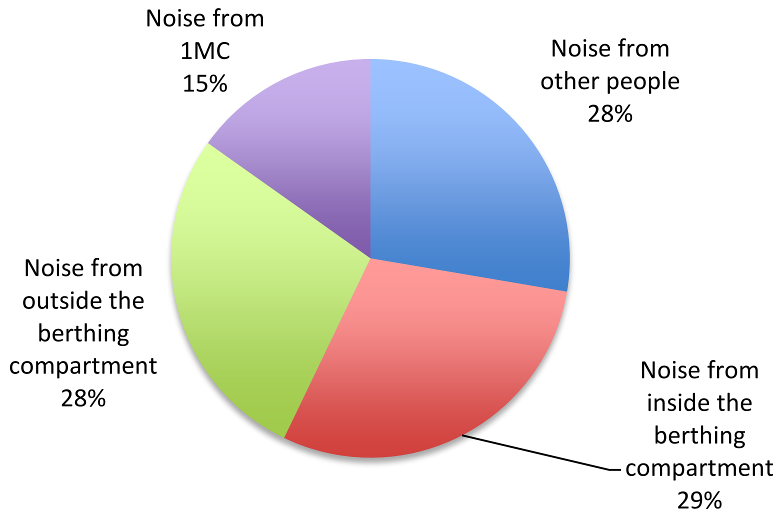

Figure 2. Sources of noise affecting sleep.

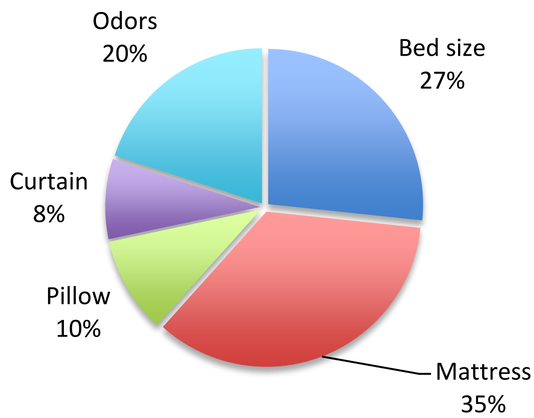

Figure 3. Sources of complaints about berthing/bedding conditions (RX Department only).

Next, participants reported the type and frequency of caffeinated beverages consumed (see Figure 4). Overall, 95% indicated drinking caffeinated beverages, with energy drinks being the most frequent (64%), followed by soft drinks (52%) and coffee (47%). The two most frequently used energy drinks were Monster ™ and Red Bull ™ (93.9%). The reported daily amount of energy drinks consumed ranged from 1 to 3 (MD = 1), 1 to 3.5 soft drinks (MD = 2), and 1 to 6 cups of coffee (MD = 2.5).

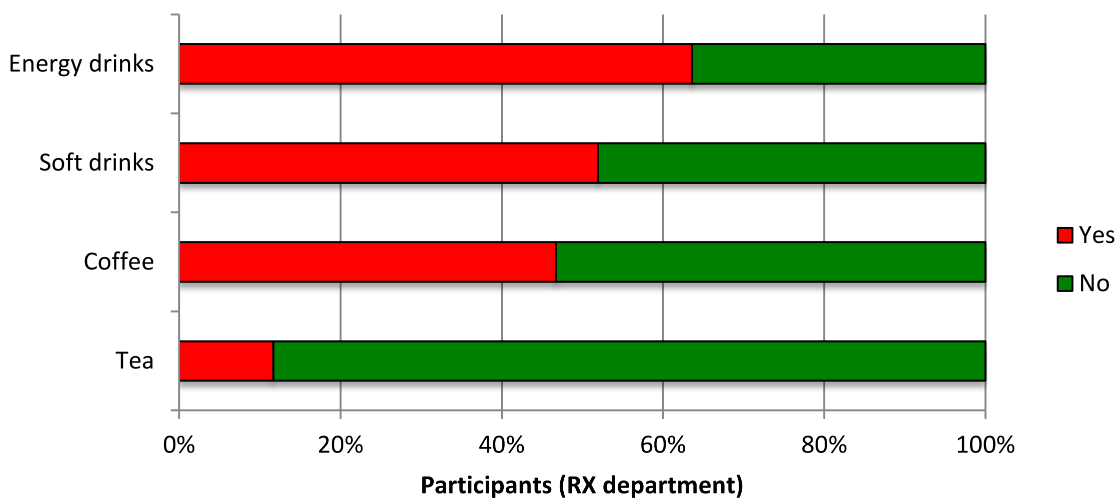

Figure 4. Consumption of caffeinated beverages (RX Department only).

Regarding the use of nicotine products, cigarettes were used by 20 participants, followed by electronic smoke (n = 9), chewing tobacco/snuff (n = 8), and cigars (n = 2).

Prescription or over-the-counter medications (e.g., Advil, Tylenol, Allegra, birth control pills, or vitamins) were used by 12 participants (16%).

More than half of the participants (60.3%) had a workout routine 3 to 4 times per week, with an average duration of one hour; mainly weight lifting and aerobic exercise.

Participants in the RX Department were not satisfied with the amount of sleep they received. Approximately 21% rated their amount of sleep as about right, whereas 79% found their sleep amount less (71.4%) or much less (7.80%) than what they needed. The sleep of other Sailors was also rated as less (62.2%) or much less (16.2%) than needed. Approximately 55% of the participants reported that their workload during the 2.5 weeks of the study did not differ from their normal workload underway. It is notable, though, that approximately 34% reported that their workload was less (31.2%) or much less (2.60%) than normal; some comments suggested that their daily routine was altered because of this study and, hence, watchstanders received more sleep ("Chain of command was relaxed this underway on watchstanders getting required sleep"; "I feel as if the COC let us off more to show that we had free time"; "The chain of command (possibly intentionally) changed the work day/altered the work load to support the sleep study").

The ESS was used to assess average daytime sleepiness (Johns, 1991); results are shown in Figure 5. The average ESS score at the beginning of the study was 9.66 ± 4.07 (MD = 10). These ESS scores suggested that 39% of the participants demonstrated increased daytime sleepiness (ESS score > 10) (Johns, 1991) even before the commencement of the underway. At the end of the study, the average ESS score increased to 10.8 ± 4.65 (MD = 11) ranging from 0 to 21 (matched pairs Wilcoxon Rank Sum test, S = 392, $p = 0.011$. The average poststudy ESS score indicated that 52% of the participants had excessive daytime sleepiness.

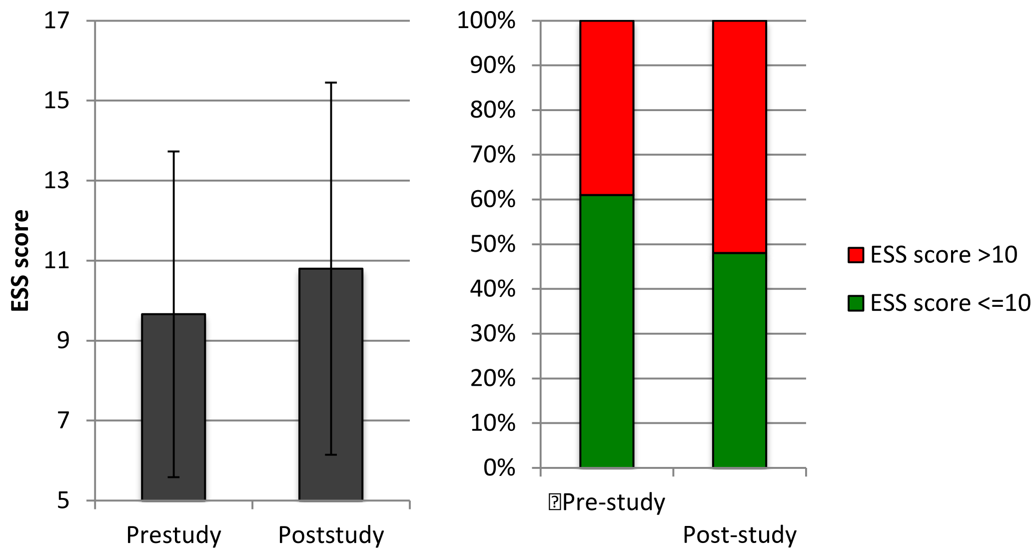

Figure 5. ESS scores comparisons.

B. SLEEP

The daily rest and sleep duration from the RX Department working 5/10 were compared with sleep data from three other ship samples. Rest and sleep of crewmembers in the RX Department compared favorably with the patterns of Sailors on the 3/9 schedule, but was significantly higher than the 6/6 and the modified 6/18 watch schedules. These results are shown in Table 2 and Figure 6.

Table 2. Daily sleep by watchstanding schedule.

Variable	RX Department 5/10 (n = 70) M ± SD	Modified 6/18 (n = 34) M ± SD	3/9 (n = 24) M ± SD	OPS 6/6 (n = 9) M ± SD
Daily Rest (Hours)	7.52 ± 0.909 [a,b]	6.62 ± 1.66	7.25 ± 0.781	6.54 ± 0.944
Daily Sleep (Hours)	6.88 ± 0.894 [a,b]	5.65 ± 1.63	6.54 ± 0.800	5.90 ± 0.898
Number of Rest Episodes per Day	1.55 ± 0.282	1.86 ± 0.518	–	–

[a] Statistically different from the modified 6/18 (nonparametric comparison with Dunn method for joint ranking, $p < 0.05$)
[b] Statistically different from the 6/6 (nonparametric comparison with Dunn method for joint ranking, $p < 0.05$)
[c] Statistically different from the modified 6/18 (nonparametric comparison with Wilcoxon Rank Sum test, $p = 0.002$)

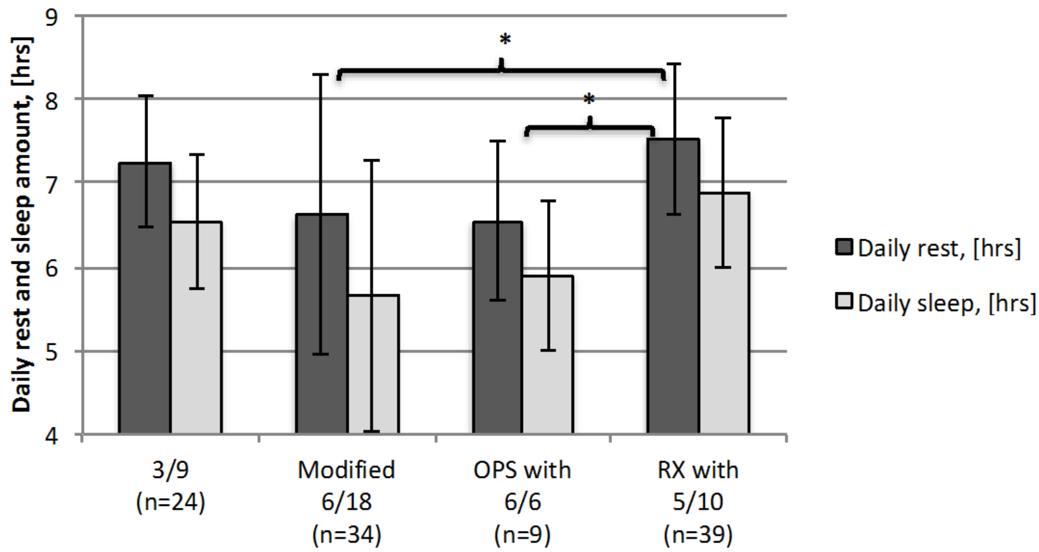

Figure 6. Daily rest and sleep amount. The asterisk denotes a statistical significant difference at the a = 0.05 level.

A nonparametric analysis, based on Spearman's *rho*, showed that daily rest and sleep duration were not correlated with age ($p > 0.50$), but they *were* correlated with the number of rest episodes per day (Rest: *rho* = 0.388, $p < 0.001$; Sleep: *rho* = 0.352, $p = 0.003$).

To further assess the impact of the 5/10 watch schedule, we analyzed the participant responses in two open-ended questions. From the 55 crewmembers answering the question "What did you like most about your current watch schedule?", approximately 38% responded they did not like anything about the 5/10 watch schedule, 18% liked being relieved by the "floating" team, and 13% liked being able to sleep later in the morning after a night watch (see Figure 7).

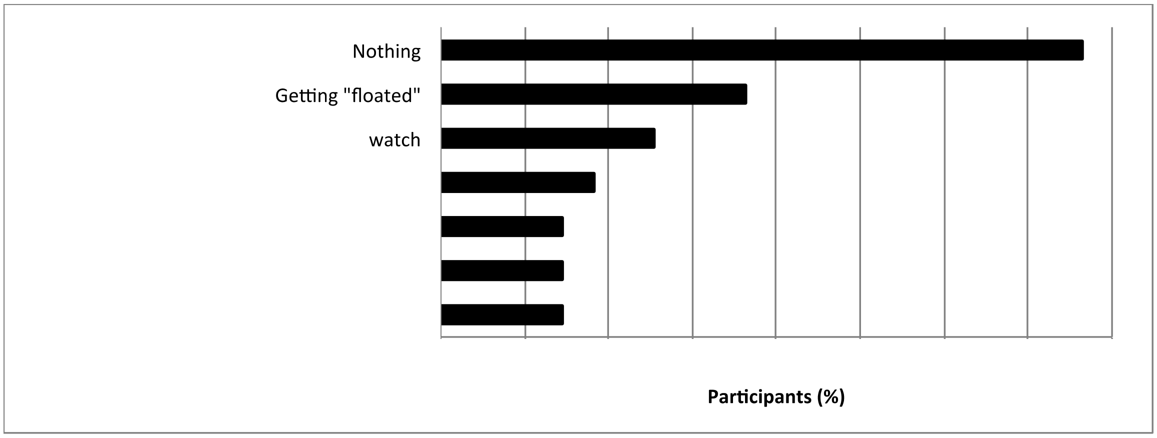

Figure 7. Responses to the question "What did you like most about your current watch schedule?"

From the 69 crewmembers answering the question "What did you like least about your current watch schedule?", approximately 73% responded that there is little time for other duties, working out, meals, and sleeping (there are only 10 hours between consecutive watches), whereas 32% noted the irregularity of sleeping times (see Figure 8).

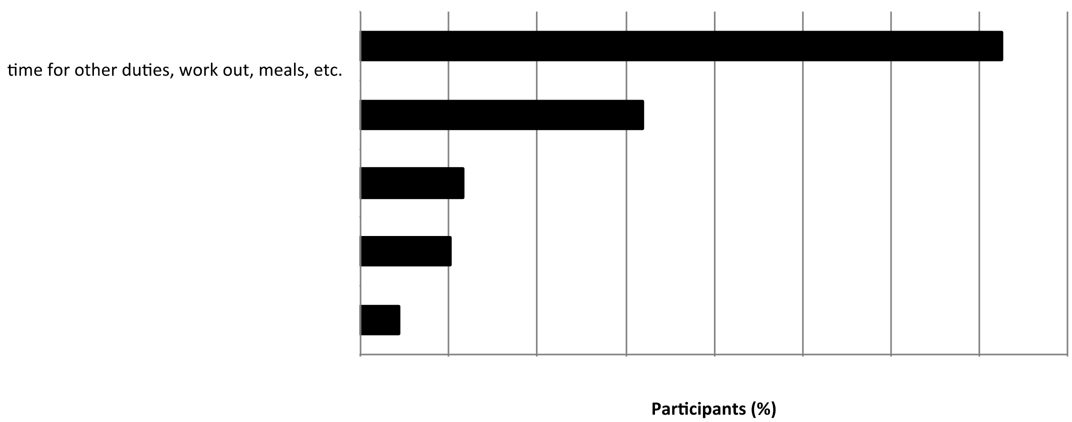

Figure 8. Responses to the question "What did you like least about your current watch schedule?"

C. ACTIVITY AND SLEEP PATTERNS

The workload analysis is based on 652 days of data derived from 64 participants from the RX Department on the 5/10 watch schedule (on average, 9.82 days of activity data per participant). These data did not include information from June 13th to June 15th when the ship was at the port of Victoria, British Columbia, Canada. Interpolation was applied to 459 15-minute intervals (0.73%).

First, the average activity on a daily basis was assessed for the entire group of RX crewmembers in the 5/10. Then, we assessed how much time was spent in each activity per week and compared this time with the corresponding NSWW criterion. Results suggest that, on average, crewmembers are on duty 12.2 hours per day, and their work time (which includes maintenance) is approximately 70% more than the NSWW criterion. Approximately 55% of the RX Department participants on the 5/10 watch schedule reported being on duty for more than 12 hours per day. Fourteen percent of the participants (6 E-6s, 2 E-5s, and 1 E-4) reported being on duty, on average, more than 14 hours per day. These crewmembers report that they are involved with maintenance, on average, 5.79 ± 1.84 hours daily compared to 3.05 ± 1.79 hours for the rest of the crewmembers on the 5/10. Results are shown in Table 3. Comparisons are based on the one-sided Wilcoxon Rank Sum test. All metrics were initially averaged by participant.

Table 3. Activity in hours.

Activity	Daily M ± SD (MD) (hrs)	Weekly M ± SD (MD) (hrs)	Comparison to NSWW Week Criterion	p-value
Nonavailable Time	11.8 ± 1.85 (11.7)	82.8 ± 12.9 (81.9)	< 87 hrs	< 0.001
Sleep	7.49 ± 1.22 (7.50)	52.5 ± 8.55 (52.5)	< 56 hrs	< 0.001
Messing	1.26 ± 0.536 (1.26)	8.81 ± 3.76 (8.84)	< 14 hrs	< 0.001
Personal Time	1.82 ± 1.62 (1.31)	12.8 ± 11.3 (9.19)	< 14 hrs	0.006
Free Time	1.26 ± 1.35 (1.02)	8.81 ± 9.47 (7.15)	> 3 hrs	< 0.001
On Duty	12.2 ± 1.85 (12.3)	85.2 ± 12.9 (86.1)	> 81 hrs	< 0.001
Productive Work	10.6 ± 2.08 (10.5)	73.9 ± 14.5 (73.7)	> 70 hrs	0.018
Watch	7.13 ± 1.59 (7.45)	49.9 ± 11.1 (52.2)	< 56 hrs	< 0.001
Work	3.43 ± 2.02 (3.47)	24.0 ± 14.2 (24.3)	> 14 hrs	< 0.001
Training	0.731 ± 0.652 (0.6)	5.12 ± 4.57 (4.20)	< 7 hrs	< 0.001
Service Diversion	0.875 ± 0.69 (0.858)	6.12 ± 4.83 (6.0)	> 4 hrs	0.001

The three diagrams in Figure 9 show the distribution of time in terms of duty time, productive work, watch, and sleep time distribution between departments. Vertical axes mark the percentage of participants in each activity; sleep is on the right axis, while duty, productive work, and watch times are on the left axis. Each diagram shows one full day of activity distributed into 96 15-minute time bins. The upper diagram shows activity for the days when participants stand watch from 0200 to 0700 and 1700 to 2200, whereas the middle diagram shows activity for the days when participants stand watch from 0700 to 1200 and 2200 to 0200. The lower diagram shows activity for the days when participants stand watch from 2200 to 0200 and 1200 to 1700.

In terms of sleep distribution and the interaction between work/watch and sleep, there are several important points to consider.

- Watchstanding comprises approximately 60% of the daily work activity. The remaining 40% is distributed among other work commitments.
- Approximately 15% of the crewmembers are working, on average, 14 hours or more per day.
- Over an entire 3-day rotation circle, a crewmember on the 5/10 watch schedule faces:
    - Two periods of sustained wakefulness. On the first day of the rotation, there is an approximately 22-hour-long period from 0100 to 2300. The second, 20-hour-long period starts at approximately 0600 of the second day, continuing until after 0200 on the third day. During these periods, sustained wakefulness is only partially ameliorated by napping during the day.
    - One night of short sleep. This 4-hour sleep episode is stopped early because of work commitments.
    - Some crewmembers in the 0200-0700 night watch do not start their sleep as early as possible in the evening before the watch. This can be attributed to other duties, the need for personal time after work, and the improper (circadian misaligned) timing of sleep.

The polar diagram in Figure 10 integrates the sleep, watch, and duty time of the typical 24-hour day, including all three sections of the 5/10 watch schedule.

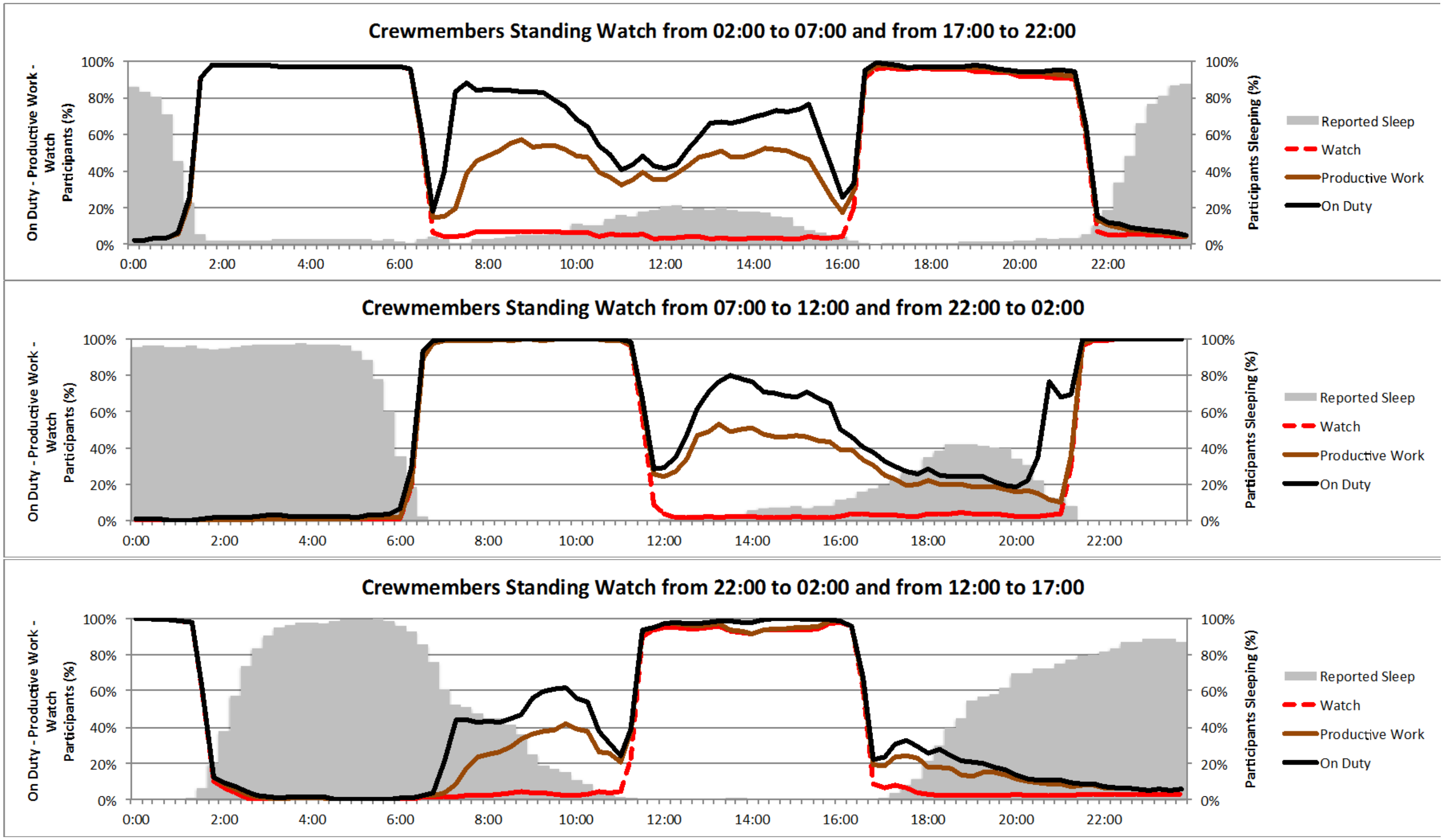

Figure 9. Activity time distribution in the 5/10 watch schedule (RX Department crewmembers).

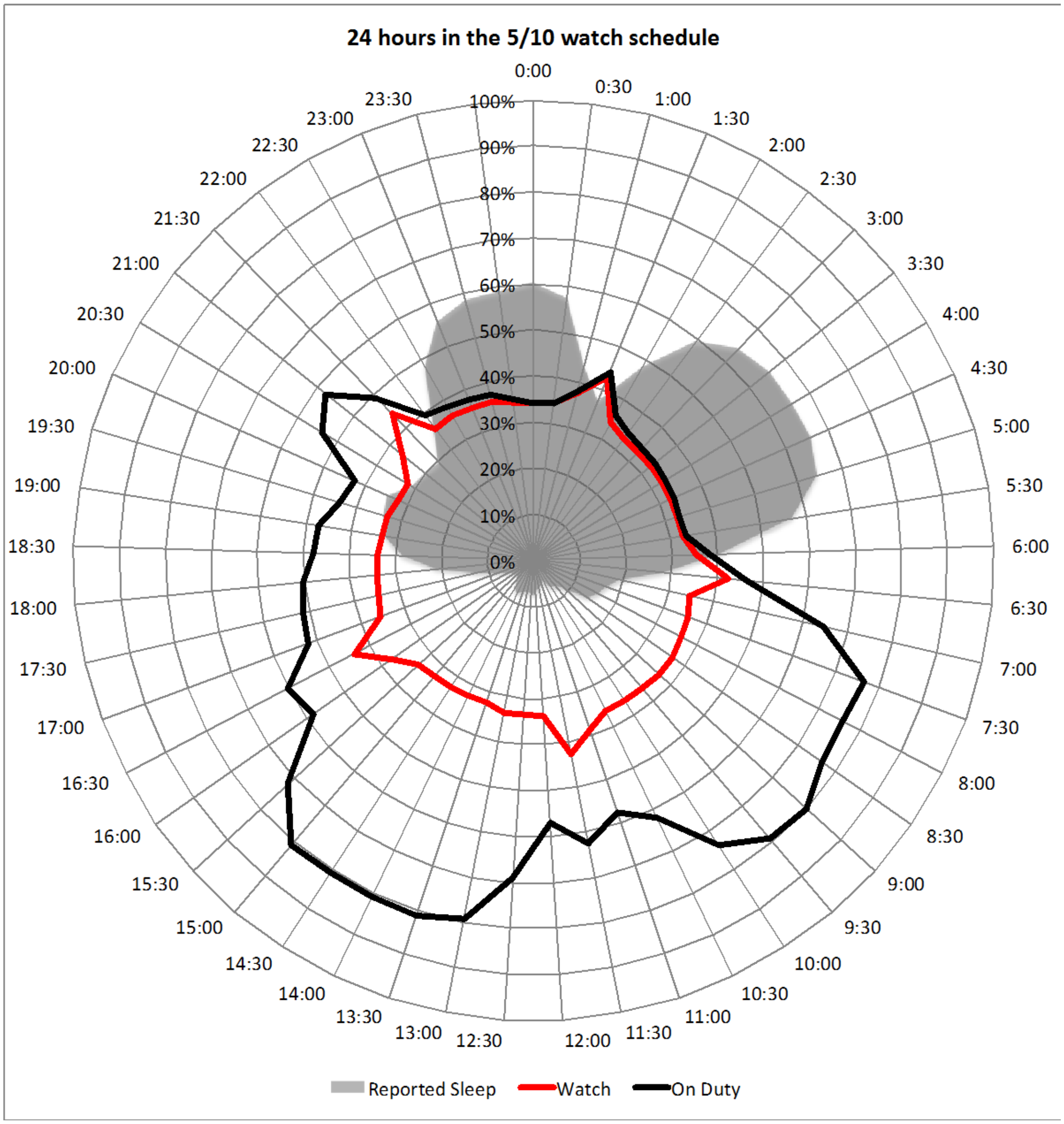

Figure 10. Typical 24-hour day in the 5/10 watch schedule. Homocentric circles denote the percentage of the crewmembers in the corresponding activity.

D. MOOD STATES

Correlation analyses were performed among POMS scores, age, daily rest duration, daily sleep duration, and ESS scores. Three correlations are worth noting. First, only the Vigor-Activity POMS scores were associated with daily average rest and sleep amount. Specifically, crewmembers with increased rest and sleep had lower (decreased) scores on the n Vigor-Activity scale (Rest: rho = –0.363, p = 0.003; Sleep: rho = –0.303, p = 0.013). Second, younger crewmembers showed higher levels of depression, anger-hostility, and total mood disturbance scores at the end of the underway period (poststudy scores). Third, crewmembers with increased daytime sleepiness at the beginning of the study have deteriorated mood states in terms of fatigue, confusion-bewilderment, and total mood disturbance. The association between daytime sleepiness and mood states, however, seems to be less strong at the end of the study. These results are shown in Table 4.

Table 4. POMS rest and sleep correlation results.

POMS Scales	Age		Daily Rest (Time in Bed) Amount	Daily Sleep Amount	ESS Score	
	Pre	Post	Post	Post	Pre	Post
Tension-Anxiety					0.224	
Depression		–0.249*				
Anger-Hostility		–0.329**				
Vigor-Activity	–0.197		–0.363**	–0.303*		
Fatigue					0.381***	0.201
Confusion-Bewilderment	–0.196				0.267*	0.204
TMD		–0.246*			0.247*	

Note 1: * $p < 0.05$; ** $p < 0.01$
Note 2: Inclusion criterion: $p < 0.10$

Sailor mood, as measured by POMS, deteriorated significantly during the underway period on five of the POMS scales: depression, anger-hostility, fatigue, and TMD scores were significantly higher, while vigor-activity scores were significantly lower. Table 5 shows all the POMS scores and compares scores between the beginning and end of the study using the two-tailed matched pairs Wilcoxon Signed Rank test. Figure 11 also shows the POMS scores.

Table 5. POMS TMD and subscale scores.

POMS Scales	Beginning M ± SD (min, max)	End M ± SD (min, max)	p-value
Tension-Anxiety	11.0 ± 5.52 (1, 24)	11.5 ± 5.92 (1, 25)	0.265
Depression	11.2 ± 9.22 (0, 32)	13.6 ± 11.1 (0, 53)	0.026
Anger-Hostility	13.8 ± 9.14 (0, 41)	18.2 ± 9.86 (1, 44)	< 0.001
Vigor-Activity	11.5 ± 5.21 (1, 25)	9.18 ± 4.79 (0, 22)	< 0.001
Fatigue	12.5 ± 4.84 (2, 22)	13.8 ± 5.71 (1, 27)	0.009
Confusion-Bewilderment	9.04 ± 4.55 (0, 20)	9.08 ± 4.75 (2, 21)	0.708
TMD	46.0 ± 27.4 (–3, 101)	57.0 ± 31.1 (–3, 130)	< 0.001

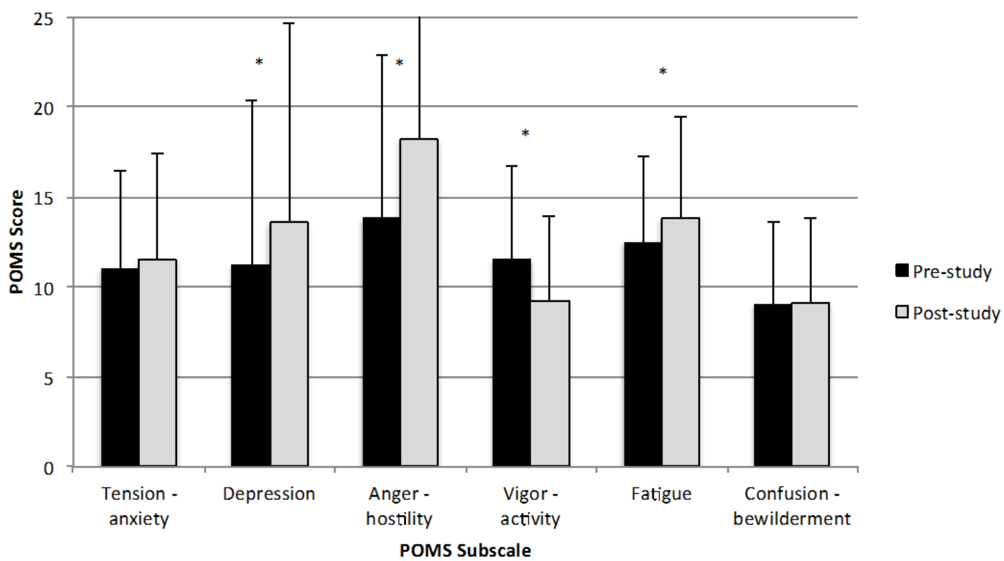

Figure 11. POMS subscale scores.

The standardized POMS test has multiple sets of norms that can be used for comparison purposes. We compared the average POMS scores for the Nimitz RX Department to the U.S. Adult Norms. Both at the beginning and end of the study, normalized scores on the POMS scales of depression, anger-hostility, fatigue, and TMD were between the 53rd and the 62nd percentiles, whereas vigor-activity was between the 36th and the 39th percentiles. Comparing beginning scores to those at the end of the study, the changes in the normalized scores of the POMS scales are shown in Figure 12. As shown by the bars, scores worsened on all POMS scales; note that the one subscale score that goes up, vigor-activity, is still at the 39th percentile relative to the POMS Adult Norms.

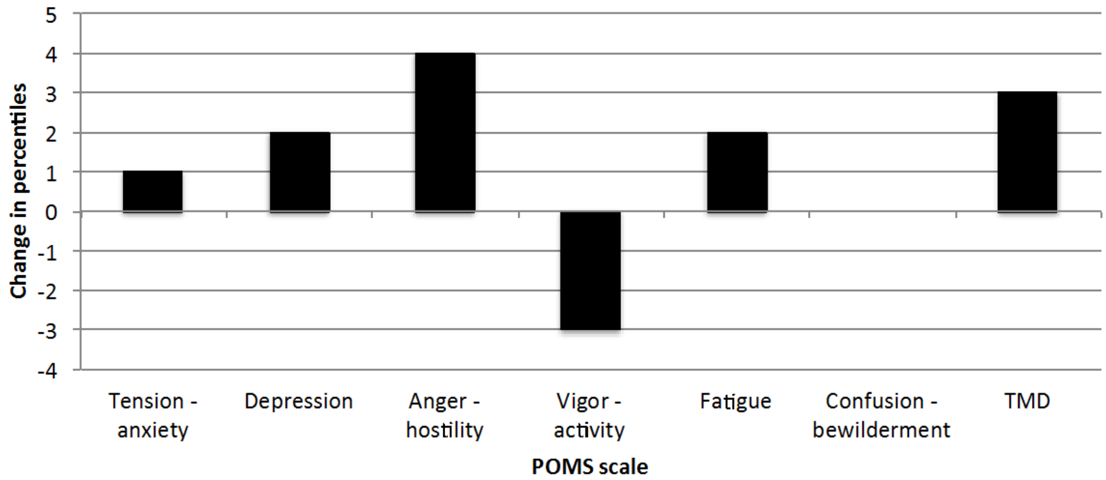

Figure 12. Change in POMS normalized scores (relative to U.S. Adult Norms).

We also assessed the number of participants with high POMS scores (indicating poorer mood), the exception being for vigor, in which a low score indicates poorer mood. For each POMS subscale, we assessed the percentage of participants with a score ≥ the 70th percentile in the adult norms (≤ 30th percentile in vigor-activity). This analysis showed that at the beginning of the study, approximately 22% of the participants had low scores on the vigor subscale, whereas 20% of the participants demonstrated high scores on the anger-hostility subscale and 13% of participants had high TMD scores. After the underway, the percentage of participants with less favorable scores increased by 143% in fatigue, 134% in depression, 98% in total mood disturbance, and 80% in anger-hostility. These results are shown in Figure 13.

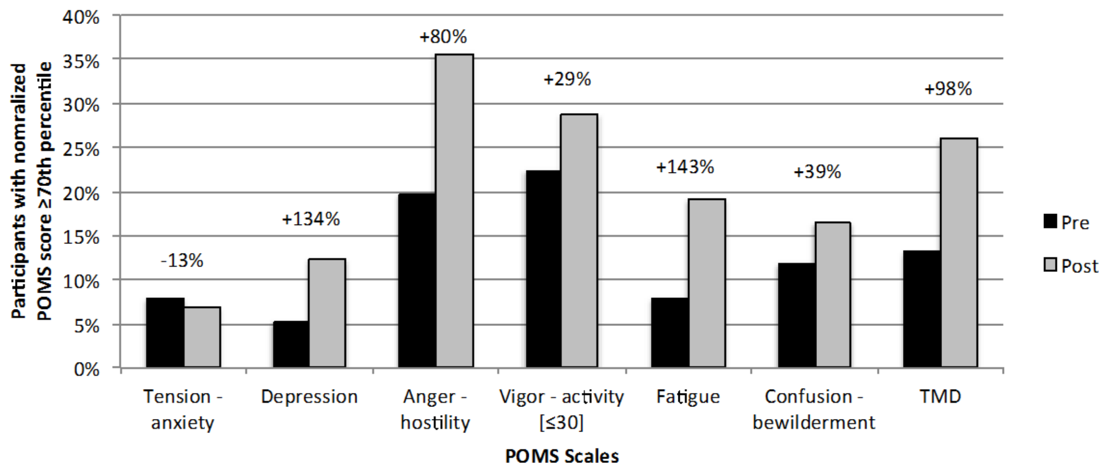

Figure 13. Percentage of participants with POMS score $\geq 70^{th}$ percentile (30^{th} percentile for vigor).

There was a significant deterioration in the mood of crewmembers in the RX Department. We compared their scores with the POMS results from participants in the Medical and Supply Departments from the same underway period of USS Nimitz, and with results from three other studies in which POMS was used.[1] Of the military populations assessed in these studies, mood deteriorates most significantly in the RX Department on USS Nimitz while working the 5/10 watchstanding schedule (see Figure 14).

[1] Studies in which POMS was used includes the White House Military Offices President's Emergency Operations Center (PEOC) before, and three weeks after, introduction of a new watchstanding schedule, the POMS assessment of mood in the crew of a U.S. Navy frigate and a U.S. Navy cruiser during deployment (Burr, Palinkas, & Banta, 1993), and POMS mood changes in U.S. Army Basic Combat Training (BCT) (Lieberman et al., 2014).

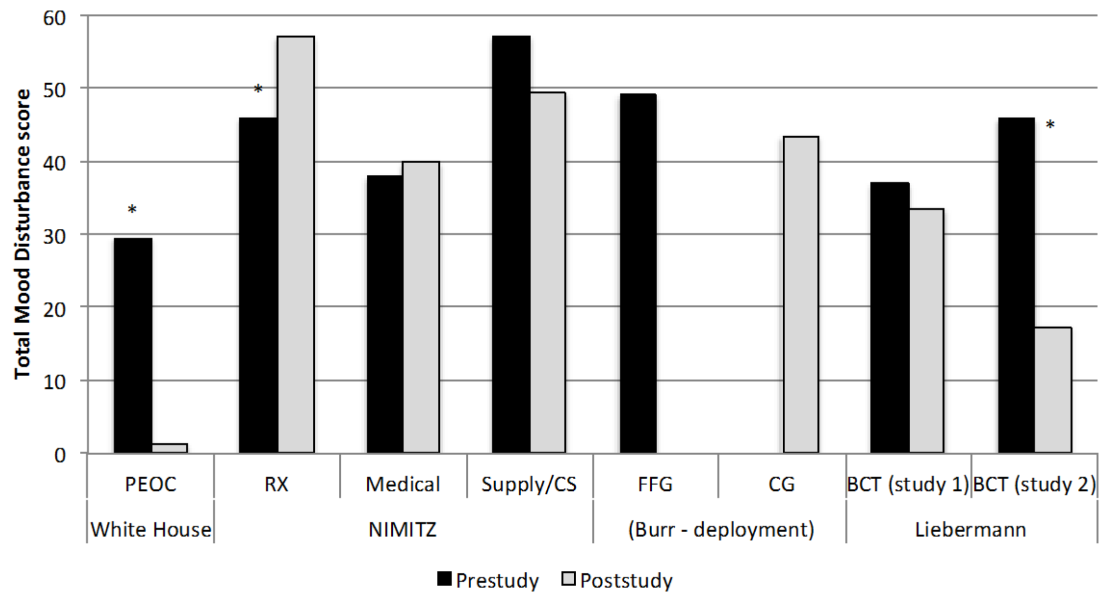

Figure 14. Reactor department POMS scores versus POMs from other data collections, for purposes of comparison.

E. PSYCHOMOTOR VIGILANCE PERFORMANCE

Psychomotor vigilance performance was assessed using standardized PVT metrics. To evaluate the PVT performance of the RX Department on the Nimitz, we compared those scores with three other sets of data collected from two U.S. Navy Arleigh Burke destroyers, 24 crewmembers on a 3hrs-on/9hrs-off watchstanding schedule, 34 crewmembers on a modified 6hrs-on/18hrs-off watchstanding schedule, and 9 Operations Department crewmembers on a 6hrs-on/6hrs-off (port and starboard) watchstanding schedule. The present PVT analysis continues to reveal a consistent trend: the 5/10 watchstanding schedule shows the lowest PVT performance among the four schedules, followed by the 6/6. The best performance was seen in the 3/9, which is followed by the modified 6/18. These results are shown in Table 6.

Table 6. PVT metrics.

Variable	RX 5/10 (n = 39) M ± SD	OPS 6/6 (n = 9) M ± SD	Modified 6/18 (n = 34) M ± SD	3/9 (n = 24) M ± SD
Mean RT (ms)	392 ± 111 [a,b]	372 ± 135	347 ± 139	323 ± 66.9
Mean 1/RT	3.22 ± 0.5 [a,b]	3.67 ± 0.928	3.90 ± 0.862	3.95 ± 0.524
Fastest 10% RT (ms)	248 ± 50.9 [a,b]	217 ± 52.7	207 ± 55.1	196 ± 28.0
Slowest 10% 1/RT	1.96 ± 0.439 [a,b]	2.18 ± 0.743	2.39 ± 0.705	2.43 ± 0.469
False Starts (FS) (%)	1.53 ± 1.56	2.28 ± 2.10	2.10 ± 2.68	2.0 ± 1.59
Lapses 500ms (%)	13.5 ± 12.2 [a]	11.9 ± 9.57	10.4 ± 12.8	7.54 ± 4.40
Lapses 355ms (%)	31.8 ± 19.4 [a,b]	26.8 ± 18.5	21.4 ± 20.8	17.0 ±9.74
Lapses 750ms+FS (%)	7.61 ± 6.77	7.98 ± 4.86	7.52 ± 8.21	5.74 ± 3.74
Lapses 600ms+FS (%)	10.9 ± 9.57	10.7 ± 6.50	9.75 ± 10.3	7.30 ± 4.03
Lapses 500ms+FS (%)	15.0 ± 12.1 [a]	14.2 ± 8.63	12.5 ± 13.6	9.54 ± 5.09
Lapses 355ms+FS (%)	33.4 ± 19.1 [a,b]	29.1 ± 17.2	23.5 ± 21.1	19.0 ± 9.78

[a] Statistically different from the modified 6/18 (nonparametric comparison with Dunn method for joint ranking, $p < 0.05$)
[b] Statistically different from the 3/9 (nonparametric comparison with Dunn method for joint ranking, $p < 0.05$)

Figures 15, 16, and 17 present diagrams of the results for PVT metrics showing that the 5/10 watch schedule differs statistically from the modified 6/18 and from the 3/9.

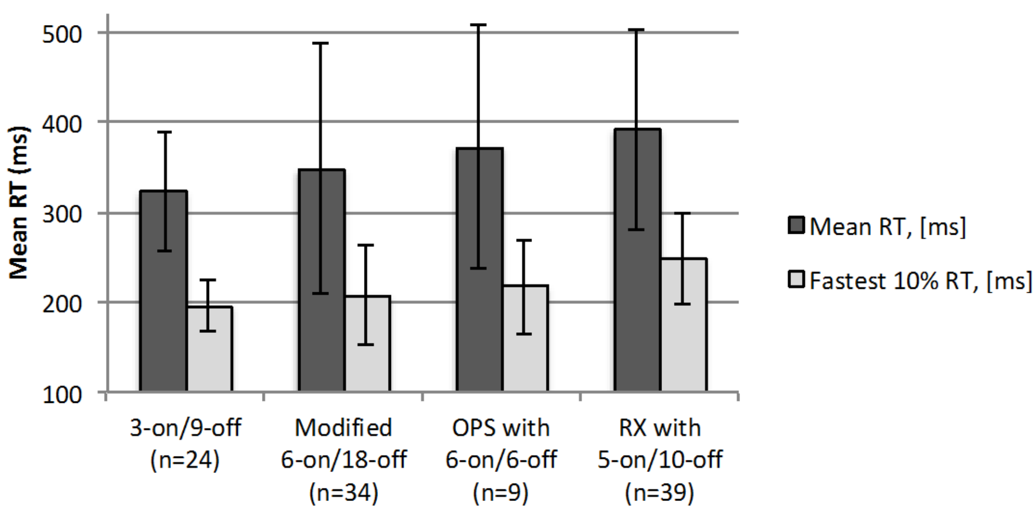

Figure 15. PVT reaction times for four different watch sections.

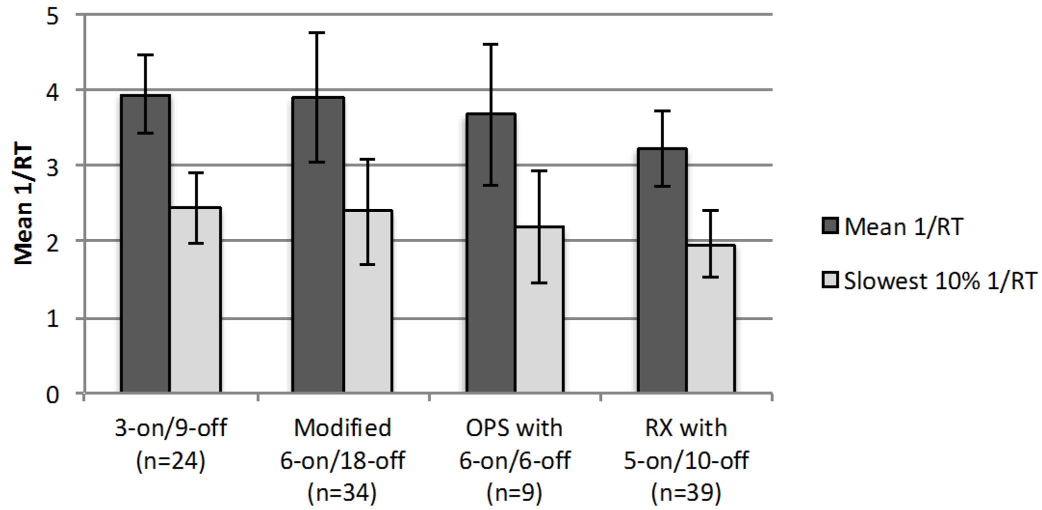

Figure 16. PVT response speeds for four different watch sections.

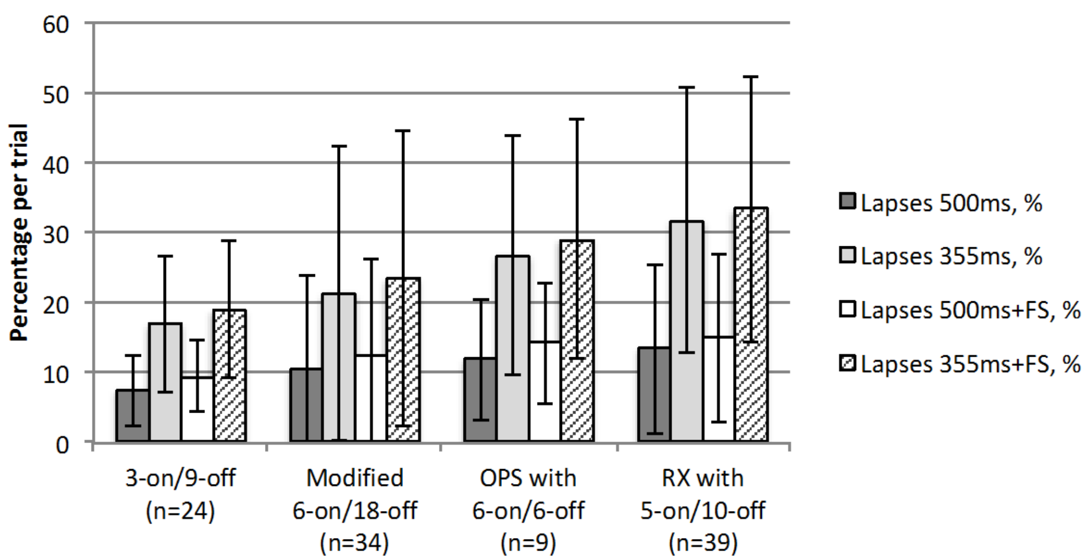

Figure 17. Percentage of lapses of 355ms and 500ms in length, and lapses combined with false starts.

F. FATIGUE AVOIDANCE SCHEDULING TOOL (FAST) PREDICTED EFFECTIVENESS SCORES

The sleep patterns of the crewmembers identified by using actigraphy and activity logs were used as inputs to the FAST program. The FAST inputs included three attributes: the 3-day rotation cycle of the 5/10 watch schedule, the average daily sleep received in this schedule (6.88 ± 0.894 hrs), and the occurrence of napping. Due to the limited numbers of participants napping between the major night sleep episodes, we modeled two different cases.

- Case A
    - Over the course of the 3-day rotation cycle, 20.6 hours (= 3*6.88) sleep is distributed among five distinct sleep episodes, which includes two naps.
    - Sleep episodes:
        - Day 1: 1900 – 2359
        - Days 2 and 3: 1130 – 14:30 (nap 1) and 2300 – 0500
        - Day 3: 1830 – 2030 (nap 2)
        - Day 4: 0230 – 0700 (Note: This is also the first day of the proceeding 3-day cycle.)
- Case B
    - In the 3-day rotation cycle, the 20.6 hours (= 3*6.88) sleep is distributed among three distinct sleep episodes with no naps.
    - Sleep episodes:
        - Days 1 and 2: 1915 – 0130
        - Days 2 and 3: 2230 – 0630
        - Day 4: 0215 – 0830 (Note: This is also the first day of the proceeding 3-day cycle.)

Figures 18 and 19 show the FAST output of predicted effectiveness for the two cases of a typical 3-day rotation. Work and sleep intervals are color-coded: black intervals indicate watch periods and blue intervals indicate sleep periods. The average predicted effectiveness in Case A, the model with naps, is 80.2 ± 6.2; for Case B, the model without naps, the average predicted effectiveness is 84.9 ± 7.7. The difference between the two models is not considered substantively significant.

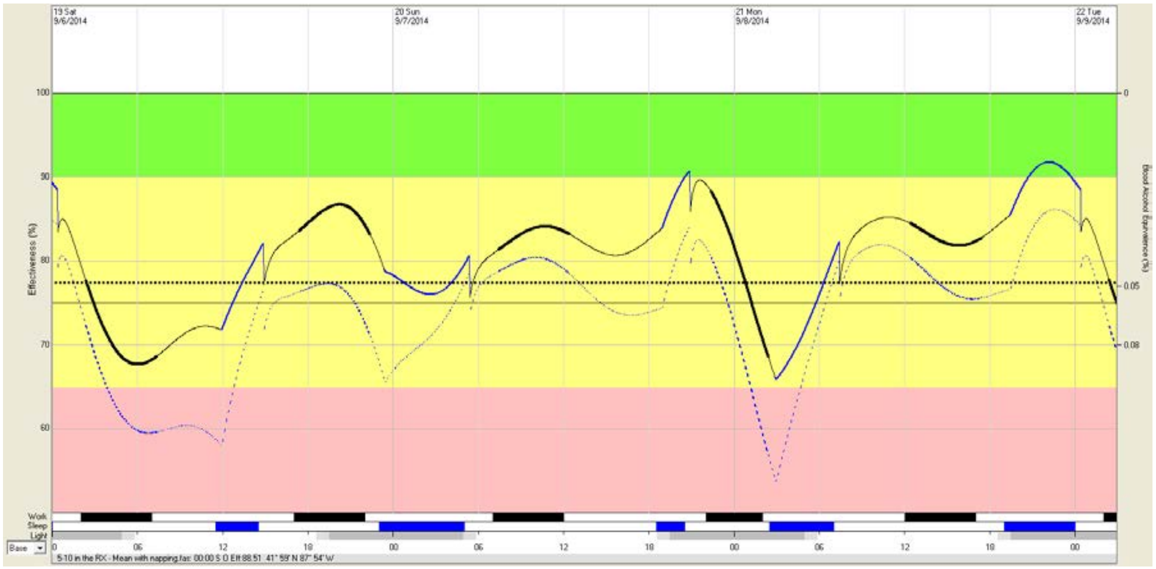

Figure 18. FAST predicted effectiveness in Case A, the typical 3-day rotation period of the 5/10 schedule (with naps).

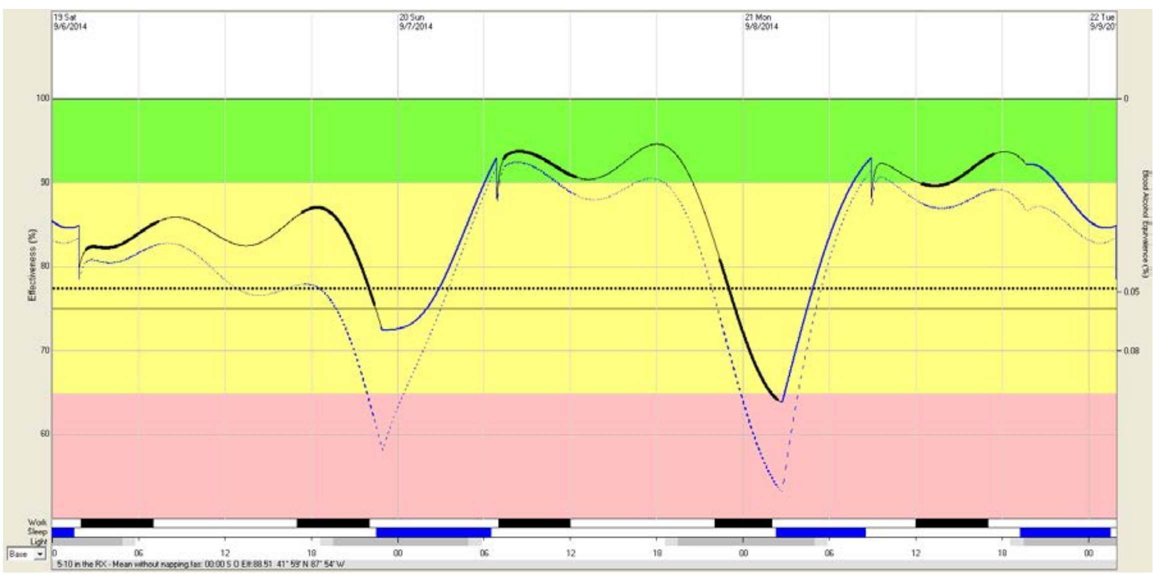

Figure 19. FAST predicted effectiveness in Case B, the typical 3-day rotation period of the 5/10 schedule (without naps).

Napping attenuates the range of predicted effectiveness in the watch periods; that is, napping may lead to a more consistent performance, whereas the absence of napping may lead to more variability in predicted effectiveness.

G. ASSOCIATION BETWEEN POSTSTUDY ESS SCORES, PVT METRICS, AND ACTIGRAPHIC SLEEP

Table 7 shows the nonparametric correlations (Spearman's *rho*) between the poststudy ESS scores, amount of rest/sleep, and the 11 PVT metrics. Scores on the ESS were significantly correlated with daily sleep duration, but not with the PVT performance.

Table 7. ESS, rest/sleep, and PVT correlations.

Variable	ESS	Daily Rest (Time in Bed) Amount	Daily Sleep Amount
Daily Time in Bed Amount			
Daily Sleep Amount	–0.244 *		
Mean RT			
Mean 1/RT			
Fastest 10% RT			
Slowest 10% 1/RT			
False Starts (%)		–0.309	–0.316
Lapses 500ms (%)			
Lapses 355ms (%)			
Lapses 750ms+False Starts (%)		–0.349 *	–0.390 *
Lapses 600ms+False Starts (%)		–0.348 *	–0.388 *
Lapses 500ms+False Starts (%)		–0.267	–0.284
Lapses 355ms+False Starts (%)			

Note 1: * $p < 0.05$
Note 2: Inclusion criterion: $p < 0.10$

Participant data was divided into two groups according to their ESS scores: Normal and Elevated. The Normal ESS group was comprised of those individuals with an ESS score less than or equal to 10, while the Elevated ESS group was made up of individuals with ESS scores greater than 10, which is the cutoff recommended by Johns (1991, 1992). Table 8 lists all variables that were compared (column 1), the average value and standard deviation of those variables for the Normal ESS group (column 2), the average value and standard deviation for the Elevated ESS group (column 3), the significance levels that resulted from comparing those means (column 4), and the percentage-wise difference in mean values between groups (column 5). The two-sided Wilcoxon Rank Sum test was used to calculate these differences. Results showed that the two groups differed significantly in both average daily time in bed and sleep duration.

Table 8. Comparison between Normal and Elevated ESS groups.

Variable [1]	Normal Group (NG) ESS ≤ 10 [2]	Elevated Group (EG) ESS > 10 [3]	p-value[A] [4]	Percent Difference in Means NG vs. EG [5]	Percent Difference in SD NG vs. EG [6]	p-value[B] [7]
Daily TIB (hrs)	7.79 (0.69)	7.33 (1.01)	0.080	–5.91%	46.4%	0.051
Daily Sleep (hrs)	7.16 (0.65)	6.68 (1.00)	0.048	–6.70%	53.9%	0.046
Mean RT (ms)	362 (49.9)	398 (95.7)	0.306	–	91.8%	0.045
Mean 1/RT	3.35 (0.34)	3.18 (0.51)	0.539	–	50.0%	0.090
Fastest 10% RT (ms)	234 (24.0)	252 (53.5)	0.579	–	123%	0.038
Slowest 10% 1/RT	2.06 (0.37)	1.91 (0.42)	0.254	–	–	0.530
False Starts (FS) (%)	1.72 (1.85)	1.39 (1.22)	0.682	–	–	0.452
Lapses 500ms (%)	10.2 (5.06)	14.2 (11.4)	0.306	–	–	0.119
Lapses 355ms (%)	26.6 (9.61)	34.1 (22.5)	0.306	–	134%	0.035
Lapses 750ms+FS (%)	6.19 (4.03)	7.67 (6.18)	0.397	–	–	0.510
Lapses 600ms+FS (%)	8.68 (4.71)	11.3 (9.18)	0.430	–	–	0.234
Lapses 500ms+FS (%)	11.9 (5.63)	15.6 (11.3)	0.365	–	–	0.139
Lapses 355ms+FS (%)	28.3 (9.24)	35.5 (21.2)	0.335	–	129%	0.033

Note: One outlier in the Normal Group (ESS ≤ 10) excluded: PVT RT exceeding the mean RT of the group by 11 standard deviations

[A] Wilcoxon Rank Sum Test results for the comparison in the mean values between groups

[B] Levene's test for equality of variances between groups

Although the two groups did not differ in the average PVT metrics assessed, they differed in the variability of their mean RT, mean response speed, fastest 10% of the RTs, percentage of 355ms lapses, and percentage of 355 ms lapses combined with false starts. In general, crewmembers with an ESS > 10, the Elevated ESS group, received less sleep and had increased variability in 5 of the 11 PVT metrics when compared to the Normal ESS group with ESS ≤ 10.

H. COMMAND RESILIENCE

Results of the Command Resilience Questionnaire (CRQ) paint an overall picture resilience based on four general areas of concern: leadership, recovery, learning orientation, and mutual support. Two other subjective measures, organizational commitment (OCQ scores) and psychological safety (PSQ scores), complement the view of organizational resilience. Table 9 shows the OCQ, PSQ, and CRQ scores for the participants in the RX Department on the 5/10 watch schedule.

Table 9. Organizational Commitment, Psychological Safety, and Command Resilience scores.

Scale	Score			
	M ± SD	MD	Minimum	Maximum
Organizational Commitment	2.19 ± 0.68	2.00	1.00	3.67
Psychological Safety	2.21 ± 0.54	2.17	1.00	3.67
Command Resilience	2.87 ± 0.48	2.85	1.70	3.80
Leadership	2.49 ± 0.94	2.33	1.00	4.67
Learning	2.67 ± 0.58	2.80	1.20	3.80
Mutual Support	2.84 ± 0.75	2.67	1.00	4.67
Recovery	3.49 ± 0.56	3.67	1.67	4.67

Figure 20 depicts the frequency of responses in each survey item. Responses from the original five-point Likert scale have been grouped into three groups: negative, neither negative nor positive, or positive. The diagram shows the items grouped in their corresponding questionnaire (Organizational Commitment Questionnaire [OCQ], Psychological Safety Questionnaire [PSQ], and Command Resilience Questionnaire [CRQ]).

Figure 20. Responses to Organizational Commitment (OCQ), Psychological Safety (PSQ), and Command Resilience (CRQ) questionnaires.

Figure 21 orders the individual items of the OCQ, PSQ, and CRQ based on the degree of disagreement with the statement. Three-quarters of the items show that 40% of respondents disagree or strongly disagree with the statements. The first five items listed are related to OCQ and PSQ.

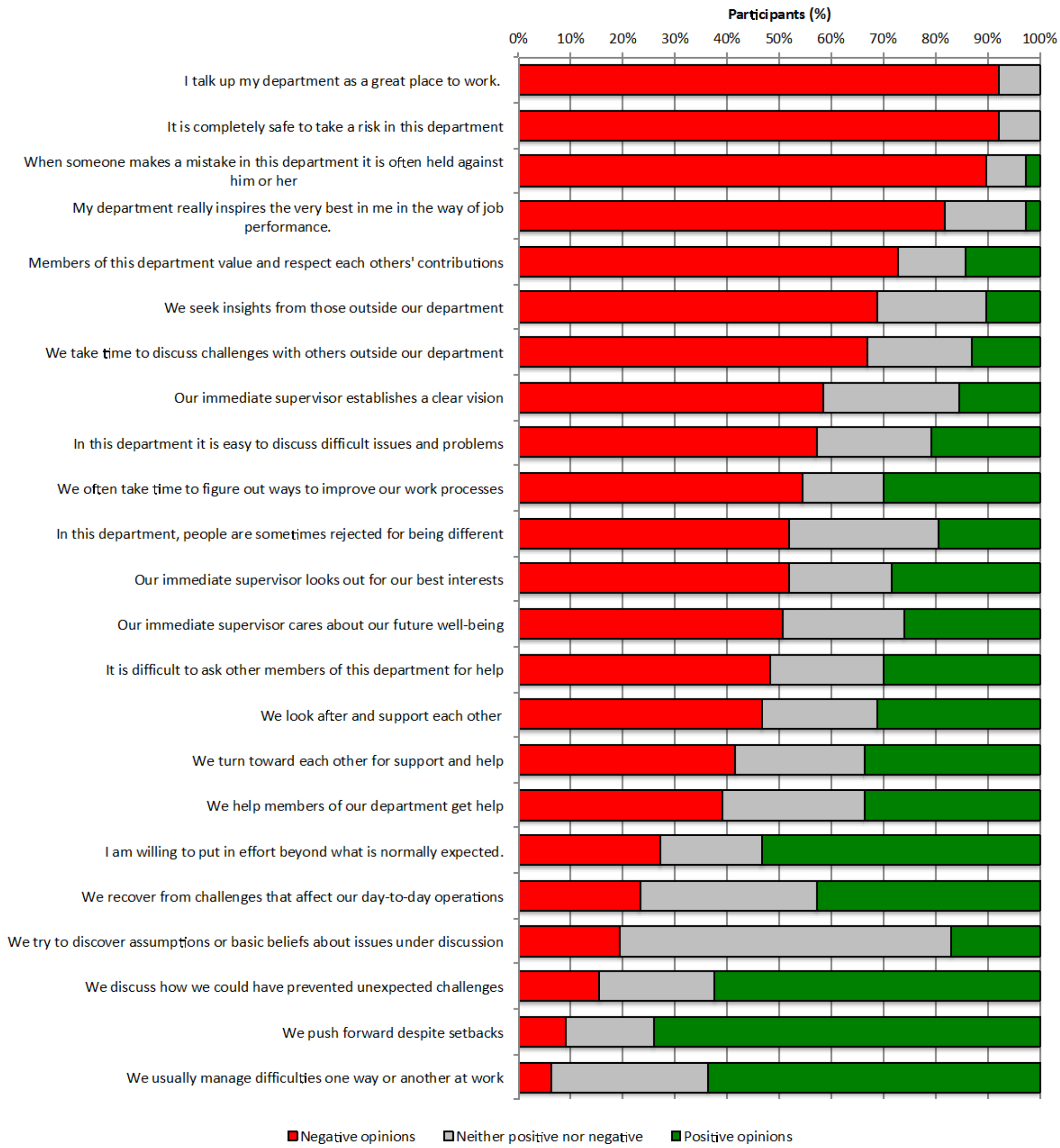

Figure 21. Responses to OCQ, PSQ, and CRQ questionnaires. Items are listed in descending order of negative responses.

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IV. DISCUSSION

This study focused on the assessment of the 5/10 watchstanding schedule based on a 3-day rotation cycle. Results show that the 5/10 watchstanding schedule is problematic compared to other watch schedules in terms of amounts of rest and sleep, subjective levels of fatigue, and psychomotor vigilance performance.

In terms of daily sleep duration, crewmembers on the 5/10 received approximately seven hours of sleep per day, which is significantly more than U.S. Navy personnel on other watch schedules (Miller, Matsangas, & Kenney, 2012; Shattuck, Matsangas, & Waggoner, 2014; Shattuck, Waggoner, Young, Smith, & Matsangas, 2014). The amount of daily sleep obtained on the 5/10 was significantly more than the modified 6/18 and the 6/6 schedules, and comparable to the 3/9 schedule. The crewmembers on the 5/10, however, reported elevated levels of fatigue. In fact, almost all of them (88%) indicated that they did not have adequate time to sleep and they did not like their watch schedule. The contradiction between the amount of daily sleep and crewmembers' negative opinions may be explained when we consider the timing of the sleep they received. Over an entire 3-day rotation cycle, a crewmember on the 5/10 watchstanding schedule sleeps at three distinctly different times each day, which is problematic for sleep hygiene.

Our findings suggest that the 5/10 schedule yields low-quality sleep with less recuperative value. Consequently, even though crewmembers receive more sleep, on average, they tend to report less vigor. It is notable that by the end of the underway phase, crewmembers' moods were significantly worse compared to the beginning of the study; specifically, scores on depression, anger-hostility, fatigue, and TMD increased, while vigor-activity scores decreased. Deteriorated mood and negative affect may have considerable effects not only at an individual level, but also in team cognition and awareness (Pfaff, 2012; Pfaff & McNeese, 2010).

Given the problems in sleep quality, we also found that crewmembers on the 5/10 had lower psychomotor vigilance performance results (comparable to the 6/6 schedule) than the modified 6/18 and the 3/9 schedules. Specifically, participants on the 5/10 had

21.4% longer PVT reaction times, and 71.5% more lapses combined with false starts than participants on the 3/9 schedule.

The disruption of the internal circadian rhythms (Colquhon, Blake, & Edwards, 1969b), referred to as circadian desynchrony, provides one explanation for our results. Irrespective of the departmental work shifts, late night and early morning shifts, accompanied by sudden returns to work, are associated with short sleep and increases in sleepiness (Sallinen & Kecklund, 2010). A fast-rotating watch schedule disturbs the sleep-wakefulness cycle (Åkerstedt, 2003) and does not allow for the circadian clock to realign, due to the continuously changing cycle. Research has shown that adjustment of the circadian diurnal rhythm to a nocturnal rhythm may take at least a week (Monk, 1986), although reports of 12 days or more have also been reported for circadian realignment to occur (Colquhon, Blake, & Edwards, 1969a; Hockey, 1983).

Overall, the findings of this study suggest that the combination of the rotating 5/10 watchstanding schedule with other work duties leads to poor sleep hygiene. Crewmembers on the 5/10 schedule experience sustained wakefulness due to extended workdays and sleeping during circadian misaligned times. Increased work commitments and collateral duties, combined with restricted sleep opportunities, lead to decreased alertness, deteriorated mood, and degraded psychomotor vigilance performance. This study further emphasizes the beneficial effect of napping in an operational environment, where opportunities for lengthy sleep episodes are restricted. Although only a few crewmembers in this study had the opportunity to nap, those who did received significantly more sleep than those that did not nap.

The results also suggest that crewmembers report low degrees of resilience, psychological commitment to the organization, and psychological safety. In terms of organizational commitment, the participants indicate high degrees of disagreement when it comes to speaking positively about their department (more than 90% of the responses indicated disagree or strongly disagree) and viewing their department as inspiring performance (approximately 80% of responses were categorized as strongly disagree or disagree). Conversely, sailors report a high degree of willingness to put in effort beyond expectations (more than 50%), even though their psychological attachment to the unit as a place for working and completing work tasks overall is low.

Psychological safety appears to be low. Data support the idea that speaking up and challenging the status quo is not valued very highly within this department. On items about valuing and showing respect, taking risks, and not holding mistakes against a person, more than 70% of responses were either disagree or strongly disagree. Approximately 50% of responses for items about rejection, ease in talking about problems, and ability to ask for help were either disagree and strongly disagree. In other words, members of the RX Department are less likely to take interpersonal risks and experience a high degree of psychological safety. And while in an environment such as the RX Department, risk taking is not an acceptable practice, these items, as a whole, focus on the individual's willingness to speak up and discuss challenges about the work environment and work practices. Moreover, when people make mistakes in this department, they feel that there are social risks and fear of retribution. As a result, a downward cycle ensues and operators may find it difficult to bring up problems.

Overall, results of this command alone do not point to a positive perception of the department's level of resilience. As to leadership, members of the RX Department do not agree that when facing setbacks as a unit their immediate supervisor provides vision, looks out for department members' well-being, and cares about their future well-being.

With respect to a learning orientation, respondents indicate that they are not likely take time to discuss setbacks with others outside the unit. A key to a learning orientation is the practice of discussing prevention and dealing with future challenges. The data suggest that within the RX Department, there is a focus on learning so they can prevent future problems. This finding makes sense due to the nature of high-reliability organizations such as the RX Department. Training and drills likely emphasize and foster a mindset of prevention, although what is lacking is a concern with learning about improving work processes. Again, this may be an intuitive response given the rigid nature of the reactor operating procedures and protocols.

Data also support the idea that members of the department are not likely to support and help others within the department in terms of getting them help when needed, turning toward each other for help, and looking after each other. This is consistent with the findings associated with organizational commitment. There does not seem to be an attachment to the organizational unit and so the support possibilities appear to be less apparent. Last, of all the subscales of the command resilience profile, recovery results point to a perception that members of the unit do not believe they are able to recover when times are tough. Recovery is a critical component to bouncing back. Respondents do not agree that they can manage through difficulties, or recover from or push forward from setbacks.

A. STUDY LIMITATIONS

This study had a number of limitations. Officers were underrepresented in our sample of the RX Department (only 2% of the study sample were officers). The surveys used to assess resilience and psychological commitment to the organization are not standardized. More work is needed to assess the external validity of the resilience and psychological commitment scales. For the resilience measures, we only examined one time interval. Additional time intervals are needed to assess changes in resilience. We anticipate that additional research will yield insights about the effect of different sleep schedules on the resilience of the unit. We also expect to see changes in resilience based on changes in leadership practices within the department.

APPENDIX

This appendix focuses on the Command Resilience Questionnaire (CRQ) and the associations between the CRQ, demographic information, sleep, ESS, POMS, the Organizational Commitment Questionnaire scores, and the Psychological Safety Questionnaire scores.

A. DEMOGRAPHICS

Analysis is based on data from 131 crewmembers (Reactor = 110, Medical = 9, Supply = 12). Table 10 shows participants' demographic information.

Table 10. Demographic information.

Variable	
Age (Years)	26.6 ± 5.30
Gender	28 F, 103 M
Rank	4 Officers, 126 Enlisted
Active Duty (Years)	5.88 ± 4.45
Total Deployment (Months)	14.5 ± 15.6
PSQI Global Score	9.47 ± 3.01 (91.4% "Poor" sleepers [1])
ME Preference Score [2]	51.3 ± 8.17
ME Preference Type [2]	
Definitely Morning	2
Moderately Morning	25
Intermediate	89
Moderately Evening	14
Definitely Evening	–

[1] PSQI score > 5
[2] ME denotes Morningness-Eveningness

B. INDIVIDUAL ITEM ANALYSIS

Figure 22 depicts the responses in each survey item grouped by questionnaire (OCQ, PSQ, and CRQ). Responses from the original five-point Likert scale have been grouped as negative, neither negative or positive, and positive.

Figure 22. Responses to Organizational Commitment, Psychological Safety, and Command Resilience questionnaires.

We performed a multiple logistic regression analysis to assess the association between the CRQ, OCQ, and PSQ item responses and daily sleep duration, ESS scores, and POMS. Responses from the original five-point Likert scale have been grouped as negative, neither negative or positive, and positive. As shown in Table 11, results identify the following patterns.

- Responses to the items on the OCQ, the PSQ, and the CRQ are, in general, dissociated from sleep and daytime sleepiness (ESS).
    - Although the trends are not statistically significant, participants with increased daily sleep duration tend to have more positive responses, whereas elevated daytime sleepiness (increased ESS scores) leads to more negative responses.
- In general, participants with deteriorated mood (increased POMS TMD, anger-hostility, confusion-bewilderment, depression, fatigue, tension-anxiety and decreased vigor-activity scores) tend not to agree with the resilience, organizational commitment, and psychological safety statements.
- POMS TMD, anger-hostility, fatigue, and vigor-activity scores are more frequently associated with the questionnaire items.
- There is a consistent pattern of associations between POMS TMD and subscales with the items of the PSQ, and the leadership part of the CRQ. The same pattern is identified in two items of the ORQ with the exception of the "I am willing to put in effort beyond what is normally expected" item, which is associated only with vigor.

Table 11. Associations between OCQ, PSQ, and CRQ items with daily sleep duration, ESS scores, and POMS scales.

Questionnaire		Item	Sleep	ESS	POMS T	POMS D	POMS A	POMS V	POMS F	POMS C	POMS TMD
Organizational Commitment		I talk up my department as a great place to work			**	*	✓	***	***		**
		I am willing to put in effort beyond what is normally expected						***			
		My department really inspires the very best in me in the way of job performance					**	***	*		*
Psychological Safety		Members of this department value and respect each other's contributions				**	**	***	✓		***
		In this department, people are sometimes rejected for being different			*	**	*	***	*	**	***
		In this department it is easy to discuss difficult issues and problems				*		**	*		**
		It is completely safe to take a risk in this department			**	**	***	***	**	**	***
		It is difficult to ask other members of this department for help	**	*				**		*	*
		When someone makes a mistake in this department it is often held against him/her				✓	**	**	**		**
Command Resilience	Leadership	Our immediate supervisor establishes a clear vision				*	***	✓	**	✓	**
		Our immediate supervisor looks out for our best interests					**	*	*		*
		Our immediate supervisor cares about our future well-being			✓	*	*	***	**	✓	**
	Learning	We often take time to figure out ways to improve our work processes				✓		*	✓		*
		We try to discover assumptions or basic beliefs about issues under discussion									
		We discuss how we could have prevented unexpected challenges									
		We take time to discuss challenges with others outside our department					*	**			**
		We seek insights from those outside our department					***	**	*		
	Mutual Support	We help members of our department get help						***			
		We look after and support each other					*	*			
		We turn toward each other for support and help									
	Recover	We usually manage difficulties one way or another at work					*	✓			
		We recover from challenges that affect our day-to-day operations	✓	✓		*	**	✓	*	*	**
		We push forward despite setbacks					*				✓

Note 1. Inclusion criterion for factor loading, $p < 0.10$

Note 2. p-values of factors loaded in the models, ✓□□□□□□□□* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

C. ANALYSIS OF OCQ, PSQ, AND CRQ SCORES

Table 12 shows the descriptive statistics of the Organizational Commitment, Psychological Safety, and Command Resilience scores.

Table 12. Organizational Commitment, Psychological Safety, and Command Resilience scores.

Scale	Score			
	M ± SD	MD	Minimum	Maximum
Organizational Commitment	2.43 ± 0.87	2.33	1.00	5.00
Psychological Safety	2.34 ± 0.67	2.33	1.00	5.00
Command Resilience	3.00 ± 0.62	2.94	1.52	4.95
Leadership	2.71 ± 1.00	2.67	1.00	5.00
Learning	2.78 ± 0.71	2.80	1.20	4.80
Mutual Support	2.96 ± 0.87	3.00	1.00	5.00
Recovery	3.55 ± 0.67	3.67	1.33	5.00

Based on Spearman's rho, nonparametric correlation analysis showed that questionnaire scores were correlated ($p < 0.01$). These results are shown in Table 13.

Table 13. Correlation between Organizational Commitment, Psychological Safety, and Command Resilience scores.

	Organizational Commitment	Psychological Safety
Command Resilience	0.591	0.633
Leadership	0.546	0.460
Learning	0.396	0.477
Mutual Support	0.460	0.589
Recovery	0.309	0.404

We also performed a multiple regression analysis to assess the association between the CRQ scores and daily sleep duration, ESS scores, POMS, OCQ scores, and PSQ scores. The results of this analysis (Table 14) are aligned with the patterns identified in the responses to the questionnaire items.

- The Organizational Commitment, Psychological Safety, and Command Resilience scores are, in general, dissociated from sleep and daytime sleepiness (ESS).
- In general, POMS TMD, anger-hostility, and vigor-activity scores are associated with the questionnaire scores.

- Participants with deteriorated mood (increased POMS TMD and anger-hostility, decreased vigor-activity) tend to have less favorable scores in Organizational Commitment, Psychological Safety, and Command Resilience (decreased scores).

Table 14. Associations between OCQ, PSQ, and CRQ items with daily sleep duration, ESS scores, and POMS scales.

Questionnaire	Sleep	ESS	POMS						
			T	D	A	V	F	C	TMD
Organizational Commitment						***			**
Psychological Safety		*			✓	***			***
Command Resilience					*	**			***
Leadership					*				***
Learning					*	**			*
Mutual Support						*			*
Recover					*	✓			*

Note 1. Inclusion criterion for factor loading, $p < 0.10$
Note 2. p-values of factors loaded in the models, ✓ * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

1. The Effect of Department

This section focuses on the comparison of survey scores between the three departments. Although the number of participants in the Medical and Supply Departments is small, a comparison may provide interesting insight. Based on the nonparametric Dunn method for joint ranking, this comparison showed that the RX Department has worse scores than the Medical Department. The same pattern is identified when compared to the Supply Department, but not at statistically significant levels ($p > 0.05$). These results are described in Table 15 and shown in Figure 23.

Table 15. Organizational Commitment, Psychological Safety, and Command Resilience scores by department.

Scale	Department		
	RX (M ± SD)	Medical (M ± SD)	Supply (M ± SD)
Organizational Commitment	2.28 ± 0.74 [A1]	3.44 ± 0.83	2.84 ± 1.28
Psychological Safety	2.23 ± 0.57 [A1,B]	3.17 ± 0.98	2.74 ± 0.80
Command Resilience	2.91 ± 0.52 [A1]	3.60 ± 0.76	3.31 ± 0.99
Leadership	2.57 ± 0.92 [A1]	3.82 ± 0.78	3.11 ± 1.27
Learning	2.71 ± 0.64	3.16 ± 0.90	3.17 ± 0.96
Mutual Support	2.87 ± 0.78 [A2]	3.63 ± 1.12	3.25 ± 1.23
Recovery	3.51 ± 0.59	3.82 ± 0.97	3.72 ± 1.03

A1 RX different from Medical, $p < 0.05$; A2 RX different from Medical, $p = 0.062$
B RX different from Supply, $p < 0.05$

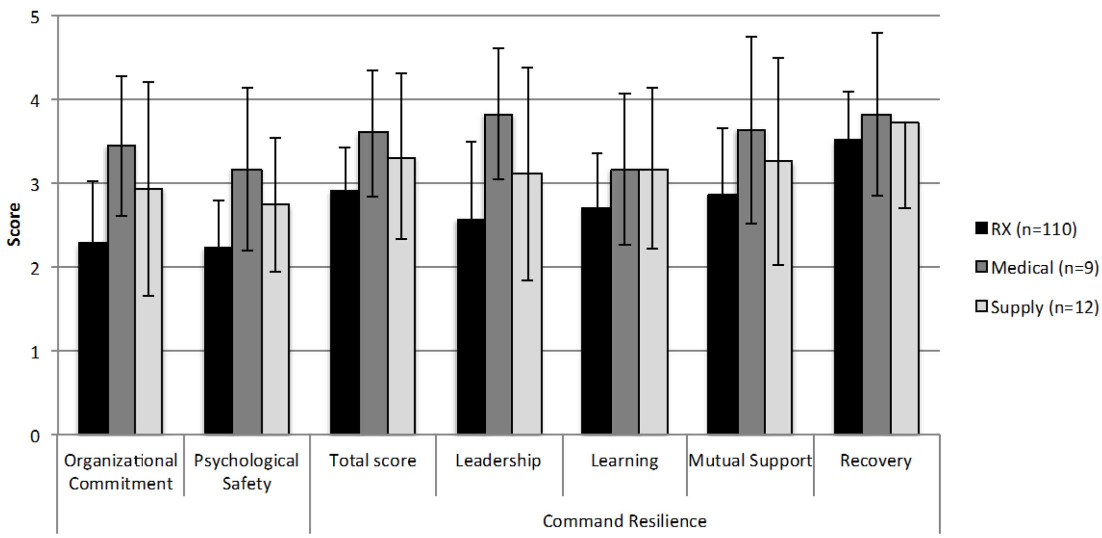

Figure 23. Organizational Commitment, Psychological Safety, and Command Resilience by department.

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