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A comparison between the 3/9 and the 5/10 watchbills

Shattuck, Nita Lewis; Matsangas, Panagiotis; Brown, Stephanie

Monterey, California, Naval Postgraduate School

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NAVAL
POSTGRADUATE
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MONTEREY, CALIFORNIA

A COMPARISON BETWEEN THE 3/9 AND THE 5/10

WATCHBILLS

by

Nita Lewis Shattuck, Panagiotis Matsangas, and Stephanie Brown

April 2015

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14. ABSTRACT

This is the second phase of a longitudinal study comparing the fatigue levels, workload, and performance of crewmembers working on the 3-hrs on/9-hrs off (3/9) and the 5-hrs on/10-hrs off (5/10) watchstanding schedules. Detailed results on the 5/10 are included elsewhere (Shattuck, Matsangas, & Powley, 2015). Crewmembers from the Reactor Department on the USS NIMITZ (N=117, 24.6±3.89 years old, 95 males, 109 enlisted, with 4.25±2.65 years of active duty) participated in this study. Results show that the 3/9 is better than the 5/10 in terms of sleep quality, subjective levels of fatigue, mood, psychomotor vigilance performance, and acceptance by the Sailors. Although crewmembers on both the 5/10 and the 3/9 received, on average, approximately seven hours of sleep per day, the sleep hygiene and acceptance of the two schedules differ considerably. On the 3/9, significantly fewer Sailors reported not having enough time to sleep, as contrasted with the 5/10 (3/9: 52%; 5/10: 88%; p<0.001). There were differences between crewmembers on the two schedules in the expression of negative opinions about the adequacy of their sleep (3/9: 30%; 5/10: 80%) with over twice as many negative opinions for the 5/10 group. Daytime sleepiness and mood states deteriorated during the underway when using the 5/10, whereas daytime sleepiness and mood states of Sailors on the 3/9 did not change. Crewmembers on the 5/10 also had lower psychomotor vigilance performance than their counterparts on the 3/9 schedule (15% longer reaction times and 59% more 355-millisecond lapses greater combined with false starts). Crewmembers on the 5/10 also had lower psychomotor vigilance performance than their counterparts on the 3/9 schedule (15% longer reaction times and 59% more 355-millisecond lapses greater combined with false starts). Overall, these results may be explained by considering the timing of sleep and the periods of sustained wakefulness experienced on the 5/10. Over a 3-day rotation cycle, a crewmember on the 5/10 watchstanding schedule sleeps at three distinctly different times on each subsequent day, experiences two periods of sustained wakefulness, and has one night with only a 4-hour opportunity for sleep. In contrast, Sailors on the 3/9 have a fixed sleep schedule every day and they experience, at most, 16- to 17-hour periods of sustained wakefulness. Even though the 3/9 schedule, as a whole, is better than the 5/10, analysis showed that two 3/9 watch sections, those standing the night watches, were accepted less by the Sailors. We postulate that concerns about the implementation of the 3/9 schedule may be ameliorated by adjusting sunlight exposure, providing sleep hygiene training, and by considering an alternative distribution of duties between watch sections to allow protected sleep times for those on night watch duty.

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

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NAVAL POSTGRADUATE SCHOOL
Monterey, California 93943-5000

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This report was prepared by:

_____   _____
Nita Lewis Shattuck, Ph.D.   Panagiotis Matsangas, Ph.D.
Associate Professor of   NRC Post-Doctoral Associate
Operations Research

_____
Stephanie Brown
Research Faculty Associate
Department of Operations Research

Reviewed by:

_____
Johannes O. Royset
Associate Chairman for Research
Department of Operations Research   Released by:

_____   _____
Robert F. Dell   Jeffrey D. Paduan
Chairman   Dean of Research
Department of Operations Research

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ABSTRACT

This work is the second phase of a longitudinal study designed to assess and compare the fatigue levels, workload, and performance of crewmembers working on the 3-hrs on/9-hrs off (3/9) and the 5-hrs on/10-hrs off (5/10) watchstanding schedules. Detailed results on the 5/10 are included elsewhere (Shattuck, Matsangas, & Powley, 2015). Crewmembers from the Reactor Department on the USS NIMITZ (N=117, 24.6±3.89 years old, 95 males, 109 enlisted, with 4.25±2.65 years of active duty) participated in this study.

Results show that the 3/9 is better than the 5/10 in terms of sleep quality, subjective levels of fatigue, mood, psychomotor vigilance performance, and acceptance by the Sailors. Although crewmembers on both the 5/10 and the 3/9 received on average approximately seven hours of sleep per day, the sleep hygiene and acceptance of the two schedules differ considerably. On the 3/9, significantly fewer Sailors reported not having enough time to sleep as contrasted with the 5/10 (3/9: 52%; 5/10: 88%; $p<0.001$). There were differences between crewmembers on the two schedules in the expression of negative opinions about the adequacy of their sleep (3/9: 30%; 5/10: 80%) with over twice as many negative opinions for the 5/10 group. Daytime sleepiness and mood states deteriorated during the underway when using the 5/10, whereas daytime sleepiness and mood states of Sailors on the 3/9 did not change. Crewmembers on the 5/10 also had lower psychomotor vigilance performance than their counterparts on the 3/9 schedule (15% longer reaction times and 59% more 355-millisecond lapses greater combined with false starts).

Overall, these results may be explained by considering the timing of sleep and the periods of sustained wakefulness experienced on the 5/10. Over a 3-day rotation cycle, a crewmember on the 5/10 watchstanding schedule sleeps at three distinctly different times on each subsequent day, experiences two periods of sustained wakefulness, and has one night with only a 4-hour opportunity for sleep. In contrast, Sailors on the 3/9 have a fixed sleep schedule every day and they experience, at most, 16- to 17-hour periods of sustained wakefulness. Even though the 3/9 schedule as a whole is better than the 5/10, analysis showed that two 3/9 watch sections, those standing the night watches, were

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I.   INTRODUCTION

Over the last two decades, multiple studies conducted at the Naval Postgraduate School have shown that United States Navy sailors are habitual shift workers. These studies have documented how the daily work/rest schedule (or watchbill) for crewmembers varies from ship to ship. The work and rest system of the ship's crew is under the control of the ship's commanding officer and depends on the organizational culture, the prior experience of the command leadership, the number of qualified crewmembers available to stand watch, and the daily activities/operations. Depending on the schedule selected, a crewmember may stand watch from 6 to 12 hours in each 24-hour period, with shift length typically varying from 3 to 6 hours. Both fixed and rotating watch systems are used in the U.S. Navy; for example, ships may choose to use a 4-hrs on/8-hrs off (4/8), 6-hrs on/6-hrs off (6/6), 6-hrs on/18-hrs off (6/18), or 3-hrs on/ 9-hrs off (3/9) schedules.

Some of these schedules result in workdays that differ in length from the naturally-occurring, 24-hour circadian day. For example, using a 5-hrs on/10-hrs off ("5 & Dime" or "5/10") leads to a *de facto* 15- or 30-hour day in length; the 5-hrs on/15-hrs off ("5/15") results in a 20-hour day. After widespread distribution of a 1969 Naval Postgraduate School master's thesis by Stolgitis (1969), U.S. Navy submarine crews adopted a 6-hrs on/12-hrs off (6/12), three-section watchstanding schedule that results in an 18-hour day.

The typical workday at sea, however, involves much more than watchstanding. In their off-watch period, crewmembers must fit in other ship duties as well as personal activities such as eating, hygiene, and sleep. As a result, crewmembers work long hours and suffer from sleep deprivation, sleep fragmentation, suboptimal performance, and worrisome levels of alertness (Green, 2009; Haynes, 2007; Mason, 2009; Miller, Matsangas, & Kenney, 2012; Paul, Ebisuzaki, McHarg, Hursh, & Miller, 2012; Rutenfranz et al., 1988; Shattuck & Matsangas, 2014).

A. SCOPE

This work is the second phase of a longitudinal study designed to assess the fatigue levels and performance of crewmembers working on the 5/10 watchstanding schedule and to compare it to the fatigue levels and performance of crewmembers working on a 3/9 schedule. Detailed results on the 5/10 are included elsewhere (Shattuck et al., 2015).

Based on a sample of USS NIMITZ Reactor (RX) Department crewmembers, this phase of the study is focused on the 3/9 watchstanding schedule and its comparison with the 5/10 schedule, as measured by:

- sleep quantity and quality, daytime sleepiness, and sleep conditions;
- workload and compliance with the Navy Standard Workweek (NSWW) model; and,
- psychomotor vigilance performance.

II. METHODS

A. EXPERIMENTAL DESIGN

This study was quasi-experimental in nature.

B. PARTICIPANTS

Participants were volunteers from the RX Department of the aircraft carrier USS NIMITZ (CNV-68).

C. WATCH SCHEDULES

The 5/10 is a three-section watchstanding schedule in which a crewmember stands watch for five hours, followed by 10 hours off watch. These five-hour watches commence at 0200, 0700, 1200, 1700, with the 2200 watch period lasting only four hours in duration. This rotating pattern iterates every three days. Figure 1 shows two 3-day cycles of the 5/10 watchstanding schedule. This continual rotation of the 5/10 results in work and rest occurring at different times each day and has long been associated with sleep problems and circadian dysyncrony (Colquhoun & Folkard, 1985; Goh, Tong, Lim, Low, & Lee, 2000; Hakola & Härmä, 2001).

Figure 1.　　5/10 watchstanding schedule layout.

In contrast, crewmembers on the 3/9 are divided into one of four watch sections (WS) of the 3/9 schedule; WS 1 (watch from 0300 to 0600 and from 1500 to 1800), WS 2 (0600-0900, 1800-2100), WS 3 (0900-1200, 2100-0000), and WS 4 (0000-0300, 1200-1500). Therefore, the daily watch schedule is fixed and crewmembers stand the same watch periods each day.

D. 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 (tea, coffee, soft drinks, energy drinks), type and frequency of tobacco products use (cigarettes, chewing tobacco, Nicorette gum or patches, electronic smoke), use of medication (prescribed or over-the-counter), and the type and frequency of an exercise routine.

The Epworth Sleepiness Scale (ESS) was used to assess average daytime sleepiness (Johns, 1991). An ESS score of 10 or more reflects above normal daytime sleepiness and the need for further evaluation (Johns, 1992).

To measure mood state and assess changes in mood, participants filled out the Profile of Mood States (POMS) (McNair, Lorr, & Droppelman, 1971). The questionnaire assesses various dimensions of mood using six subscales: Anger–Hostility; Confusion-Bewilderment, Depression, Fatigue; Tension–Anxiety; and Vigor-Activity. Total Mood Disturbance (TMD) score is derived by summing five of the subscales and subtracting Vigor. 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."

The posttest survey included the ESS, the Pittsburgh Sleep Quality Index (PSQI), the POMS, and a morningness-eveningness preference scale. Participants were asked to indicate their watchstanding schedule, to rate 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 underway workload (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. Participants' sleep history was assessed using the PSQI (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989).

In the last section of the posttest questionnaire, participants were asked whether they liked or did not like the 3/9 schedule by stating their opinion in terms of 16 factors (predictability of the daily schedule, ability to coordinate Shipboard or Departmental evolutions, feeling alert, sleep quality, adequacy of sleep time, availability of off-watch duty time, ability to plan the day, duration of the watch, adequacy of time for meals, mood, caffeine consumption, stress, availability of work-out time, availability of personal time, adequacy of time for Shipboard or Departmental Training, and noise in the berthing compartment). For each factor, the participant had to choose between a positive and a negative statement. For example, participants had to choose whether they had "more personal time" or "less personal time."

2.   Sleep Assessment

Sleep was assessed with actigraphy using the Motionlogger Watch (Ambulatory Monitoring, Inc. - AMI; Ardsley, NY). Data were collected in one-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). Participants also completed an activity log, documenting their daily routine in accordance with the NSWW categories. The activity logs covered a 24-hour period in 15-minute intervals.

3.   Psychomotor Vigilance Test (PVT)

Performance data were collected using the Psychomotor Performance Task (PVT) (Dinges & Powell, 1985). PVT performance is affected not only 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 interstimulus 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 is 10 minutes in duration (Loh, Lamond, Dorrian, Roach, & Dawson, 2004). Shortened versions, however, have also recently been validated to assess sleep deprivation effects (Basner & Dinges, 2011; Loh et al., 2004). Operational demands on the ship precluded the use of the 10-minute version in this study. Therefore, we used a three-minute version of PVT included on the AMI actigraphs with ISI ranging from 2 to 10 seconds. A red backlight appeared on the actigraphy display for one second and the letters "PUSH" were used as visual stimuli; the response time was then displayed in milliseconds.

4.   The Fatigue Avoidance Scheduling Tool (FAST)

The Fatigue Avoidance Scheduling Tool (FAST) is based on the Sleep and Fatigue, Task Effectiveness (SAFTE) model, and was developed for the Department of Defense (DOD). It is the official DOD-sanctioned model for predicting fatigue-related performance degradation. The Naval Safety Center requires that SAFTE/FAST be applied to all mishap investigations (Department of the Navy, 2014). SAFTE-FAST has been validated using actual performance in aircrew 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, an eight-hour period of excellent sleep at night results in normal daytime predicted effectiveness that ranges between 90% and 100%, the green horizontal band on the FAST graph. Predicted effectiveness between 65% and 90%, the yellow band 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 band on the FAST graph, indicates performance that is well below the level

acceptable for operations. The red band represents predicted effectiveness resulting from staying awake for two full days and one night. Reaction times for individuals in the red band are greatly slowed, more than twice the normal level.

E.   PROCEDURES

The study protocol was approved by the Naval Postgraduate School Institutional Review Board. Data collection for the second phase (3/9) commenced on USS NIMITZ on November 3 and ended on November 14, 2014. RX Department personnel were briefed on the research protocol and study procedures over three separate presentations. Those individuals who agreed to participate in the study signed informed consent forms and received further training prior to being issued equipment for the study. Participants filled out the prestudy surveys and received their sleep watches and activity logbooks. All participants were instructed to fill out their activity logs daily and, at a minimum, take the 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.

F.   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 activity 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 watchstander, 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 November 3 to November 14, 2014. From the 1,882 rest intervals, only 20 intervals (1.1%) were imputed. From the rest/in-bed intervals, 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. The duration of each PVT trial was 3 minutes, with a minimum ISI of 2 seconds, and a maximum ISI of 10 seconds.

All PVT responses were aggregated; first by trial and then by participant. The initial PVT data set included 49,248 responses. Since actiwatches were issued over the first two days of the underway period, we omitted those responses obtained on November 3 and 4 (omitted n=4,937). We also omitted the PVT data from Participant 1 because the actiwatch was erroneously set to one-minute PVT (omitted responses n=174).

The PVT data set included some outlying values with reaction times of 10 seconds or more. Since the PVT was not performed in controlled conditions, we postulate that these extraordinarily long responses may be attributed to distracting environmental factors such as noise or crewmember distractions, rather than excessive fatigue. For this reason, we omitted from reaction time (RT) calculations those responses with RT≥10 seconds, although we still counted them as lapses and included them in the calculation of lapses (n = 61 responses). With the settings used, approximately 18 to 24 PVT responses were expected in each three-minute PVT trial. Trials with fewer than 10 responses were omitted from analysis (n = 73). Two trials were also omitted from the analysis because more than 50% of the responses were false starts. Lastly, we omitted from PVT analysis participants with less than nine trials (i.e., less than one trial per day).

After these reduction procedures, the PVT analysis was performed on 1,715 trials from 83 participants working on the 3/9 watch schedule. On average, each participant included in the analysis provided 21 PVT trials (median = 20). 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) to assess performance in 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.

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 3/9 watchstanding schedule. Sleep log data were entered into an Excel spreadsheet and screened for completeness and accuracy. Specifically, we looked for any instances with missing activity 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 and wake periods; hence, we were able to deduce 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 10; SAS Institute; Cary, NC). After assessing and rejecting the data for normality with the Shapiro-Wilk W test, comparisons were based on nonparametric methods. Specifically, we used the Wilcoxon Rank Sum test, while, for multiple comparisons, we used the Dunn method for joint ranks. For these multiple comparisons, statistical

significance was assessed using the Benjamini–Hochberg False Discovery Rate (BH-FDR) controlling procedure (Benjamini & Hochberg, 1995). Correlation analysis was performed using the nonparametric Spearman's *rho*. The criterion for statistical significance was set at p = 0.05. Data are presented as mean (M) ± standard deviation (SD) or median (MD), as appropriately needed. The basic analytical approach is a between-subjects analysis to compare performance on the 3/9 and the 5/10 watchstanding schedules.

First, all variables underwent descriptive statistical analysis to describe our population in terms of demographic characteristics. Next, analysis focused on the comparison between the 5/10 and the 3/9 watchstanding schedules in terms of rest and sleep, mood, psychomotor vigilance performance, work/rest distribution, and subjective assessments of the two schedules.

Although not the main focus of this report, we also assessed the association between poststudy ESS scores, daily rest and 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: those participants with Epworth scores less than or equal to 10 (referred to as the Normal ESS Group) and participants with Epworth scores greater than 10 (referred to as the Elevated ESS Group).

A small number of crewmembers (n = 28) participated in both the 5/10 and 3/9 data collection periods. For this reason, we also compared the two schedules using a between-subject approach. Results from this between-subjects analysis are provided in the Appendix to this report.

III. RESULTS

A. BASIC INFORMATION

Initially, 142 crewmembers of the RX Department volunteered to participate in the 3/9 study. Of these 142 crewmembers, 117 stood watch on one of the four Watch Sections (WS) of the 3/9 schedule, 42 in WS 1, 27 in WS 2, 23 in WS 3, and 25 in WS 4 and were selected for further analysis. The 25 crewmembers who were not used in the analysis were either assigned to the drill team (n=1), were floaters (n=10), did not stand watch (n=1), were under instruction (n=5), or stood watch on other schedules (n=8). Table 1 shows participants' demographic information.

Table 1.   Demographic information of the RX Department participants.

Demographics	Entire Data Set N=142	3/9 n=117
Age (years)	25.5±4.79	24.6±3.89
Gender	26 F, 116 M	22 F, 95 M
Rank (officers/enlisted)	17/ 125	8/ 109
Active duty (years)	4.86±3.62	4.25±2.78
Total deployment (months)	9.72±11.0	8.53±9.38
PSQI Global score	8.02±3.05	8.09±3.03
"Poor" sleepers [1]	79.0%	79.3%
ME Preference Score [2]	50.7±8.71	50.1±8.29
ME Preference type [2]		
Definitely morning	1	0
Moderately morning	25	18
Intermediate	90	78
Moderately evening	19	17
Definitely evening	3	2

[1] PSQI score>5

[2] ME denotes Morningness-Eveningness

With the exception of reported sleep adequacy, the pattern of factors affecting sleep did not differ between the two watchstanding schedules. Sailors working on the 3/9 reported that the most frequent factor affecting their sleep was noise (3/9: 63%; 5/10: 73%), followed by temperature (3/9: 48%; 5/10: 56%), bedding conditions (3/9: 35%; 5/10: 39%), and light in the berthing compartment (3/9: 44%; 5/10: 34%). The frequency

patterns did not differ in the noise factors and the factors included in the bedding conditions;' however, just 52% of the Sailors on the 3/9 reported that they did not have enough time to sleep, compared to 88% of the Sailors on the 5/10 (p<0.001). These results are shown in Figures 2, 3, and 4. "1 Main Circuit" (1MC) is the term for the shipboard public address system.
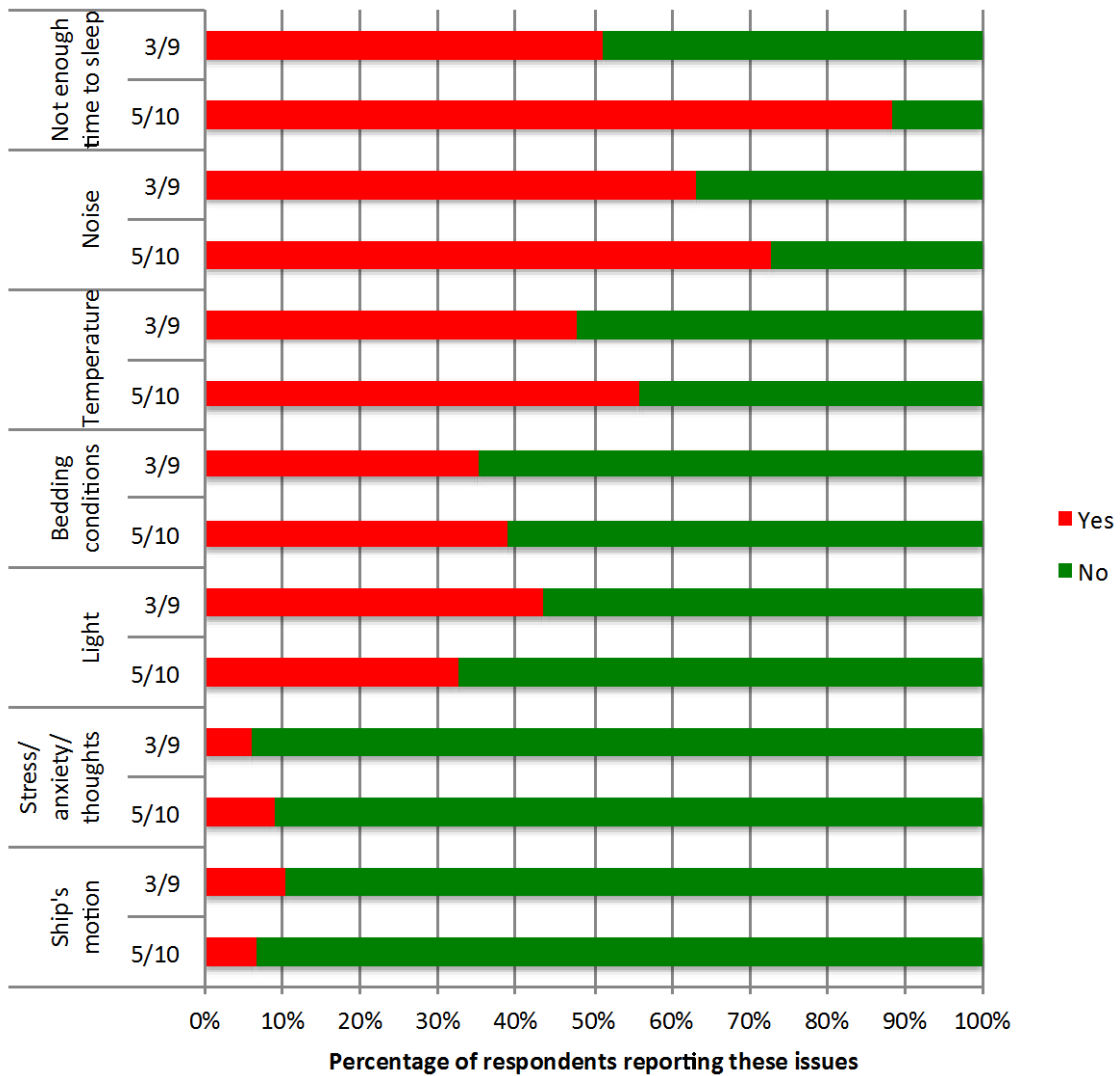
Figure 2.　　Factors affecting sleep.
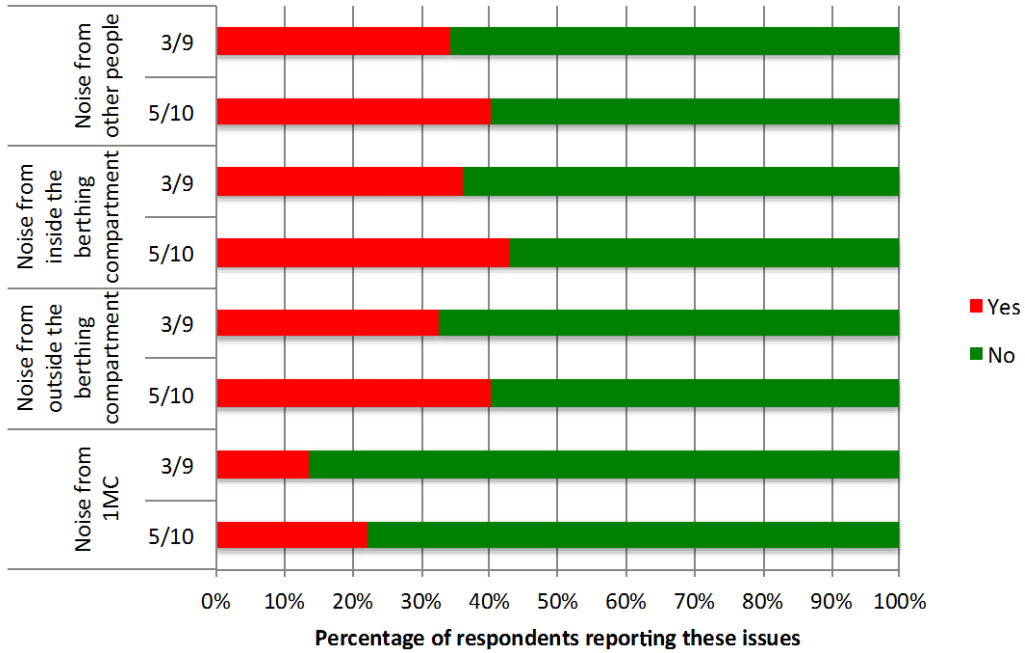
Figure 3.   Sources of noise affecting sleep.
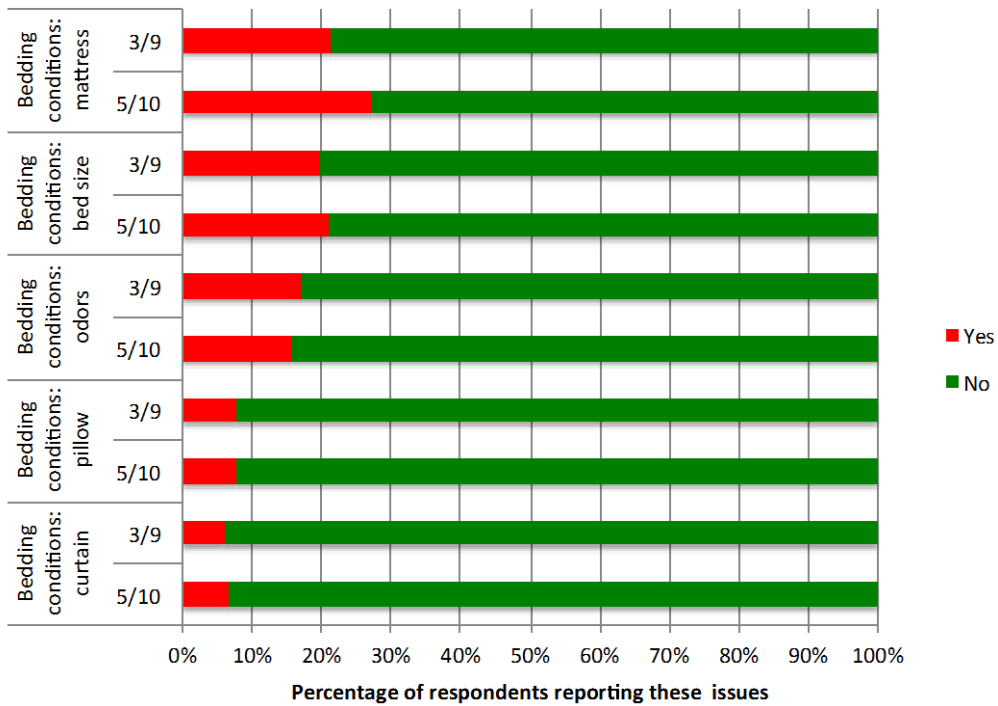
Figure 4.   Sources of complaints about berthing/bedding conditions.

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Next, participants reported the type and frequency of caffeinated beverages consumed (see Figure 5). Overall, 86% indicated drinking caffeinated beverages, with coffee being the most frequent (56%), followed by energy drinks (37%, all Monster ™ or Red Bull ™) and soft drinks (36%). The reported daily amount of energy drinks consumed ranged from 0.5 to 3 (MD=1), 0.5 to 7.5 soft drinks (MD=1), and 0.5 to 6 cups of coffee (MD=2). Compared to Sailors in the 5/10 schedule, on the 3/9 schedule, significantly fewer Sailors reported consuming energy drinks (Δ= –27%) and soft drinks (Δ= –16%), although 9% more 3/9 Sailors reported consuming coffee.
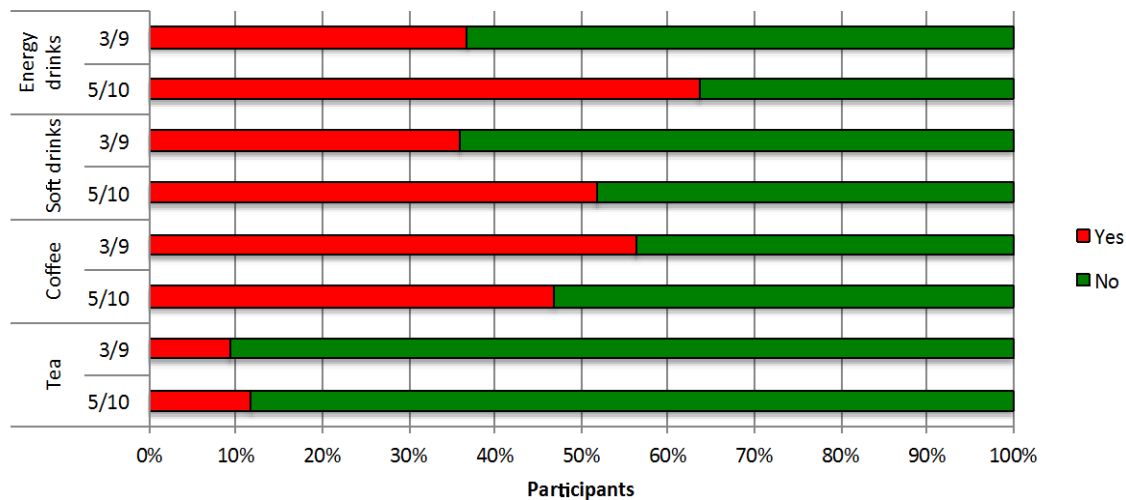
Figure 5.   Consumption of caffeinated beverages.

Regarding the use of nicotine products, cigarettes were used by 24 participants, followed by chewing tobacco/snuff (n = 12), electronic smoke (n = 7), Nicorette gum or nicotine patch (n = 2), and cigars (n = 1). Prescription or over-the-counter medications (e.g., Advil, Tylenol, Allegra, Ibuprofen, Melatonin, Naproxin, Nexium, Valtrey, birth control pills, or vitamins) were used by 17 participants (15%).

More than half of the participants (63.3%) reported working out from 2 to 6 times per week (median = 4), with a median duration of one hour. The workout routines reported by the RX Department participants were mainly weight lifting and aerobic exercise.

B.   SLEEP

Crewmembers on the 3/9 schedule rested (that is, time in bed), on average, 7.30 ± 1.02 hours per day and slept for 6.68 ± 0.96 hours. Daily rest duration, daily sleep duration, and number of sleep episodes per day on the 3/9 did not differ from the corresponding values in the 5/10 (Wilcoxon Rank-Sum test, $p > 0.10$). Although daily rest and sleep did not differ among the four sections of the 3/9 sections (Dunn method for Joint Ranking, $p > 0.50$), Sailors who were working WS 4 had significantly more fragmented sleep than Sailors from the other three sections (Dunn method for Joint Ranking, $p < 0.05$).

Additionally, the daily rest and sleep durations of the 3/9 watchstanding schedule did not differ from that observed in Sailors on the 5/10 schedule (Dunn method for Joint Ranking, $p > 0.30$). However, Sailors from WS 4 had more fragmented sleep than Sailors on the 5/10 (Dunn method for Joint Ranking with control, $p = 0.012$), whereas Sailors from WS 1 and WS 2 had less fragmented sleep than those on the 5/10 (Dunn method for Joint Ranking with control, $p < 0.015$). Table 2 and Figure 6 show the durations for daily rest and sleep, and the number of sleep episodes per day for Sailors on the 5/10 schedule, the 3/9 schedule, and the four sections of the 3/9.

Table 2.   Daily sleep by watchstanding schedule. Data presented as $M \pm SD$.

Variable	5/10 (n=70) [a]	3/9 (n=106) [a]	3/9 WS 4 (0000-0300) and (1200-1500) (n=24) [a]	3/9 WS 1 (0300-0600) and (1500-1800) (n=35) [a]	3/9 WS 2 (0600-0900) and (1800-2100) (n=25) [a]	3/9 WS 3 (0900-1200) and (2100-0000) (n=22) [a]
Daily rest (hrs)	7.52 ± 0.909	7.30 ± 1.02	7.63 ± 1.21	7.17 ± 1.08	7.34 ± 0.933	7.13 ± 0.742
Daily sleep (hrs)	6.88 ± 0.894	6.68 ± 0.960	6.89 ± 1.15	6.55 ± 1.03	6.77 ± 0.868	6.58 ± 0.699
Number of rest episodes per day	1.55 ± 0.282	1.51 ± 0.437	1.87 ± 0.366	1.57 ± 0.475	1.26 ± 0.225	1.32 ± 0.342

[a] Number of participants with sleep data
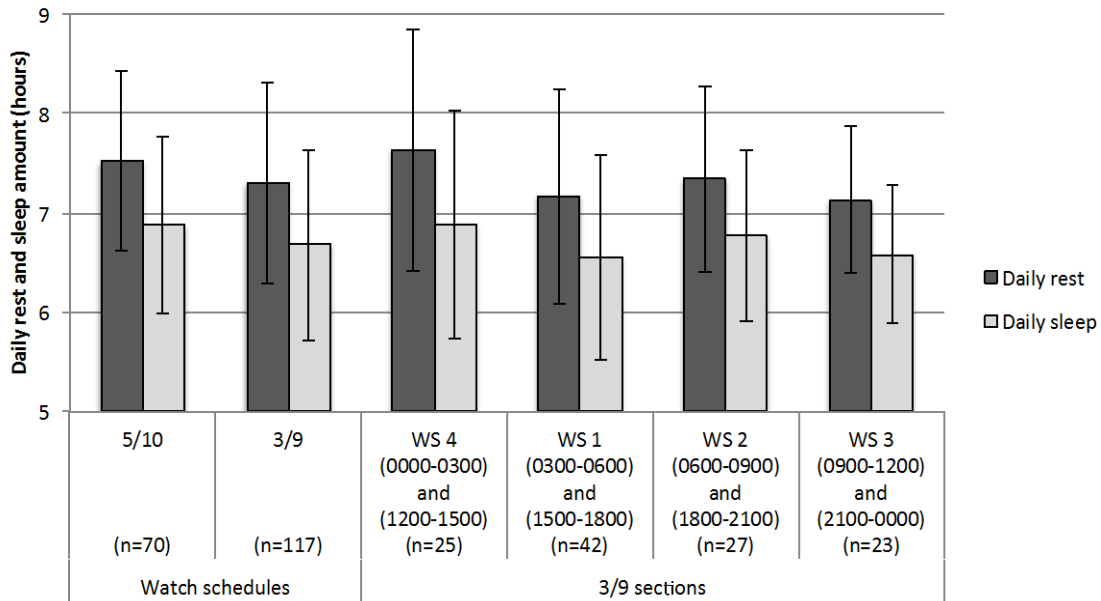
Figure 6.   Daily rest and sleep amount.

Participants in the RX Department working on the 3/9 schedule reported being significantly more satisfied with their new schedule, compared to Sailors on the 5/10, in terms of the amount of sleep they received (see Figure 7). Approximately 40% of 3/9 participants reported having a negative opinion about the adequacy of their sleep. In contrast, 80% of the participants on the 5/10 rated their sleep as inadequate—twice the number as seen in the 3/9.
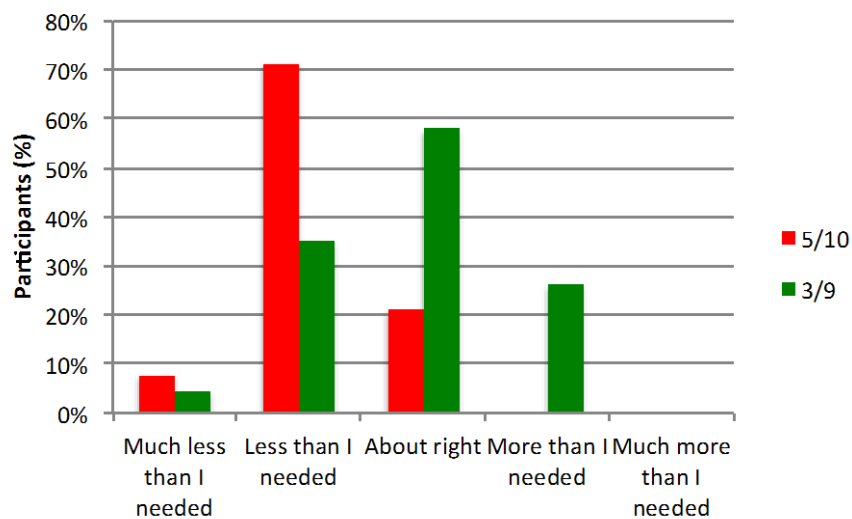
Figure 7.   Responses to the statement "The sleep I received on this underway was . . . ."

The same trend was identified in the responses about the adequacy of sleep of other Sailors (see Figure 8). Approximately 28% of the Sailors on the 3/9 had a negative opinion about the adequacy of the sleep received by other Sailors. In contrast, 78% of the participants on the 5/10 had a negative opinion of the adequacy of sleep of other Sailors.
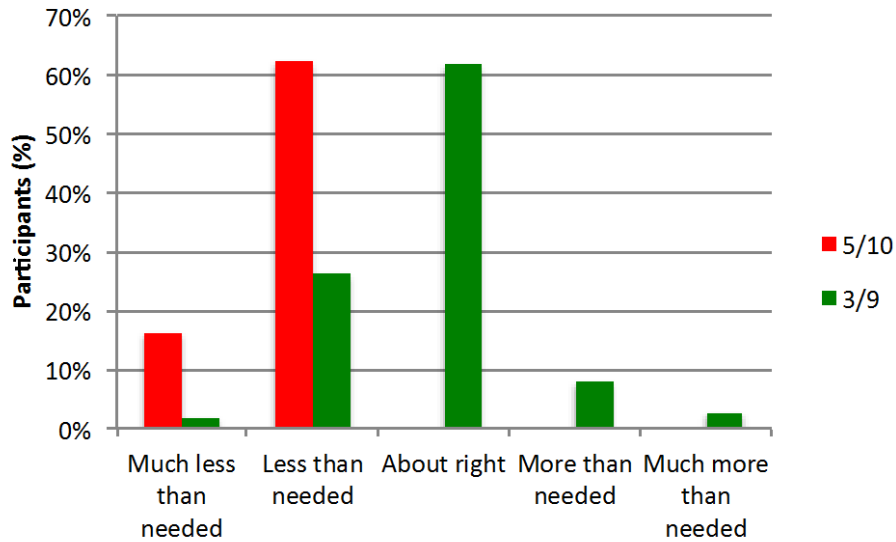
Figure 8.   Responses to the statement "The sleep received by other Sailors on this underway was . . . ."

As assessed by the ESS, the average daytime sleepiness of participants on the 3/9 schedule are shown in Figure 9. The average ESS score at the beginning of the study was 8.68 ± 3.97 (MD=8), and did not change when compared to scores at the end of the study (8.81 ± 4.50, MD = 9, matched pairs Wilcoxon Rank Sum test, S=86.5, p=0.780). In contrast, Sailors on the 5/10 began the study with an average ESS score of 9.66 ± 4.07 (MD=10), which increased further to 10.8 ± 4.65 (MD=11) at the end of the study (matched pairs Wilcoxon Rank Sum test, S=392, p=0.011).
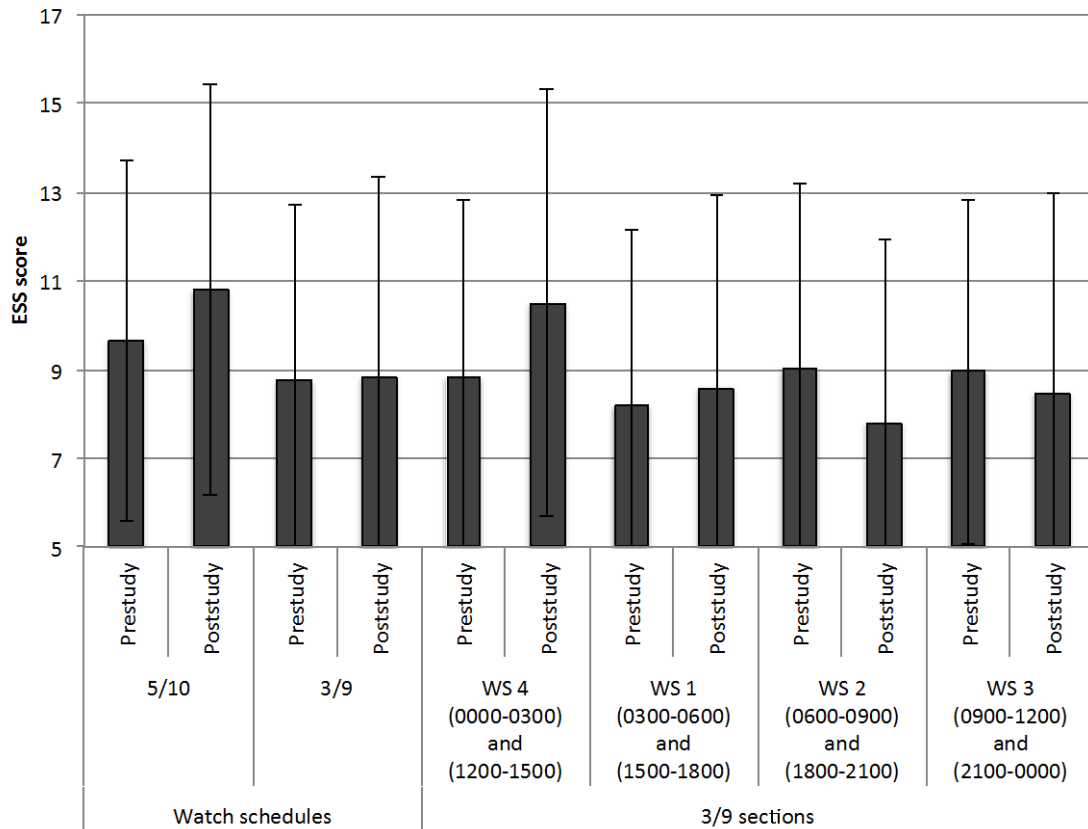
Figure 9.   ESS score comparisons.

The 3/9 Sailors from WS 4, however, showed a marginal increase in ESS scores, from 8.84 ± 4.02 to 10.5 ± 4.83 (one-sided matched pairs Wilcoxon Rank Sum test, S=43.0, p=0.082), while Sailors from WS 2 showed a marginal decrease in ESS scores, from 9.04 ± 4.17 to 7.80 ± 4.17 (one-sided matched pairs Wilcoxon Rank Sum test, S=46.5, p=0.066).

The ESS scores suggested that 33% of the participants on the 3/9 schedule exhibit elevated daytime sleepiness (ESS score>10) (Johns, 1991) at the beginning of the study, increasing to 38% at the end (percentages denote the weighted average). The corresponding percentages of Sailors with elevated daytime sleepiness on the 5/10 schedule were 39% and 52% ($\Delta = 13\%$, whereas in the 3/9 $\Delta = 5\%$). These results are shown in Figure 10.

18
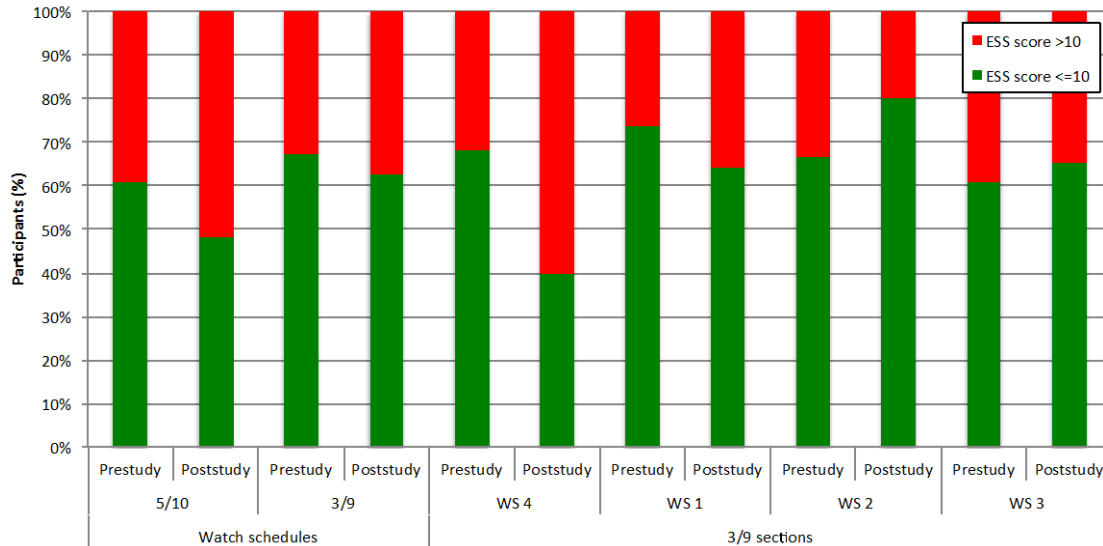
Figure 10.   ESS score comparisons.

C.   ACTIVITY AND SLEEP PATTERNS

The workload analysis for the 3/9 Sailors was based on 831 days of self-reported activity log data derived from 91 RX Department participants working the 5/10 watchstanding schedule (on average, 9.13 days of activity data per participant). Interpolation was applied to 916 missing 15-minute intervals (1.15%).

Results suggest that crewmembers on the 3/9 schedule are on duty an average of 11.1 hours per day, compared to an average of 12.2 hours for Sailors on the 5/10 schedule (Wilcoxon Rank Sum test, Z=3.91, p<0.001). Furthermore, compared to the 5/10, fewer Sailors on the 3/9 work extended workdays. Specifically, only 31% of Sailors on the 3/9 schedule work more than 12 hours daily, compared to 55% of Sailors on the 5/10 schedule (Fisher's Exact test, p = 0.005). On the 5/10, schedule 15% of crewmembers work an average of 14 hours or more per day, compared to only 4% of crewmembers on the 3/9 schedule (Fisher's Exact test, p = 0.022). The daily activity patterns for the two watchstanding schedules and the four watch sections of the 3/9 are shown in Table 3.

Table 3.   Average daily activity in hours, presented as M ± SD.

Activity	5/10 (n=64)	3/9 (n=91)	3/9 Sections			
			WS 4 (n=17)	WS 1 (n=35)	WS 2 (n=21)	WS 3 (n=18)
Nonavailable time	11.8 ± 1.85	12.9 ± 1.93	12.8 ± 2.34	12.8 ± 1.81	12.9 ± 2.10	13.3 ± 1.62
Sleep	7.49 ± 1.22	7.37 ± 1.04	7.30 ± 1.26	7.47 ± 1.12	7.56 ± 0.89	7.04 ± 0.74
Messing	1.26 ± 0.54	1.52 ± 0.55	1.37 ± 0.52	1.59 ± 0.56	1.54 ± 0.63	1.54 ± 0.48
Personal time	1.82 ± 1.62	2.39 ± 1.60	2.59 ± 1.90	2.28 ± 1.51	2.21 ± 1.54	2.62 ± 1.63
Free time	1.26 ± 1.35	1.65 ± 1.55	1.53 ± 1.63	1.51 ± 1.50	1.62 ± 1.68	2.06 ± 1.45
On Duty	12.2 ± 1.85	11.1 ± 1.93	11.2 ± 2.34	11.2 ± 1.81	11.1 ± 2.10	10.7 ± 1.62
Productive Work	10.6 ± 2.08	9.58 ± 2.12	9.16 ± 2.27	9.52 ± 2.07	10.0 ± 2.35	9.60 ± 1.84
Watch	7.13 ± 1.59	6.20 ± 0.73	6.46 ± 0.60	6.14 ± 0.75	6.28 ± 0.80	5.99 ± 0.67
Work	3.43 ± 2.02	3.38 ± 2.14	2.70 ± 2.35	3.38 ± 1.97	3.74 ± 2.49	3.62 ± 1.83
Training	0.731 ± 0.65	0.497 ± 0.67	0.631 ± 0.96	0.405 ± 0.48	0.599 ± 0.75	0.429 ± 0.62
Service diversion	0.875 ± 0.69	0.984 ± 0.93	1.42 ± 0.99	1.24 ± 0.99	0.458 ± 0.69	0.704 ± 0.64

Next, we assessed whether the weekly time on duty exceeded the NSWW criterion of 81 hours weekly. In contrast to Sailors on the 5/10, in which Sailors worked more than the allotted time in the NSWW (85.2 ± 12.9 hours; Wilcoxon Signed-Rank test, $p < 0.001$), Sailors on the 3/9 did not exceed the criterion (77.5 ± 13.5 hours; Wilcoxon Signed-Rank test, $p = 0.012$). The average weekly activity for Sailors on the two watchstanding schedules and for the four watch sections of the 3/9 is shown in Table 4.

Table 4.   Average weekly activity in hours, presented as M ± SD.

| Activity	5/10	3/9	3/9 Sections			
			WS 4	WS 1	WS 2	WS 3
Nonavailable time (87 hrs)	82.8 ± 12.9	90.6 ± 13.5	89.6 ± 16.4	89.9 ± 12.7	90.5 ± 14.7	92.9 ± 11.4
Sleep (56 hrs)	52.5 ± 8.55	51.6 ± 7.25	51.1 ± 8.80	52.3 ± 7.86	52.9 ± 6.24	49.3 ± 5.18
Messing (14 hrs)	8.81 ± 3.76	10.7 ± 3.87	9.55 ± 3.64	11.1 ± 3.93	10.8 ± 4.39	10.8 ± 3.39
Personal time (14 hrs)	12.8 ± 11.3	16.7 ± 11.2	18.2 ± 13.3	15.9 ± 10.6	15.5 ± 10.8	18.4 ± 11.4
Free time (3 hrs)	8.81 ± 9.47	11.5 ± 10.9	10.7 ± 11.4	10.6 ± 10.5	11.3 ± 11.7	14.4 ± 10.3
On Duty (81 hrs)	85.2 ± 12.9	77.5 ± 13.5	78.5 ± 16.4	78.1 ± 12.7	77.5 ± 14.7	75.2 ± 11.4
Productive Work (70 hrs)	73.9 ± 14.5	67.1 ± 14.8	64.1 ± 15.9	66.6 ± 14.5	70.1 ± 16.5	67.2 ± 12.9
Watch (56 hrs)	49.9 ± 11.1	43.4 ± 5.08	45.2 ± 4.19	43.0 ± 5.25	43.9 ± 5.60	41.9 ± 4.66
Work (14 hrs)	24.0 ± 14.2	23.7 ± 15.0	18.9 ± 16.4	23.7 ± 13.8	26.2 ± 17.4	25.3 ± 12.8
Training (7 hrs)	5.12 ± 4.57	3.48 ± 4.72	4.42 ± 6.70	2.83 ± 3.36	4.19 ± 5.21	3.00 ± 4.31
Service diversion (4 hrs)	6.12 ± 4.83	6.89 ± 6.52	9.91 ± 6.94	8.65 ± 6.94	3.21 ± 4.82	4.93 ± 4.47

The four diagrams in Figure 11 show the distribution of time in terms of duty time, productive work, watch, and sleep time distribution among the four sections of the 3/9 schedule. Vertical axes mark the percentage of participants in each activity; sleep is shown on the right axis, while duty, productive work, and watch times are on the left

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

- Watchstanding on the 5/10 schedule comprises approximately 60% of the daily work activity. The remaining 40% is distributed among other work commitments. This pattern is also evident in the 3/9 schedule; i.e., 55% of the day is taken up with watchstanding, while 45% of the day is other commitments.

- Compared to 15% of the 5/10 crewmembers, only 4% of crewmembers on the 3/9 are working, on average, 14 hours or more per day.

- Over an entire three-day rotation circle, a crewmember on the 5/10 schedule faces two periods of sustained wakefulness, a 22-hour period from 0100 to 2300 in the first day, and a 20-hour period from 0600 of the second day, continuing until after 0200 on the third day. In contrast, Sailors in all sections of the 3/9 face, at most, 16- to 17-hour periods of sustained wakefulness.

- Furthermore, all crewmembers working on the 5/10 have one night with only a four-hour sleep opportunity once every three days. In contrast, nights with constrained sleep are evident only in WS 4 of the 3/9 schedule.

- In general, WS 4 of the 3/9 seems to be the most problematic in terms of sleep hygiene because of two reasons.

  o First, Sailors have their major sleep episode in the evening, between 1600 and 2300. Crewmembers that are not adapted to this sleep pattern may find it difficult to sleep in the early evening and their sleep may be less recuperative.

  o After their midnight to 0300 watch period, more than 60% of the Sailors in the watch section remain awake instead of using this time for sleeping. Further analysis showed that approximately 20% of the Sailors use this time for maintenance, while 40% to 60% of the Sailors use it for messing or as personal/free time.

The polar diagrams in Figure 12 integrate the sleep, watch, and duty time of the typical 24-hour day in the 5/10 and the 3/9 schedules. Each diagram includes all sections of the corresponding watch schedule.

Crewmembers Standing Watch 0000-0300 and 1200-1500
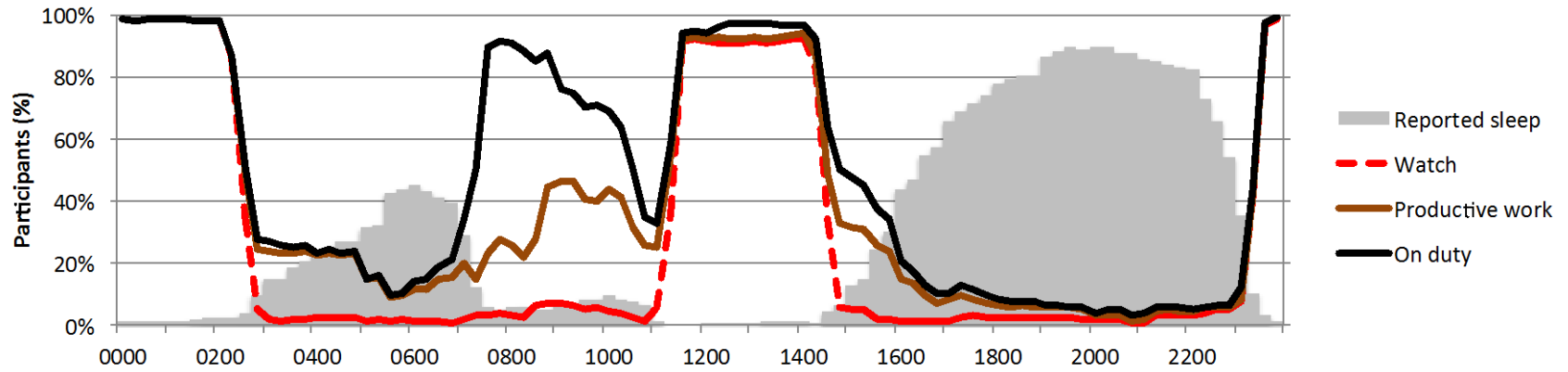
Crewmembers Standing Watch 0300-0600 and 1500-1800

Crewmembers Standing Watch 0600-0900 and 1800-2100

Crewmembers Standing Watch 0900-1200 and 2100-0000
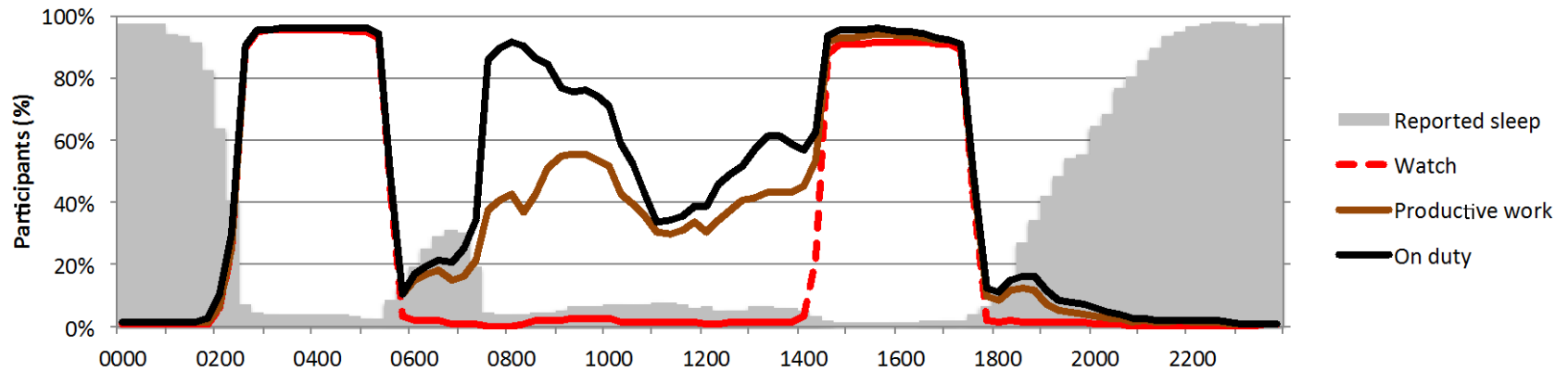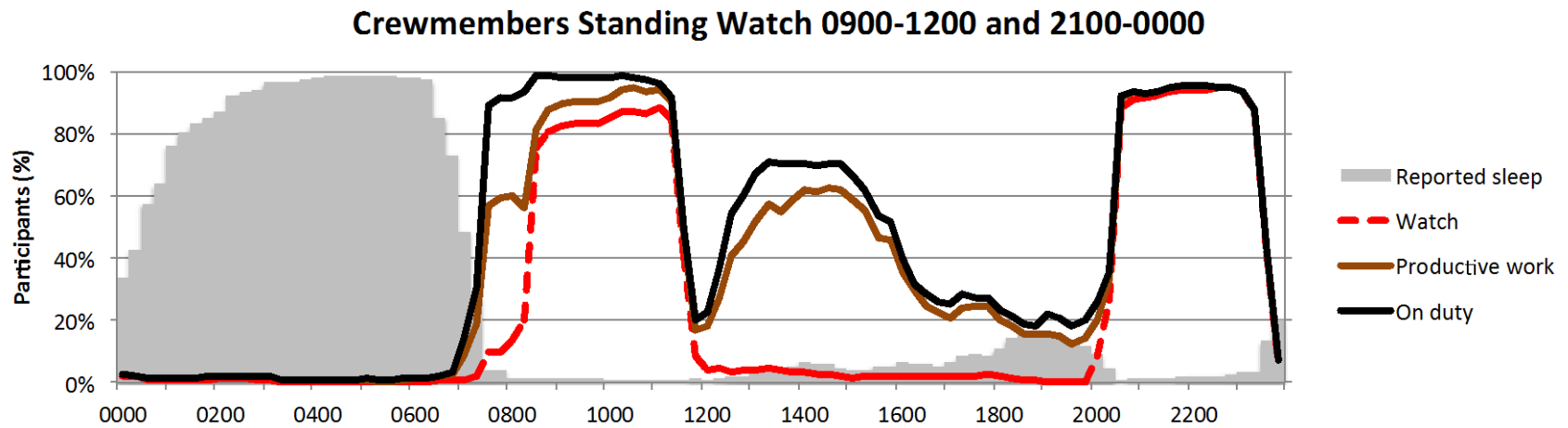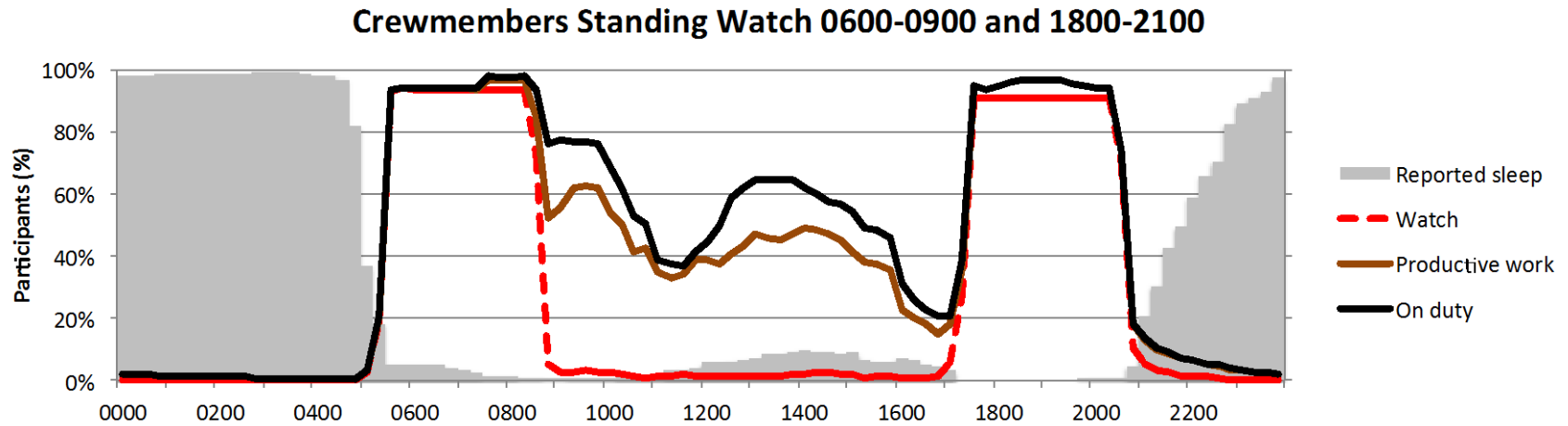
Figure 11. Activity time distribution in the four sections of the 3/9 watch schedule (RX Department crewmembers).
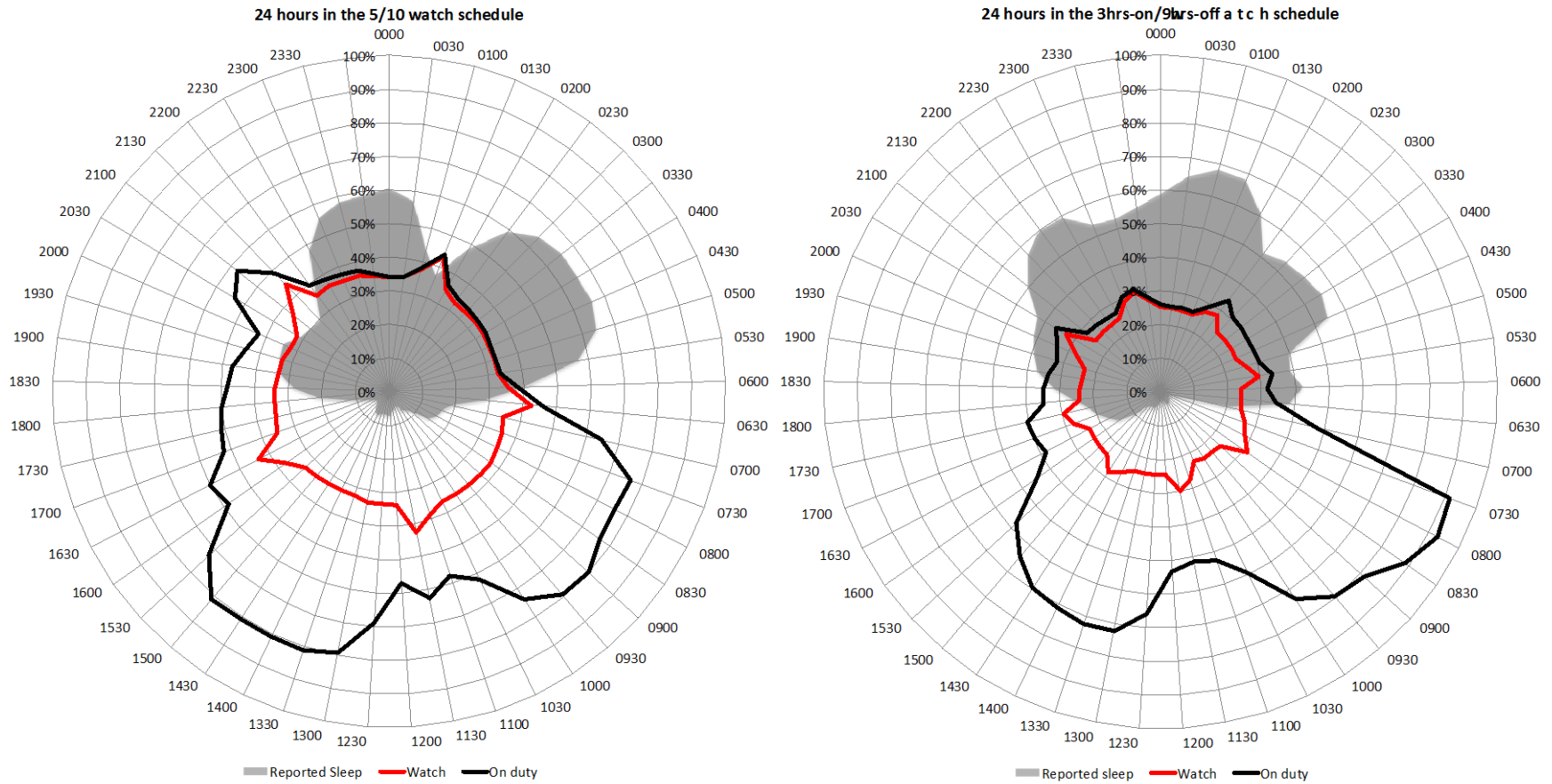
Figure 12.   Typical 24-hour day in the 5/10 and the 3/9 watch schedules. Homocentric circles denote the percentage of the crewmembers in the corresponding activity.

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, all POMS scores except Vigor-Activity were associated with daily average rest and sleep amount in the 3/9 schedule. In contrast, when the RX Department was working on the 5/10 schedule, only the Vigor-Activity score was correlated with daily rest and sleep. Second, age was not associated with POMS scores. However, when the RX Department was working on the 5/10 schedule, younger crewmembers showed higher levels of depression, anger-hostility, and total mood disturbance scores at the end of the underway period (poststudy scores). This finding is extremely interesting since younger crewmembers require more sleep (8.5 to 9 hours per night) and, consequently, are accruing a more serious sleep debt. These results are shown in Table 5.

Table 5.   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			–0.182	–0.218[*]		0.467[***]
Depression			–0.163	–0.168		0.492[***]
Anger-Hostility			–0.227	–0.223		0.486[***]
Vigor-Activity						
Fatigue			–0.247[*]	–0.268[*]		0.552[***]
Confusion-Bewilderment		–0.157	-0.174	–0.187		0.454[***]
Total Mood Disturbance			–0.226[*]	–0.231[*]		–0.543[***]

Note 1: [*] p<0.05; [**] p<0.01; [***] p<0.001
Note 2: Inclusion criterion: p<0.10

Next, we calculated the difference in POMS scores between the beginning and the end of the study (i.e., Δ(score) = postscore – prescore). A comparison showed that Δ(TMD) differed between Sailors working on the 3/9 and the 5/10 (Wilcoxon Rank Sum test, $Z = 3.99$, $p < 0.001$). Specifically, TMD scores on the 3/9 showed a statistically marginal decrease (Wilcoxon Signed Rank test, $S = 600$, $p = 0.077$), suggesting an improvement in the mood of Sailors working on the 3/9. In contrast, the mood of Sailors

working on the 5/10 deteriorated significantly during the underway period (Wilcoxon Signed Rank test, S = 663, p < 0.001). Change scores showed the same pattern—that the 3/9 is better than the 5/10—in terms of Anger-Hostility, Depression, Tension-Anxiety, Fatigue, and Confusion-Bewilderment (all score differences are statistically significant according to BH-FDR). POMS TMD and subscale results are shown in Figures 13 to 19. Vertical bars denote the standard error of the mean. Data labels show the p-value of the comparison between the corresponding 3/9 watch section on the 5/10 schedule. Table 6 shows, in detail, all POMS TMD and subscale scores for the 5/10 and the four sections of the 3/9 watch schedules.
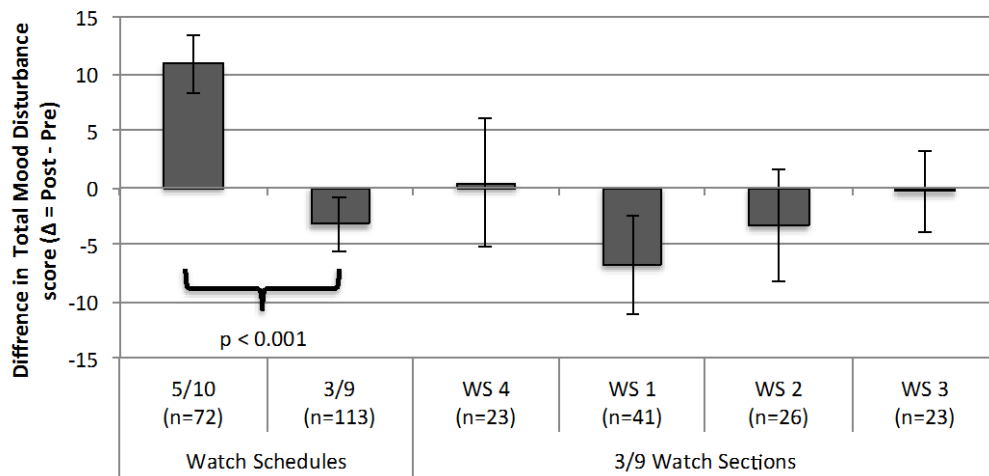

Figure 13.   Difference in TMD scores.
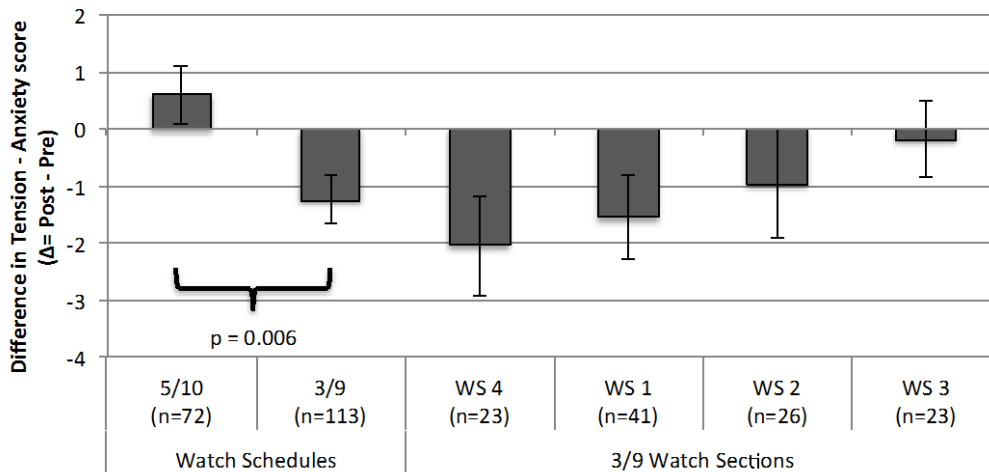
Figure 14.   Difference in Tension-Anxiety scores.
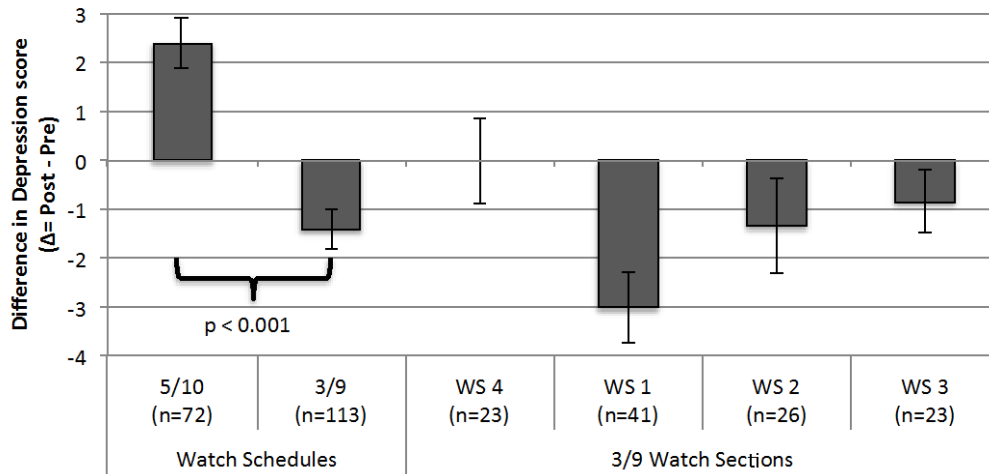
Figure 15.   Difference in Depression scores.
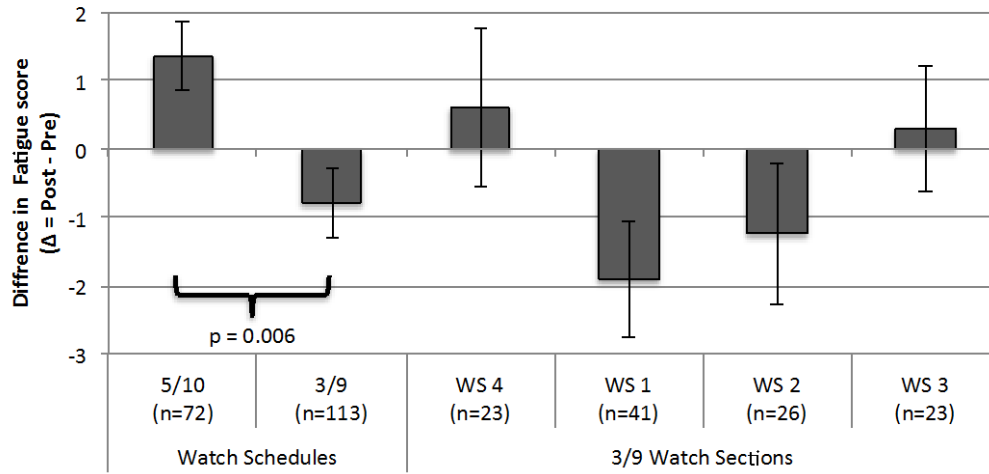
Figure 16.   Difference in Fatigue scores.
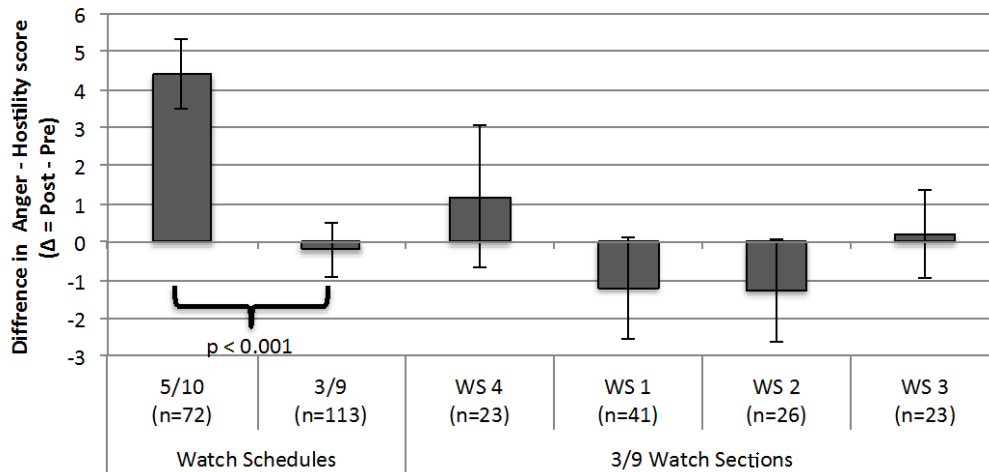
Figure 17.   Difference in Anger-Hostility scores.
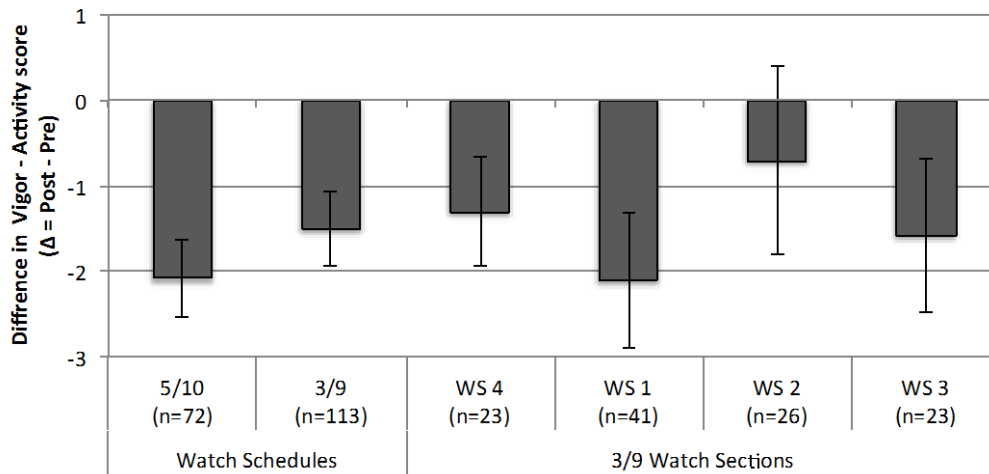
Figure 18.   Difference in Vigor-Activity scores.
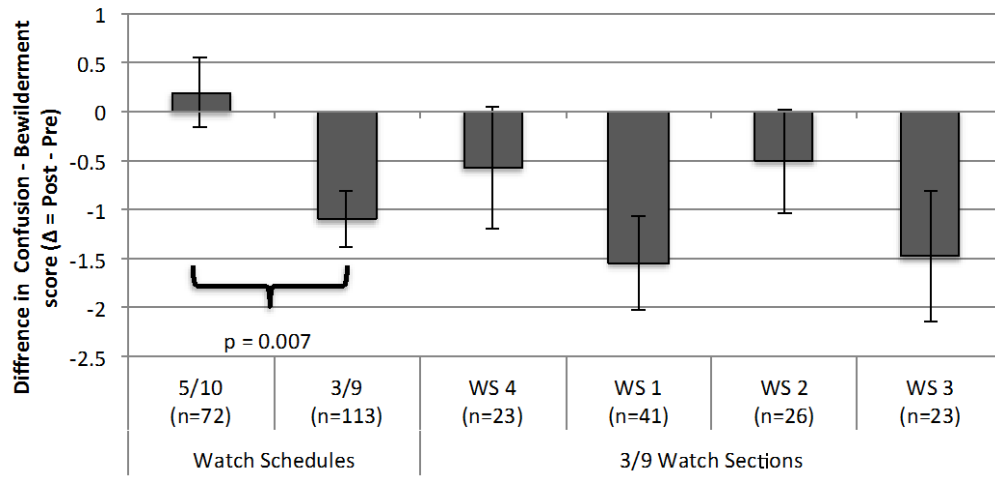
Figure 19.   Difference in Confusion-Bewilderment scores.

Table 6.   POMS TMD and Subscale Scores for the 5/10 and the four sections of the 3/9 watch schedules. Data presented as M ± SD.

| POMS Scales | 5/10 | | 3/9 | | 3/9 | | | | | | | |
| | | | | | WS 4 | | WS 1 | | WS 2 | | WS 3 | |
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Tension-Anxiety	11.0±5.52	11.5±5.92	8.97±5.30	7.73±5.02	10.2±5.16	8.38±5.0	9.95±5.71	8.33±5.45	7.48±5.02	6.35±4.03	7.70±4.58	7.52±5.19
Depression	11.2±9.22	13.6±11.1	10.2±10.8	8.70±10.2	9.0±7.98	9.0±9.23	13.2±12.1	10.2±12.0	7.37±9.93	6.04±7.82	9.44±11.0	8.61±10.1
Anger-Hostility	13.8±9.14	18.2±9.86	12.5±9.08	12.2±9.93	13.6±7.07	14.8±10.1	15.5±9.64	14.3±10.7	8.67±8.52	7.39±8.12	10.6±8.92	10.8±8.34
Vigor-Activity	11.5±5.21	9.18±4.79	12.8±5.68	11.4±5.78	12.1±4.76	11.2±5.61	12.7±6.75	10.7±5.88	12.9±4.24	12.0±6.32	13.6±6.16	12.0±5.34
Fatigue	12.5±4.84	13.8±5.71	9.01±5.58	8.20±5.81	10.1±4.62	10.8±6.09	10.1±6.65	8.05±5.90	7.59±4.46	6.27±4.83	7.65±5.47	7.96±5.75
Confusion-Bewilderment	9.04±4.55	9.08±4.75	7.68±4.60	6.64±4.28	7.79±4.74	7.50±4.47	8.27±5.01	6.76±4.24	6.11±3.25	5.46±3.39	8.35±4.91	6.87±5.0
Total Mood Disturbance	46.0±27.4	57.0±31.1	35.6±32.8	32.1±32.7	38.5±25.0	39.3±29.8	44.4±37.0	37.0±36.1	24.3±29.1	19.5±26.7	30.1±32.0	29.8±33.1

E. PSYCHOMOTOR VIGILANCE PERFORMANCE

The PVT analysis shows that Sailors working on the 5/10 watchstanding schedule have a significantly worse PVT performance than the 3/9 (see Table 7). Specifically, 9 of the 11 PVT metrics were different at a statistically significant level (nonparametric comparisons, based on Wilcoxon Rank Sum tests, with p-values adjusted according to BH-FDR).

Table 7.   PVT metrics presented as M ± SD.

Variable	5/10 (n=39)	3/9 (n=83)	3/9 Sections			
			WS 4 (n=23)	WS 1 (n=26)	WS 2 (n=20)	WS 3 (n=14)
Mean RT, (ms)	392±111	340±132 [a]	298±72.2	377±182	347±123	334±96.0
Mean 1/RT	3.22±0.5	3.91±0.777 [a]	4.01±0.750	3.81±0.895	3.93±0.704	3.72±0.682
Fastest 10% RT, (ms)	248±50.9	203±38.6 [a]	193±27.5	209±49.2	197±33.3	215±37.3
Slowest 10% 1/RT	1.96±0.439	2.38±0.693 [a]	2.62±0.677	2.24±0.771	2.32±0.617	2.32±0.635
False Starts (FS), %	1.53±1.56	1.69±2.20	1.21±1.07	1.66±1.94	2.65±3.54	1.16±1.02
Lapses 500ms, %	13.5±12.2	8.91±7.99 [a]	6.64±4.66	11.6±11.3	8.32±6.35	8.50±6.03
Lapses 355ms, %	31.8±19.4	19.4±15.9 [a]	14.7±10.9	24.0±21.6	18.4±12.3	19.9±14.0
Lapses 750ms+FS, %	7.61±6.77	6.00±5.75	4.11±2.66	7.61±7.75	7.00±5.80	4.68±4.17
Lapses 600ms+FS, %	10.9±9.57	8.30±6.88 [a]	5.75±3.57	10.1±9.33	8.82±6.56	6.74±5.06
Lapses 500ms+FS, %	15.0±12.1	10.6±8.25 [a]	7.85±4.74	13.3±11.4	11.0±7.13	9.65±6.23
Lapses 355ms+FS, %	33.4±19.1	21.1±15.8 [a]	15.9±11.0	25.7±21.4	21.1±12.0	21.0±14.0

[a] Statistically different according to BH-FDR

Figures 20 to 22 present the results for PVT metrics, showing that the 5/10 watch schedule differs statistically from the 3/9.
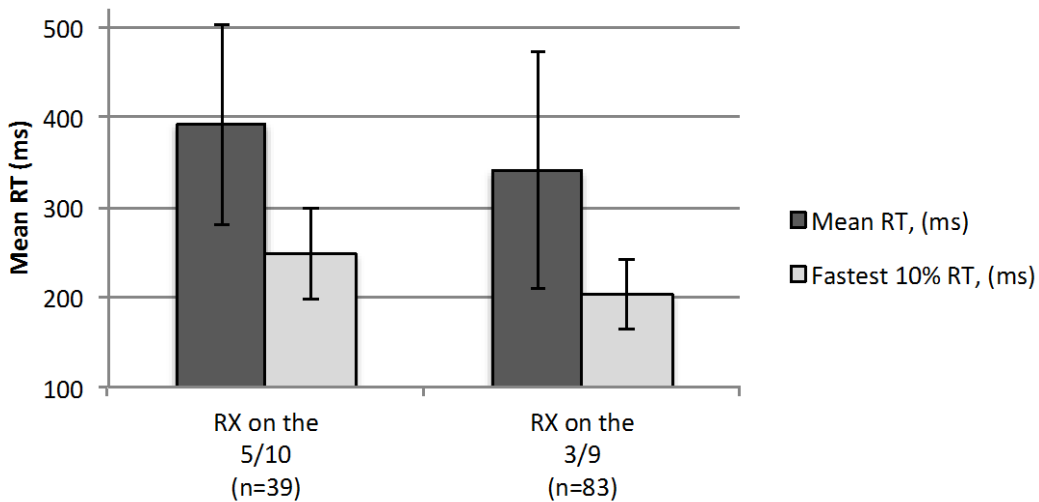
Figure 20.   PVT reaction times.
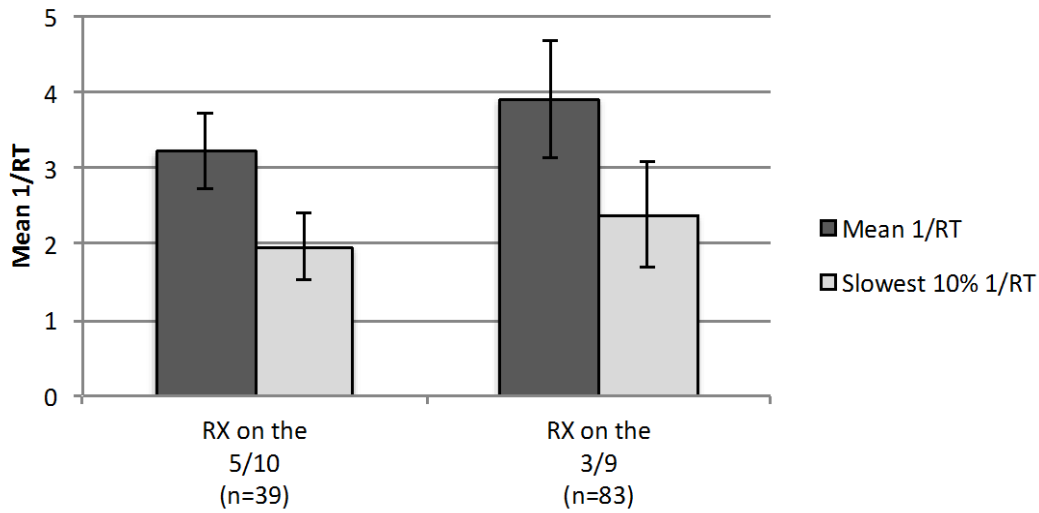
Figure 21.   PVT response speeds.
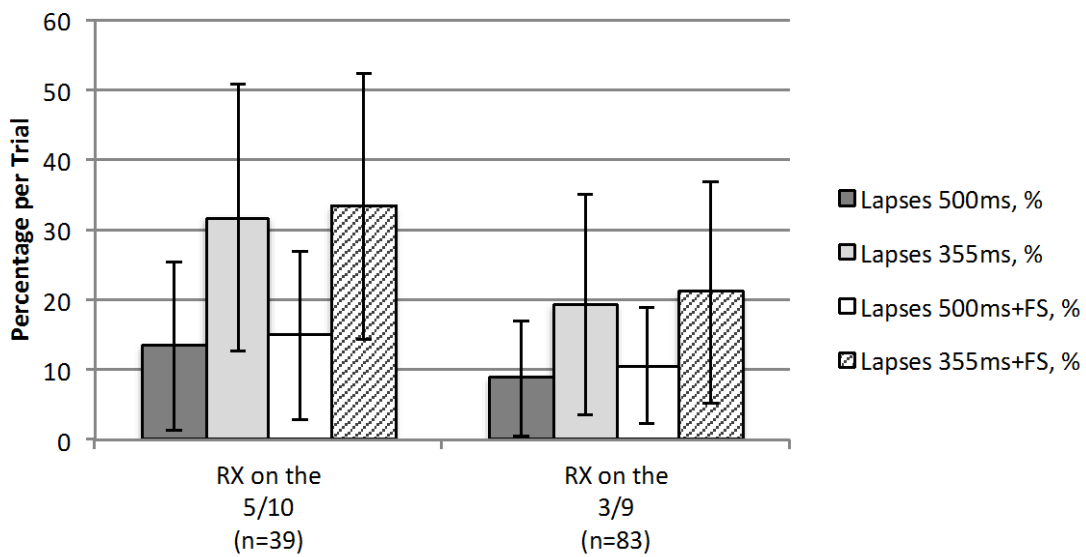
Figure 22.   Percentage of lapses of 355ms and 500ms in length, and lapses combined with false starts.

F.   FACTORS CONTRIBUTING TO THE ACCEPTANCE OF THE 3/9

In the posttest questionnaire, participants had to choose between things that they liked or did not like in the 3/9 watch schedule. Specifically, they had to choose between a positive and a negative statement for each of 16 factors associated with the crewmember acceptance of the 3/9. For example, participants had to choose whether they had more to time to sleep (positive statement) or less time to sleep (negative statement) on the 3/9

schedule. Overall, participants provided 879 (66%) positive and 456 (44%) negative responses. Most responses showed that Sailors liked the predictability of the daily schedule in the 3/9 (90%), the ability to plan daily activities (93%), and the fact that time on watch goes faster (91%). Approximately 75% of the responses also showed that Sailors felt more alert/better able to focus and had more time for meals.

There were, however, differences between watch sections. WS 3 had 85% positive responses, followed by WS 2 with 75%. The largest number of negative responses were for WS 4 (56%) and WS 1 (55%), the two sections that are required to stand watch from midnight to 0300 and 0300 to 0600—the worst time to work and hardest to stay alert. These results are shown in Figure 23.
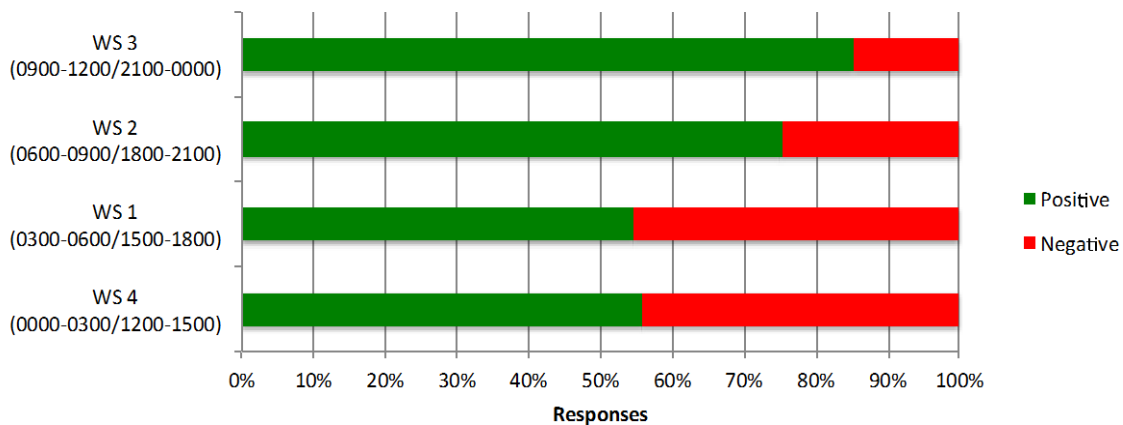
Figure 23.   Positive and negative responses by 3/9 section.

Responses for the remaining questions in the posttest questionnaire showed that Sailors had mixed opinions about the 3/9. Specifically, Sailors in WS 4 and 1 reported that they had less time than before to sleep ($\approx$ 56%), had worse sleep quality ($\approx$ 54%), had less time for off-watch duties ($\approx$ 72%), found it hard to coordinate with shipboard or departmental evolutions ($\approx$ 76%), and do not have enough time for shipboard or departmental training ($\approx$56%). Furthermore, approximately 67% of the participants in three of the four sections noted that they did not have adequate personal time. These results are shown in Figure 24. The diagram for the entire 3/9 watch schedule shows the responses weighted by section.
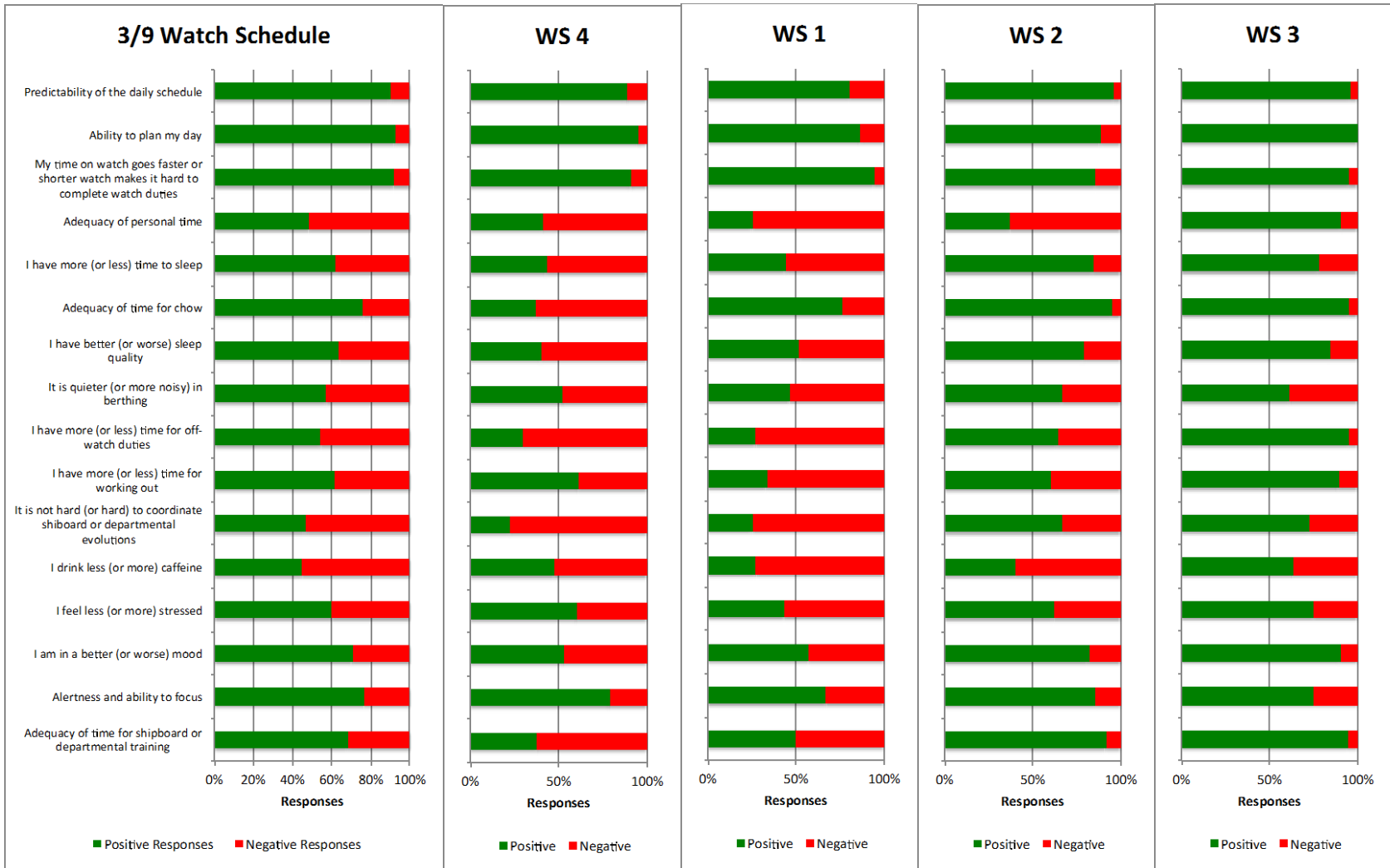
Figure 24. Responses on the factors contributing to acceptability of the 3/9 watch schedule.

To further assess the impact of the 3/9 watchstanding schedule, we examined participant responses to two open-ended questions. From the 109 crewmembers answering the question "What did you like most about your current watch schedule?", approximately 48% responded that they liked the consistency of the daily watch and sleep schedule, whereas 14% liked the short, three-hour, duration of their shifts (see Figure 25). In contrast to these positive results, we note that 38% of the crewmembers working on the 5/10 responded that they did not like anything in the 5/10 watch schedule. It is interesting to note that three Sailors working on WS 4 of the 3/9 responded that they liked the 3/9 because of the time they had available to work after getting off the 0000 to 0300 shift.
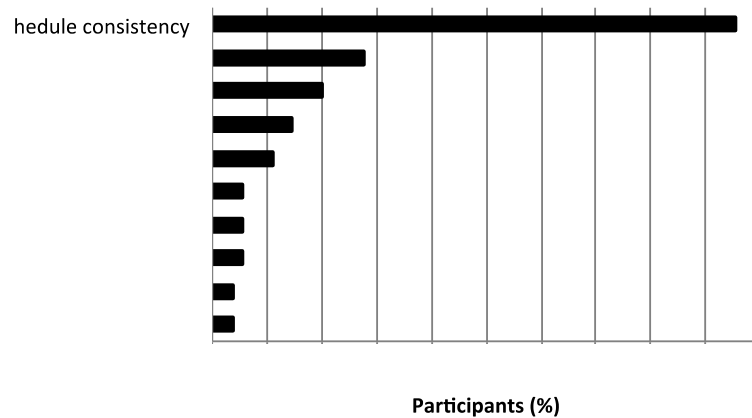
Figure 25.   Responses to the question "What did you like most about your current watch schedule?"

From the 102 crewmembers answering the question "What did you like least about your current watch schedule?", approximately 37% responded that the nine hours between shifts are less than what is needed for meals, working out, free/personal time, or for other work duties. In contrast, 73% of the crewmembers working on the 5/10 responded that there is little time for other duties, working out, meals, etc. The next worst factor reported by crewmembers on the 3/9 was the difficulty in adjusting to the sleep pattern of the 3/9, and the difficulty in falling asleep reported by 17% of the participants (see Figure 26).

ations, work out, meals, free time, etc.

Participants (%)
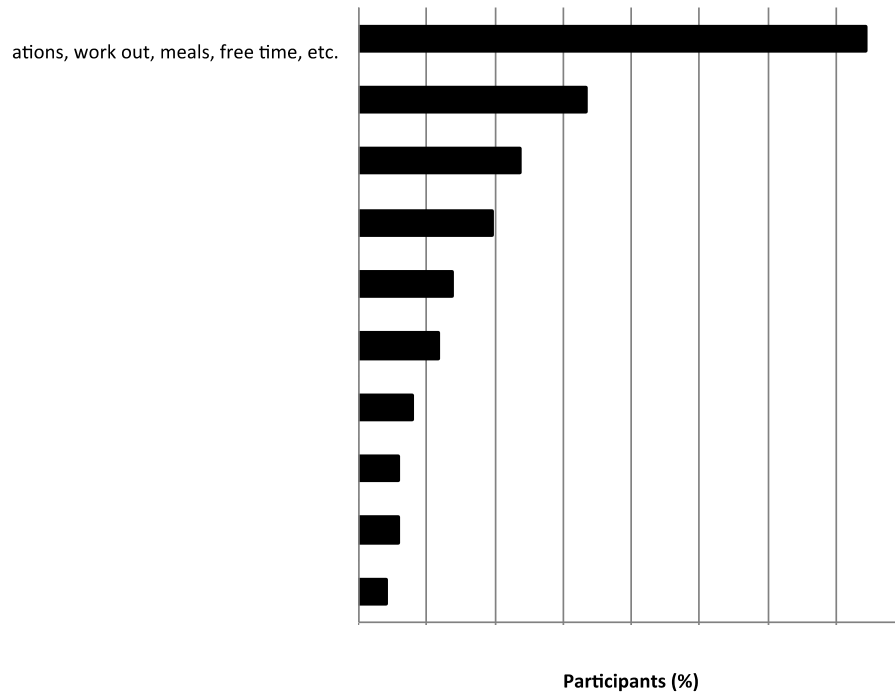
Figure 26.   Responses to the question "What did you like least about your current watch schedule?"

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

Table 8 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, and to some extent with PVT lapses.

Table 8.   ESS, rest/sleep, and PVT correlations.

Variable	ESS	Daily Rest (Time in Bed) Amount	Daily Sleep Amount
Daily Time in Bed Amount	–0.346 [**]		
Daily Sleep Amount	–0.294 [**]		
Mean RT	0.191		
Mean 1/RT			
Fastest 10% RT			
Slowest 10% 1/RT	–0.208		
False Starts, %			
Lapses 500ms, %	0.239 [*]		
Lapses 355ms, %	0.190		
Lapses 750ms+False Starts, %	0.210		
Lapses 600ms+False Starts, %	0.232 [*]		
Lapses 500ms+False Starts, %	0.245 [*]		
Lapses 355ms+False Starts, %	0.204		

Note 1: Unadjusted p-values: [***] p<0.001; [**] p<0.01; [*] 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 9 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 9.   Comparison between Normal and Elevated ESS Groups.

Variable	Normal Group (NG) ESS<=10	Elevated Group (EG) ESS>10	p-value[A]	Percent Difference in Means NG vs. EG	Percent Difference in SD NG vs. EG	p-value[B]
[1]	[2]	[3]	[4]	[5]	[6]	[7]
Daily TIB, (hrs)	7.40±1.04	6.96±0.91	0.050	–5.95%		0.611
Daily Sleep, (hrs)	7.16±0.65	6.33±0.82	0.018	–11.6%		0.179
Mean RT, (ms)	322±98.9	363±166	0.303			0.106
Mean 1/RT	3.35±0.34	3.83±0.79	0.420			0.850
Fastest 10% RT, (ms)	202±39.0	206±39.3	0.509			0.928
Slowest 10% 1/RT	2.45±0.67	2.28±0.73	0.264			0.527
False Starts (FS), %	1.62±2.41	1.76±1.93	0.730			0.661
Lapses 500ms, %	7.72±6.43	10.6±9.87	0.162		53.5%	0.100
Lapses 355ms, %	18.3±15.6	21.1±16.8	0.303			0.842
Lapses 750ms+FS, %	5.04±4.17	7.27±7.41	0.260		77.7%	0.042
Lapses 600ms+FS, %	8.68±4.71	9.67±8.70	0.187		84.7%	0.064
Lapses 500ms+FS, %	11.9±5.63	12.4±10.2	0.185		81.2%	0.083
Lapses 355ms+FS, %	19.9±15.3	22.9±16.3	0.336			0.607

[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.

The pattern of differences in the PVT metrics was not as clear. In general, the group with Normal ESS scores had decreased RT and fewer lapses than the group with Elevated ESS scores, but not at statistically significant levels. The group with Elevated ESS scores, however, had an increased variability of percentage of 500ms lapses and percentage of 750/600/500ms lapses combined with false starts. In general, crewmembers with an ESS > 10, the Elevated ESS Group, received less sleep and had increased variability in 4 of the 11 PVT metrics when compared to the Normal ESS Group with ESS ≤ 10.

IV. DISCUSSION

This report describes the results of the second phase of a longitudinal study to assess and compare two watchstanding schedules—the 3/9 and the 5/10—typically used in the United States Navy. Although we should not ignore concerns about how the 3/9 should be implemented, our results show that the 3/9 is better than the 5/10 in terms of sleep quality, subjective levels of fatigue, mood, psychomotor vigilance performance, and acceptance by the Sailors.

In terms of daily sleep duration, the two schedules did not differ significantly. Crewmembers on both the 5/10 and the 3/9 received approximately seven hours of sleep per day; however, the sleep hygiene and acceptance of the two schedules differ considerably. Approximately 52% of the Sailors on the 3/9 reported that they did not have enough time to sleep, compared to 88% of the Sailors on the 5/10 ($p<0.001$). It was no surprise to see that twice as many Sailors on the 5/10 (80%) had a negative opinion about the adequacy of their sleep, compared to Sailors on the 3/9 (40%). Daytime sleepiness increased during the underway when using the 5/10 ($p=0.011$), whereas in the 3/9, daytime sleepiness did not change. The same pattern is found in mood states: mood of Sailors on the 5/10 deteriorated significantly during the underway period, whereas the mood of Sailors on the 3/9 actually improved slightly. This mood trend is not trivial from an operational perspective, As mood plays a significant role in team effectiveness (Cohen & Bailey, 1997; Zaccaro, Rittman, & Marks, 2001). Deteriorated mood and negative affect may have considerable effects on performance—not only at an individual level, but also in team cognition and awareness (Pfaff, 2012; Pfaff & McNeese, 2010).

Overall, these results seem contradictive. For both schedules, Sailors sleep about the same amount *on average*, but they report having *less time to sleep* and *feel sleepier* while working on the 5/10. This contradiction may be explained when we consider the timing of sleep and the periods of sustained wakefulness. Over a three-day rotation cycle, a crewmember on the 5/10 watchstanding schedule sleeps at three distinctly different times on each subsequent day. The 5/10 Sailors also experience two periods of sustained wakefulness during a typical three-day cycle, one 22–hour period from 0100 to 2300 on the first day, and another 20-hour period from 0600 of the second day until after 0200 on

the third day. Furthermore, all crewmembers working the 5/10 have one night with only a four-hour opportunity for sleep once every three days. In contrast, Sailors working on the 3/9 have a fixed sleep schedule every day and experience, at most, 16- to 17-hour periods of sustained wakefulness. Severely restricted sleep opportunities for night sleep are evident only in one of the 3/9 watch teams, WS 4.

More importantly, we found that crewmembers on the 5/10 had lower psychomotor vigilance performance results than their counterparts on the 3/9 schedule. Specifically, participants on the 5/10 had 15% longer reaction times and had 59% more errors (defined as lapses greater than 355 milliseconds duration, combined with false starts) than did participants on the 3/9 schedule.

Referred to as circadian desynchrony, the disruption of the internal circadian rhythms provides one explanation for our results (Colquhoun, Blake, & Edwards, 1969b). While working the 5/10, Sailors work a rapidly rotating schedule, which rotates forward every day. Such a condition is known to disturb the sleep-wakefulness cycle and does not allow for the circadian clock to realign due to the continuously changing cycle (Åkerstedt, 2003). 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 been also reported for circadian realignment to occur (Colquhoun, Blake, & Edwards, 1969a; Hockey, 1983).

Even though the 3/9 schedule as a whole is better than the 5/10, our analysis showed that the two watch sections standing the night watches were less accepted by the Sailors. Specifically, Sailors in WS 4 and WS 1 reported that they had less time to sleep ($\approx 56\%$) in the 3/9 than in the 5/10, had worse sleep quality ($\approx 54\%$), had less time for off-watch duties ($\approx 72\%$), found it hard to coordinate with shipboard or departmental evolutions ($\approx 76\%$), and did not have enough time for shipboard or departmental training ($\approx 56\%$). From a sleep hygiene perspective, we identified two reasons that explain some of these opinions. First, Sailors in WS 4 have their major sleep episode in the evening between 1600 and 2300, whereas Sailors in WS 1 have theirs between 1900 and 0130. Crewmembers who have not adapted to this sleep pattern will find it difficult to sleep in the early evening and the sleep they receive may be less recuperative. Second, after standing their midnight-to-0300 watch, more than 60% of the Sailors in WS 4 remain

awake instead of sleeping. They use this time for maintenance, meals, or as personal/free time. We postulate that these two issues may be ameliorated by adjusting sunlight exposure to allow them to better entrain to sleeping earlier in the evening and by providing personnel with sleep hygiene training. Minimizing sunlight exposure after the 1200-1500 watch will facilitate circadian entrainment that will eventually help them adapt (to some degree) to their WS 4 watch/sleep pattern. Sailors should also be given a basic understanding regarding their sleep needs and why they should use available opportunities, particularly in the evening/nighttime hours, for sleep. However, the fact that some crewmembers use their nighttime for maintenance duties suggests that the chain of command should consider an alternative distribution of duties between watch sections; a distribution taking into account that WS 4 and WS 1 stand watch during nighttime hours. For example, given the watch patterns in WS 4, the maintenance duties of WS 4 Sailors could be taken over by Sailors of the other watch sections for the period of time when they are standing night watch. Such an allocation of work and sleep may increase the satisfaction for the 3/9, by increasing the sense of equity between crewmembers (Miller, 2006). Furthermore, Sailors in WS 4 could be allowed to forego the morning cleaning stations, and late sleepers chits could be provided and be strongly encouraged.

From a human-centered perspective, the results of this study suggest that the 3/9 is a better watchstanding schedule than the 5/10. However, the two watchstanding schedules have different characteristics in terms of the number of qualified personnel needed to implement them. The 3/9 is a four-section watchbill in which Sailors stand watch for only six hours per day; the 5/10 has three sections, with individuals standing watch, on average, eight hours each day. Therefore, the 5/10 requires 25% fewer qualified watchstanders than the 3/9 schedule. Such a difference may be a critical resource constraint. This perspective, however, oversimplifies the problem of optimized shiftwork to a simple enumeration of the minimum number of qualified personnel needed. Such approaches have been used in the past, but inevitably lead to watch systems with increased sleep deprivation, fatigue, and circadian desynchrony (Miller, 2013a, 2013b). Rather than using a 5/10, a more reasonable approach to a three-section watchbill could be a 4/8 watchstanding schedule—still requiring 25% less than the 3/9, but

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allowing watchstanders to sleep at the same time each day. However, the issues of accommodating the day sleepers will be vital for this watchbill to be fully accepted. This 4/8 watchbill still needs to be evaluated.

A. STUDY LIMITATIONS

This study had a number of limitations. First, the study participants were volunteers, performing their normal daily duties; there was no randomization in the assignment to watch schedule and hence, the study is quasi-experimental in nature. Officers were underrepresented (1.3%) in our sample of the RX Department when working on the 5/10.

Given that the data collection periods were four months apart, the operational commitments of the ship may differ between the two phases of the study. Consequently, the operational tempo and other organizational factors may have also affected our results. Furthermore, WS 1 (standing watch from 0300 to 0600 and from 1500 to 1800) was oversampled, compared to the other sections (42 Sailors in WS 1, 25 in WS 4, 27 in WS 2, and 23 in WS 3) and average differences between the 5/10 and 3/9 schedules could be skewed because of this over-representation of these night workers. In an attempt to account for these differences, we tried to break out each watch team and display the trends for that specific team.

Lastly, the comparison of the two watch schedules is based on a between-subjects analysis, an approach that assumes independence of the two samples. However, 28 crewmembers participated in both data collection periods (i.e., 35% of the 5/10 and 24% of the 3/9 sample were studied both times). Given this number of participants in both periods, we decided to first perform a between-subjects analysis as our basic approach, which made it possible to use all available participants. We did follow-on, within-subjects analysis, which is included in the Appendix of this report. It should be noted that both the between-subjects and within-subjects methods produced the same pattern of results.

B. ACKNOWLEDGEMENTS

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APPENDIX

This appendix focuses on the within-subject comparison of the 5/10 and 3/9 watch schedules using the subsample of 28 crewmembers that participated in both data collection periods.

A. DEMOGRAPHICS

Table 10 shows participants' demographic information. Age, active duty time, and total deployment refer to the second data collection period.

Table 10.   Demographic information.

Variable	
Age (Years)	25.7 ± 3.01
Gender	5 F, 23 M
Rank	1 Officer, 27 Enlisted
Active Duty (Years)	4.95 ± 2.0
Total Deployment (Months)	10.6 ± 9.13
Morningness-Eveningness Preference Score	49 (no differences between data collections, $p > 0.60$)

On the 3/9 schedule, 6 of the 28 participants worked in WS 4, 8 in WS 1, 8 in WS 2, and 6 in WS 3. The average PSQI scores did not differ between schedules (3/9: 8.53±3.08; 5/10: 9.33±2.80; matched pairs Wilcoxon Signed Rank test, $p > 0.40$). PSQI scores suggest that in both schedules, approximately 96% of the participants were "poor sleepers" with a PSQI score more than, or equal to, 5.

ESS scores did not differ between schedules at the beginning of the underway periods (matched pairs Wilcoxon Signed Rank test, $p > 0.50$). Compared to daytime sleepiness when working the 3/9 schedule, however, Sailors working in the 5/10 had significantly elevated daytime sleepiness at the end of the underway (3/9: 7.70±4.32; 5/10: 10.6±4.47; matched pairs Wilcoxon Signed Rank test, S=107, $p < 0.001$). Furthermore, the pattern of change in ESS scores differs between schedules when assessing differences between the beginning and the end of the underway. Specifically, when working the 5/10, daytime sleepiness increased (1-side matched pairs Wilcoxon Signed Rank test, S=49.5, p=0.092), whereas on the 3/9, sleepiness decreased (1-side

matched pairs Wilcoxon Signed Rank test, S=57.5, p=0.060). These results are shown in Figure 27.
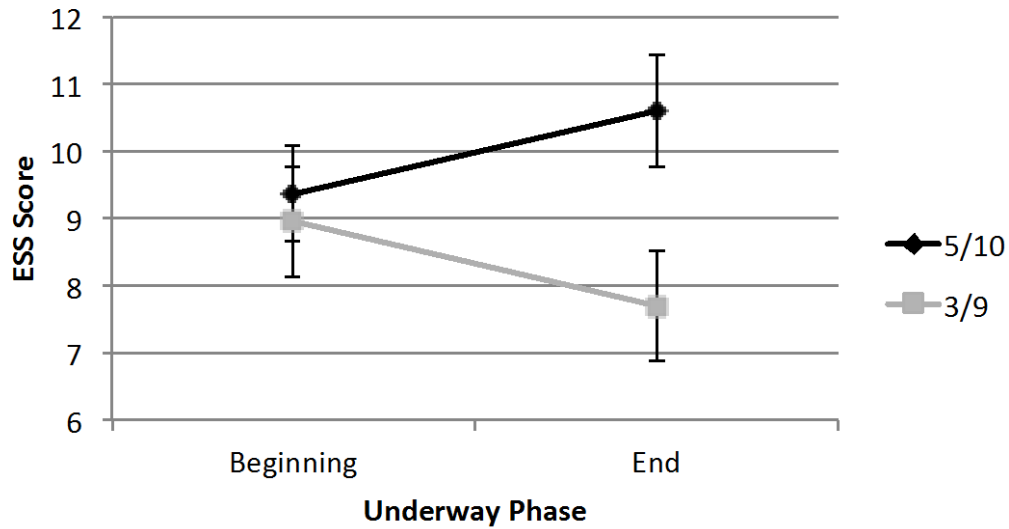
Figure 27.   Change in ESS scores from beginning to end of data collection period (higher scores are worse).

B.   SLEEP

Daily rest duration, daily sleep duration, and number of sleep episodes per day did not differ between the 3/9 and 5/10 schedules (Wilcoxon Signed Rank test, $p > 0.50$). Table 11 shows the daily rest/sleep duration and the number of sleep episodes per day for the 5/10 schedule, the 3/9 schedule, and the four sections of the 3/9.

Table 11.   Daily sleep by watchstanding schedule. Data presented as M ± SD.

Variable	5/10	3/9	3/9 WS 4 (0000-0300) and (1200-1500)	3/9 WS 1 (0300-0600) and (1500-1800)	3/9 WS 2 (0600-0900) and (1800-2100)	3/9 WS 3 (0900-1200) and (2100-0000)
Daily rest (hrs)	7.54±1.01	7.37±1.02	7.38±1.37	7.38±0.708	7.30±1.33	7.46±0.801
Daily sleep (hrs)	6.92±0.95	6.81±0.935	6.65±1.25	6.87±0.624	6.75±1.21	6.96±0.772
Number of rest episodes per day	1.53±0.238	1.44±0.348	1.69±0.303	1.49±0.380	1.18±0.246	1.43±0.301

C. MOOD STATES

The within-subject analysis of mood states is based on the 24 participants with POMS data: 4 in WS 4, 8 in WS 1, 6 in WS 2, and 6 in WS 3. Given the small number of participants, WS results are not provided.

First, we calculated the difference in POMS score between the beginning and end of the study (i.e., Δ(score) = postscore – prescore). A comparison showed that Δ(TMD) differed between Sailors working on the 3/9 and the 5/10 (Wilcoxon Rank Sum test, S = 61.5, p = 0.078). Specifically, TMD scores on the 3/9 did not change during the underway (prescore TMD = 37.4, postscore TMD = 34.5; Wilcoxon Signed Rank test, S = 16, p = 0.693). In contrast, Sailor mood while on the 5/10 deteriorated significantly during the underway period (prescore TMD = 52.7, postscore TMD = 64.7; Wilcoxon Signed Rank test, S = 118, p = 0.001). The same pattern, that the 3/9 is better than the 5/10, is evident in the change scores of anger-hostility (p=0.026), depression (p=0.099), tension-anxiety (p=0.077), and confusion-bewilderment (p=0.059) (score differences were statistically not significant, according to BH-FDR). POMS TMD and subscale results are shown in the Figures 27 and 28. Vertical bars denote the standard error of the mean. Data labels show the p-value of the comparison between the corresponding 3/9 watch section on the 5/10 schedule.
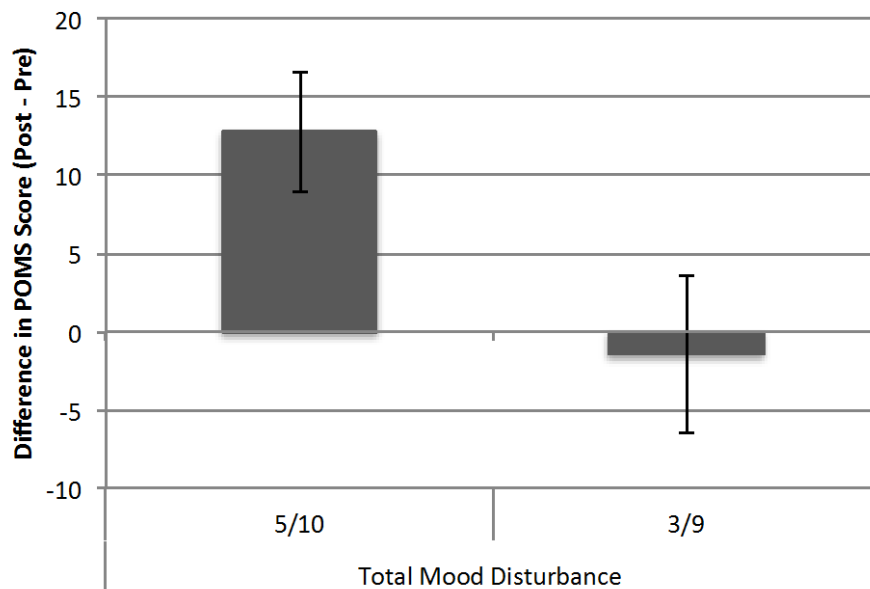
Figure 28.   Difference in TMD scores.
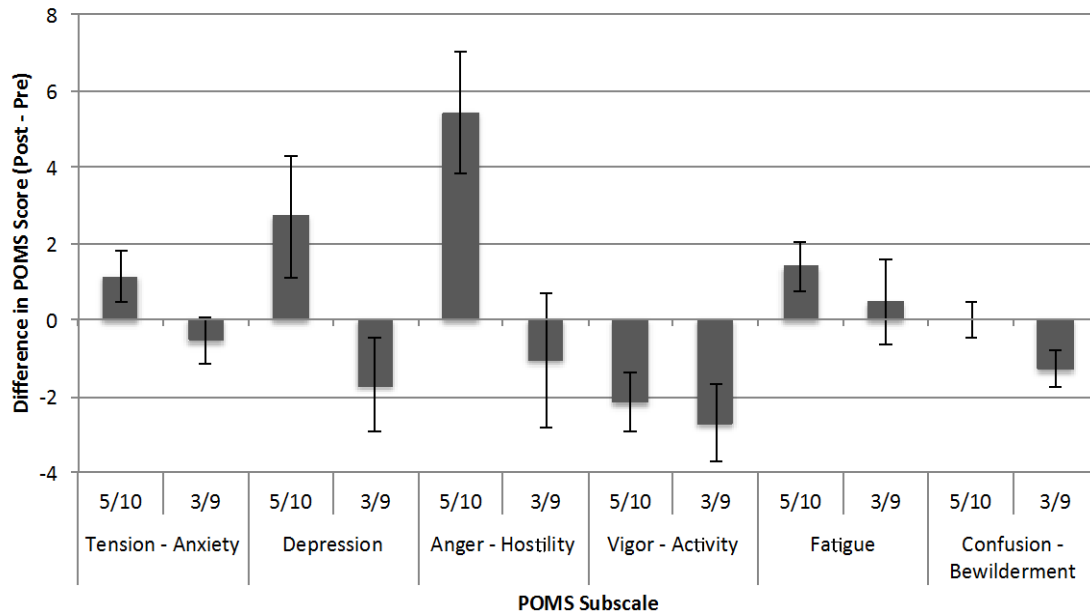
Figure 29.   Difference in POMS subscale scores. Vertical bars denote the standard error of the mean.

D.   PSYCHOMOTOR VIGILANCE PERFORMANCE

The within-subject analysis of PVT performance is based on only 12 participants: 4 in WS 4, 2 in WS 1, 4 in WS 2, and 2 in WS 3. Given the small number of participants, WS results are not provided. The PVT analysis shows that Sailors on the 5/10 watchstanding schedule have worse PVT performance than those on the 3/9 (see Table 12), with 10 of the 11 PVT metrics significantly different (according to BH-FDR). The 5/10 was not only associated with increased reaction times and lapses, but also with increased variability, compared to the 3/9. Figures 34 through 36 present the results for PVT metrics showing that the 5/10 watchstanding schedule differs statistically from the 3/9.

Table 12.   PVT metrics presented as M ± SD.

Variable	5/10	3/9	Mean Values Δ%	p val.[A]	Standard Deviation Δ%
Mean RT, (ms)	394±83.5	289±49.6	–26.7%	0.0005 [B]	–40.6%
Mean 1/RT	3.14±0.46	4.10±0.84	30.6%	0.0005 [B]	82.6%
Fastest 10% RT, (ms)	253±42.1	196±39.7	–22.5%	0.0005 [B]	–5.70%
Slowest 10% 1/RT	1.95±0.38	2.59±0.52	32.8%	0.0005 [B]	36.8%
False Starts (FS), %	1.09±0.97	1.28±1.13		0.320	
Lapses 500ms, %	12.7±6.86	5.49±2.51	–56.8%	0.0005 [B]	–63.4%
Lapses 355ms, %	35.6±20.5	15.5±9.75	–56.5%	0.0005 [B]	–52.4%
Lapses 750ms+FS, %	6.00±4.42	3.60±2.20	–40.0%	0.016 [B]	–50.2%
Lapses 600ms+FS, %	9.06±4.94	4.75±2.34	–47.6%	0.003 [B]	–52.6%
Lapses 500ms+FS, %	13.8±7.00	6.78±2.55	–50.9%	0.0005 [B]	–63.6%
Lapses 355ms+FS, %	36.6±20.1	16.8±9.17	–54.1%	0.005 [B]	–54.4%

[A] Unadjusted pairwise comparisons based on Wilcoxon Rank Sum Test. [B] Statistically different according to BH-FDR.
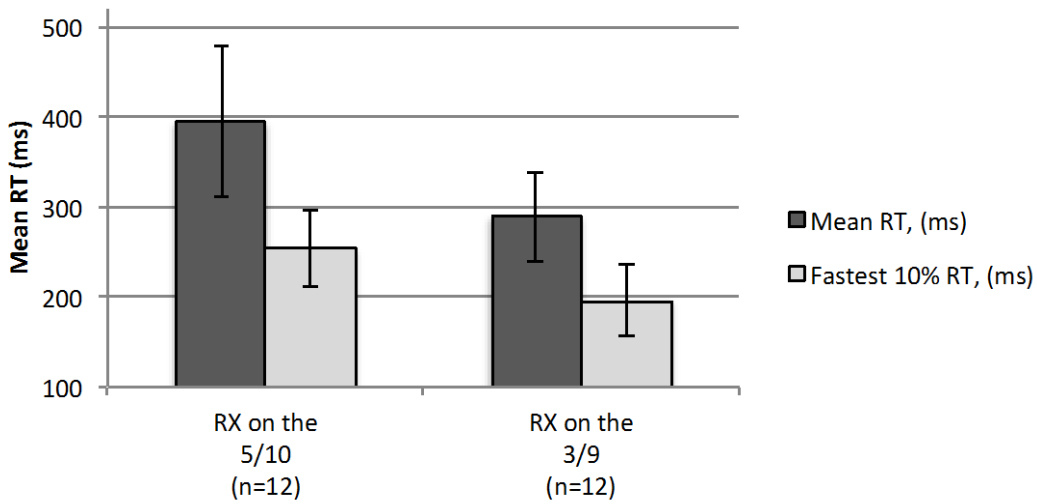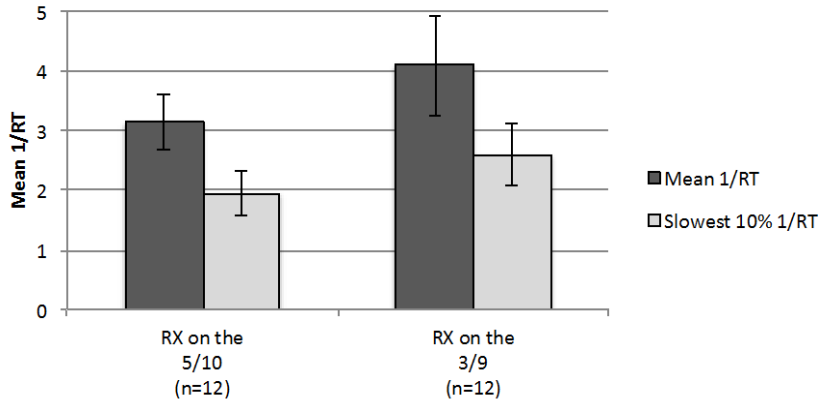

Figure 30.   PVT reaction times.
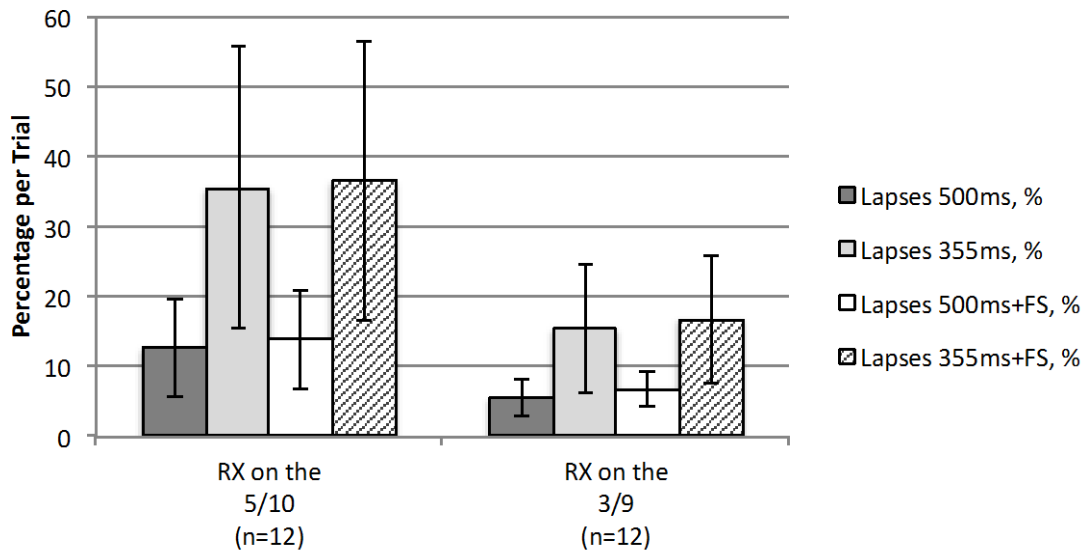
Figure 31.   PVT response speeds.

Figure 32.   Percentage of lapses of 355ms and 500ms in length, and lapses combined with false starts.

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