NPS-OR-18-002

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

ASSESSMENT OF A NOVEL 3HRS-ON/3HRS-OFF/3HRS-ON/15HRS-OFF WATCHSTANDING SCHEDULE ON THE USS STOCKDALE (DDG-106)

by

Panagiotis Matsangas and Nita Lewis Shattuck

January 2018

Approved for public release; distribution is unlimited

Prepared for: Commanding Officer, USS STOCKDALE (DDG-106)

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED *(From-To)***
09-30-2016	Technical Report	March 2016 – September 2016

4. TITLE:
Assessment of the novel 3hrs-on/3hrs-off/3hrs-on/15hrs-off watchstanding schedule on the USS STOCKDALE (DDG-106)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S):
Panagiotis Matsangas and Nita Lewis Shattuck

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-18-002

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES):

10. SPONSOR/MONITOR'S ACRONYM(S)
MCESG

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 assessed the utility of the novel 3hrs-on/3hrs-off/3hrs-on/15hrs-off (3-3-3-15) watchstanding schedule on the USS STOCKDALE (DDG 106) while the ship was conducting underway operations. Crewmembers (N=129) completed a survey to provide their opinion about the utility and the acceptance of the 3-3-3-15 as compared to their previous schedule, i.e., the 3hrs-on/9hrs-off (3/9). The novelty of the 3-3-3-15 lies in the clustering of the two shifts, which are divided by a 3-hour off period, and the long 15-hour off period after the second shift. The predicted effectiveness of the 3-3-3-15 was assessed with the Fatigue Avoidance Scheduling Tool (FAST).

Crewmembers reported sleeping 5.80±1.23 hours daily. The average PSQI Global score was 7.29±2.89, with ~73% of the participants identified as "poor sleepers". In comparison to the 3/9, the average rate of non-negative responses of the 3-3-3-15 (to include positive and neutral responses) ranged between 80% and 90%. The largest acceptance (positive) rates were identified in sleep affordability, the adequacy of time to complete off-watch duties and shipboard/departmental qualifications, to work out, to have more personal time, to be able to plan daily activities.

Given that sleep satisfaction and acceptance rates of the 3-3-3-15 were equivalent or better than other watchstanding schedules, our results suggest that the 3-3-3-15 may be a useful schedule from an ergonomic and sleep hygiene perspective. Evidence also suggest, however, that the 3-3-3-15 may not be as good for officers whose duties demand high level of situational awareness about ship operations, for watchstanders in the Operations Department or for bridge watch duties.

Overall, the 3-3-3-15 has the potential to be a useful alternative to existing watch standing schedules in terms of crew fatigue levels, acceptance by the crewmembers, and workload management when working in a Navy vessel. Being a novel schedule, however, more effort should be focused on how to best implement the 3-3-3-15 on a ship, and what are the factors that affect the utility of the 3-3-3-15 at sea.

15. SUBJECT TERMS
Watch standing schedules, sleep quality

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Nita Lewis Shattuck
Unclassified	Unclassified	Unclassified	Unclassified	52	**19b. TELEPHONE NUMBER** (831) 656-2281

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

THIS PAGE INTENTIONALLY LEFT BLANK

NAVAL POSTGRADUATE SCHOOL
Monterey, California 93943-5000

Ronald A. Route
President

Steven Lerman
Provost

The report entitled "*Assessment of a novel 3hrs-on/3hrs-off/3hrs-on/15hrs-off watchstanding schedule on the USS STOCKDALE (DDG-106)*" was prepared for the Commanding Officer of the USS STOCKDALE (DDG-106).

Further distribution of all or part of this report is authorized.

This report was prepared by:

Panagiotis Matsangas, Ph.D.

Nita Lewis Shattuck, Ph.D.

Reviewed by:

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

Released by:

Patricia Jacobs
Chair
Department of Operations Research

Jeffrey D. Paduan
Dean of Research

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

This study assessed the utility of a novel 3hrs-on/3hrs-off/3hrs-on/15hrs-off (3-3-3-15) watchstanding schedule on the USS STOCKDALE (DDG 106) while the ship was conducting underway operations. Crewmembers (N=129) completed a survey to provide their opinion about the utility and the acceptance of the 3-3-3-15 as compared to their previous schedule, i.e., the 3hrs-on/9hrs-off (3/9). The novelty of the 3-3-3-15 lies in the clustering of the two 3-hour shifts, which are divided by a 3-hour off-watch period, and the long 15-hour off-watch period after the second shift. The predicted effectiveness of the 3-3-3-15 was assessed with the Fatigue Avoidance Scheduling Tool (FAST).

Crewmembers reported sleeping 5.80±1.23 hours daily. The average PSQI Global score was 7.29±2.89, with ~73% of the participants identified as "poor sleepers". In comparison to the 3/9, the average rate of non-negative responses of the 3-3-3-15 (to include positive and neutral responses) ranged between 80% and 90%. The highest acceptance (positive) rates were identified in questions about sleep affordability, the adequacy of time to complete off-watch duties and shipboard/departmental qualifications, to work out, to have more personal time, to be able to plan daily activities.

Given that sleep satisfaction and acceptance rates of the 3-3-3-15 were equivalent or better than other watchstanding schedules, our results suggest that the 3-3-3-15 may be a useful schedule from an ergonomic and sleep hygiene perspective. Evidence also suggests, however, that the 3-3-3-15 may not be as good for officers whose duties demand a high level of situational awareness concerning shipboard operations, for watchstanders in the Operations Department, or for bridge watchstanders.

Overall, the 3-3-3-15 has the potential to be a useful alternative to existing watch standing schedules in terms of crew fatigue levels, acceptance by the crewmembers, and workload management when working on a Navy vessel. Because it is a novel schedule, however, more effort should be focused on how to best implement the 3-3-3-15 schedule and determining the factors that affect the utility of the 3-3-3-15 at sea.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION AND SCOPE

Multiple factors affect the quantity and quality of sleep obtained by members of the military (Troxel et al., 2015). Extended work hours, unscheduled operational demands/commitments, reduced manning, stress are some of these factors which contribute to the sleep debt and degraded alertness observed in much of the military population(Miller, Matsangas, & Kenney, 2012; Miller, Matsangas, & Shattuck, 2008). Therefore, optimizing watchstanding schedules to increase crewmembers' performance and alertness levels is of critical importance.

Researchers from the Naval Postgraduate School were contacted by the Commanding Officer, USS STOCKDALE (DDG 106), to assess the utility of the novel 3hrs-on/3hrs-off/3hrs-on/15hrs-off (3-3-3-15) watchstanding schedule while the ship was conducting underway operations.

This work is part of a multi-year effort at the Naval Postgraduate School to systematically and empirically assess the wide range of watch schedules used on U.S. Navy ships to provide insight and guidance for future naval operations (Miller et al., 2012; Shattuck, Matsangas, & Dahlman, 2018; Shattuck, Matsangas, Mysliwiec, & Creamer, In press).

Based on a sample of USS STOCKDALE crewmembers, this study focused on the assessment of the 3-3-3-15 watchstanding schedule in terms of:

- Reported sleep quantity and quality, sleep conditions;
- Acceptance by the crewmembers working on the 3-3-3-15 as compared to the previous schedule they were working on (the 3hrs-on/9hrs-off); and
- Fatigue Avoidance Scheduling Tool (FAST) predicted effectiveness.

THIS PAGE INTENTIONALLY LEFT BLANK

II. METHODS

A. PARTICIPANTS

Participants (N=129) were volunteers from the USS STOCKDALE (DDG 106), an Arleigh Burke class destroyer, Flight IIA (9,300 tons). Crewmembers had been working the same schedule for four weeks before the data collection commenced.

B. THE 3-3-3-15 WATCH SCHEDULE

Crewmembers using the 3-3-3-15 watchstanding schedule stand watch in two 3-hours shifts, followed by 15 hours off watch. The two shifts are three hours apart. Crewmembers in the 3-3-3-15 are working in one of four watch sections (WS); WS 1 (watch from 0000 to 0300 and from 0600 to 0900), WS 2 (0300-0600, 0900-1200), WS 3 (1200-1500, 1800-2100), and WS 4 (1500-1800, 2100-2400). Therefore, the daily watch schedule is fixed and crewmembers stand the same watch periods each day.

Before the 3-3-3-15, crewmembers were working on the fixed 4-section 3hrs on/9hrs off (3/9) schedule. Crewmembers using the 3/9 stand watch for three hours followed by nine hours off watch.

C. EQUIPMENT AND INSTRUMENTS

The study survey included questions about demographics, sleep-related issues, questions about the utility and acceptance of the 3-3-3-15, and one standardized sleep questionnaire. Questions included age, gender, rate/rank, department, years on active duty, factors affecting sleep, type and frequency of caffeinated beverage use (e.g., tea, coffee, soft drinks, energy drinks), tobacco use, the type and frequency of an exercise routine, and use of prescribed/over the counter medications.

Participants were asked to indicate whether they had been standing watch since the last port visit, 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 at their assignment (5-point Likert scale: “Much less than usual,” “Less than usual”; “About the same”; “More than usual”; “Much more than usual”). The study survey also included two open-ended questions (“What did you like most about your current watch schedule,” “What did you like least about your current watch schedule.”)

Participants’ sleep history was assessed using the Pittsburg Sleep Quality Index (PSQI) (Buysse, Reynolds III, 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 (best) to 3 (worse). The total score, ranging from 0 (best) 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 characterized as poor sleepers. 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).

In the last section of the survey, crewmembers were asked to rate 17 factors associated with the acceptability of the 3-3-3-15 schedule as compared to the 3/9 schedule they were using prior. These questions addressed the predictability of the daily schedule, ease of coordination for Shipboard or Departmental evolutions, feeling alert and able to focus, sleep quality, adequacy of time to sleep, availability of off-watch duty time, ability to plan the day, adequacy of time to complete watch duties, 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 three statements (“worse,” “the same,” “better”).

The 3-3-3-15 was also assessed using the Fatigue Avoidance Scheduling Tool (FAST) (version 3.3.01T by Fatigue Science). FAST is based on the Sleep and Fatigue, Task Effectiveness (SAFTE^{TM} © 2000-2008 Fatigue Science) model, which was initially 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.

D. PROCEDURES

The Naval Postgraduate School Institutional Review Board determined the study to be non-human subject research (Determination 2016.0085-DD-N and 2017.0168-DD-N). Data were collected in May 2015 from crewmembers working on the 3-3-3-15 schedule for one month while the ship was underway. Upon completion of the data collection, de-identified survey questionnaires were mailed to NPS for analysis.

E. ANALYTICAL APPROACH

Statistical analysis was conducted with a statistical software package (JMP Pro 12; 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 ranking with control. The criterion for statistical significance was set at $p = 0.05$. Data are presented as mean (M) ± standard deviation (SD).

First, all variables underwent descriptive statistical analysis to describe our population. Sleep satisfaction, PSQI scores, and consumption of caffeinated beverages was compared with previously collected data on the USS NIMITZ (Shattuck & Matsangas, 2015a; Shattuck, Matsangas, & Brown, 2015; Shattuck, Matsangas, & Powley, 2015), the USS BENFOLD (Shattuck, Matsangas, & Waggoner, 2014), and the USS JASON DUNHAM (Shattuck & Matsangas, 2014).

III. RESULTS

A. BASIC INFORMATION

Analysis is based on the responses from 129 crewmembers standing watch using the 3-3-3-15 schedule. Of these 129 crewmembers, 29 (22.8%) stood watch in WS 1 (0000-0300, 0600-0900), 32 (25.2%) in WS 2 (0300-0600, 0900-1200), 30 (23.6%) in WS 3 (1200-1500, 1800-2100), and 36 (28.4%) in WS 4 (1500-1800, 2100-2400). Participants were on average 27 years of age, predominantly enlisted males. Table 1 shows participants' demographic information.

Table 1. Demographic information.

Age, M ± SD years	27.3 ± 6.19
Gender	13 F, 115 M (1 missing)
Rank	(1 missing)
Officers	11.7% (12 O1-O3, 3 CWO)
Enlisted	88.3% (30 E1-E3, 70 E4-E6, 13 E7-E9)
Department	
Combat Systems	14 (10.9%)
Engineering	78 (60.9%)
Executive	10 (7.81%)
Operations	11 (8.60%)
Weapons	15 (11.7%)
Active Duty, M ± SD years	6.33 ± 5.46

The most frequent factor Sailors reported to affect their sleep was noise (56.6%), followed by not having enough time to sleep (41.9%), temperature (33.3%), light (31%), and bedding conditions (23.3%). The reported sources of noise were noise from inside and outside the berthing compartment, other people and noise from the 1 Main Circuit (1MC).

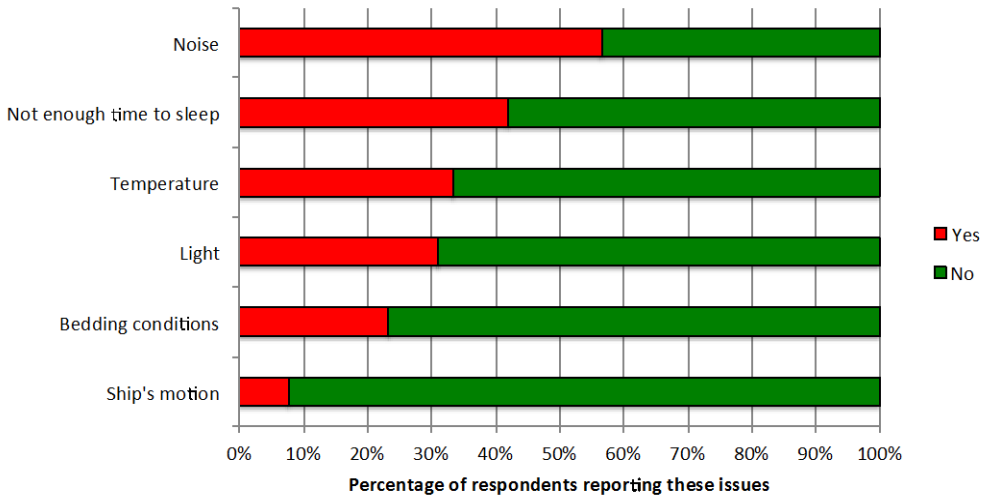

Figure 1. Factors affecting sleep.

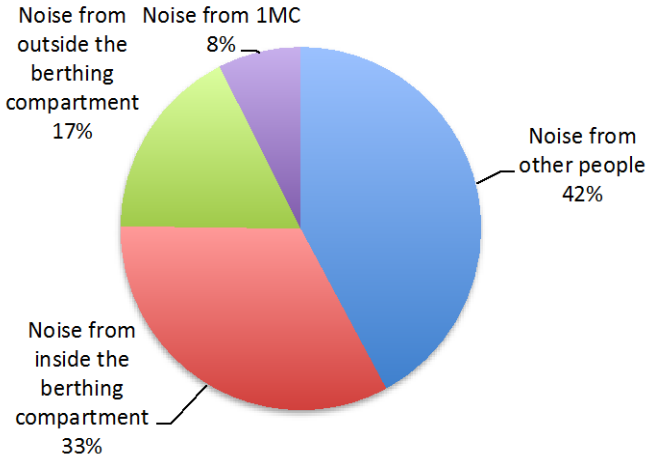

Figure 2. Sources of noise affecting sleep.

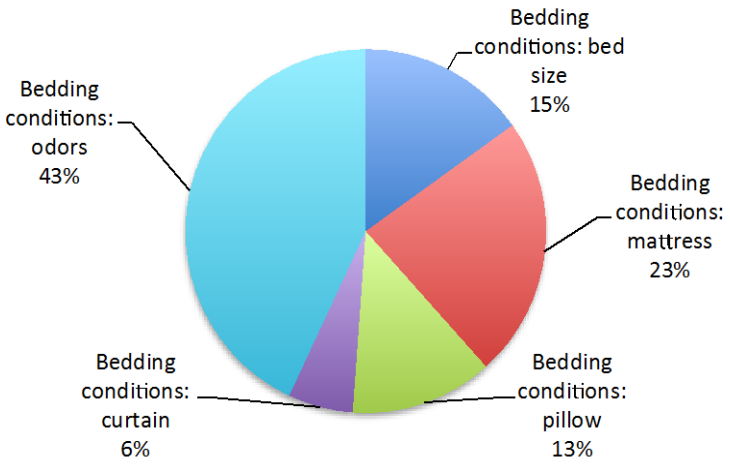

Figure 3. Sources of complaints about berthing/bedding conditions.

Participants reported the type and frequency of caffeinated beverages they consumed (see Figure 5). Overall, 88.7% of the participants indicated drinking some type of caffeinated beverage (mostly coffee followed by soft drinks, energy drinks, and tea), which did not differ from the USS NIMITZ (Shattuck & Matsangas, 2015a; Shattuck, Matsangas, & Brown, 2015; Shattuck, Matsangas, & Powley, 2015). Coffee was the most frequent used beverage (66% of the participants drinking 2 cups per day – median value), followed by soft drinks (22% of the participants drinking 1.5 servings per day – median value), and energy drinks (18% of the participants drinking 1.25 servings per day – median value).

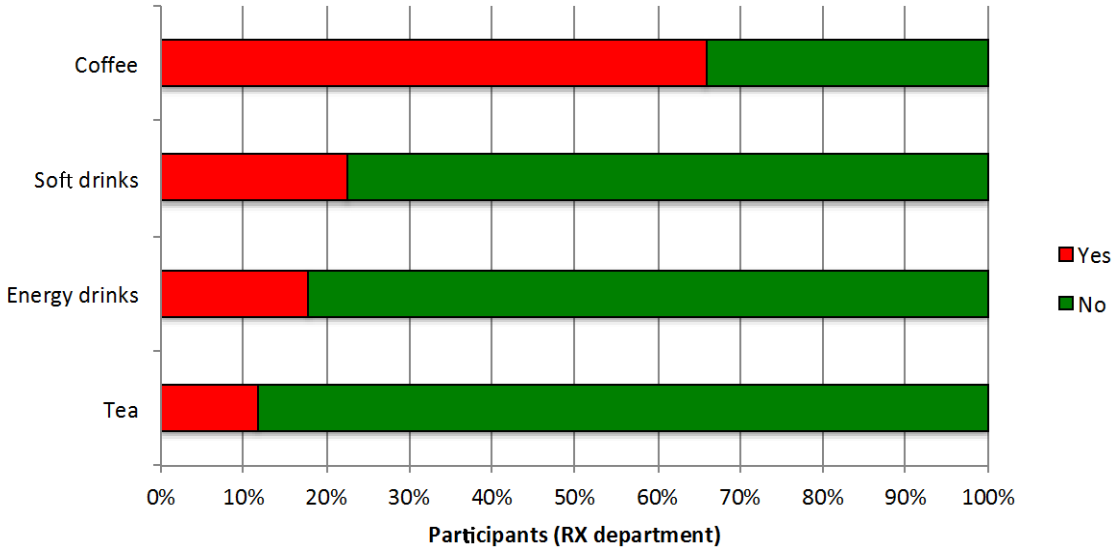

Figure 4. Consumption of caffeinated beverages.

Forty (31%) participants reported using tobacco products. Use of prescription or over-the-counter medications (e.g., Ibuprofen, Motrin, Naproxen, Mobic, Simvastatin, Telmisartan, Zyrtec, Sudafed, sleeping pills) were reported by 13 (10%) participants. Approximately 79% of the participants reported working out from 1 to 14 times per week (median = 5), with a median duration of one hour.

The average duration of sleep during the month prior to the data collection was 5.80±1.23 hours. Crewmembers working in WS 3 (1200-1500 & 1800-2100) reported the largest duration of sleep (6.38±1.20) followed by WS 4 (1500-1800 & 2100-0000) with 5.77±0.668 hours, and WS 1 (0000-0300 & 0600-0900) with 5.68±1.23 hours. The least amount of sleep was reported by crewmembers working in WS 2 (0300-0600 & 0900-1200) with 5.40±1.56 hours.

In general, participants were satisfied with the amount of sleep they received (Figure 6). Approximately 72% of the crewmembers were satisfied with their sleep amount, while 28% found their sleep amount less than what they needed. The satisfaction rate when using the 3-3-3-15 was equivalent to the rate reported by crewmembers of the Reactor Department of the USS NIMITZ on the 3/9. However, the satisfaction rate on the 3-3-3-15 was significantly higher than that of USS NIMITZ crewmembers on the 5/10 schedule (20%) (Shattuck, Matsangas, & Brown, 2015; Shattuck, Matsangas, & Powley,

2015). The sleep of other Sailors was also rated as about right (64%), compared to less or much less than needed (29%) (Figure 7). Approximately 79% of the participants reported that their workload prior to the data collection did not differ from their normal workload underway.

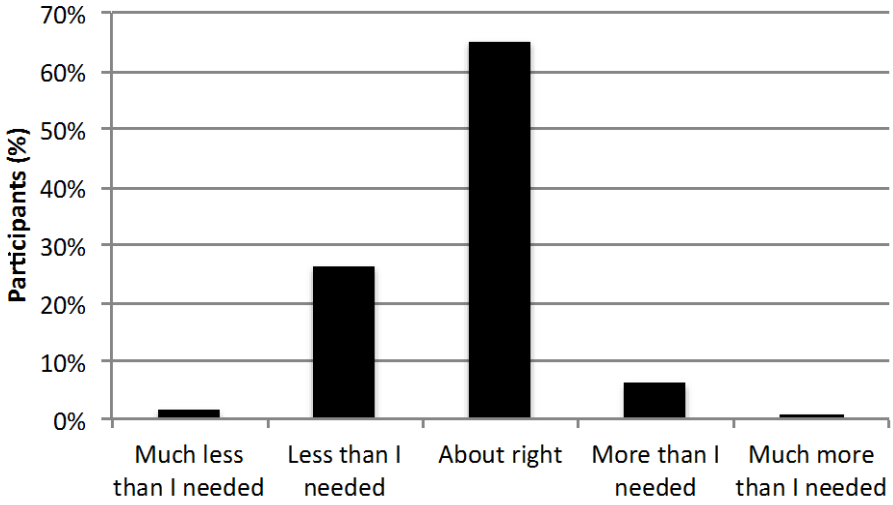

Figure 5. Responses to the statement "The sleep I received on this underway was . . . ."

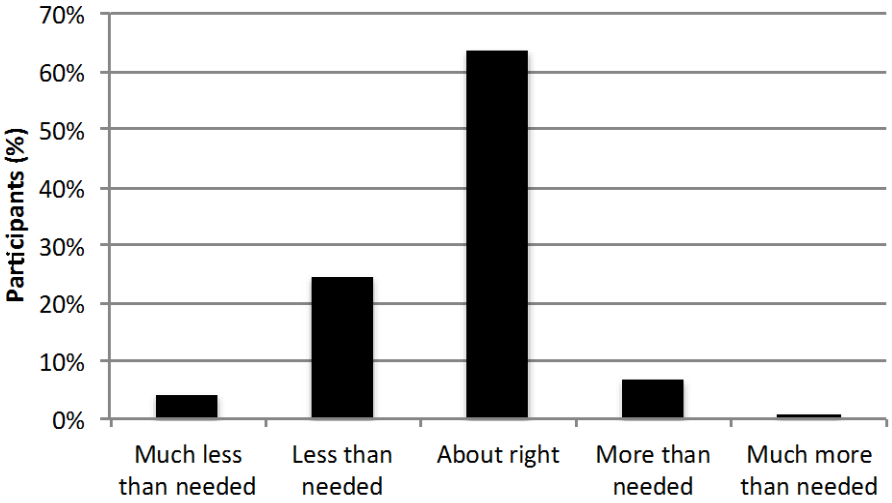

Figure 6. Responses to the statement "The sleep received by other Sailors on this underway was . . . ."

The weighted average PSQI Global score was 7.29 ± 2.89, without significant differences amongst the four watch sections (Dunn method for joint ranking, all $p>0.25$). PSQI scores indicated that approximately 73% of the participants were "poor sleepers" (PSQI score>5). Even though the percentage of poor sleepers ranged from 67% in WS 3 (1200-1500 & 1800-2100) to 78% in WS 4 (1500-1800 & 2100-0000), no statistically significant differences were identified between watch sections (Fisher's exact test, $p=0.495$). As assessed by PSQI scores, the sleep quality reported by crewmembers on the USS STOCKDALE working on the 3-3-3-15 was better than their peers working on the modified 6/18 (USS BENFOLD, PSQI=9.17±2.78; $Z=3.28$, $p=0.004$), on the 5/10 (USS NIMITZ, PSQI=9.74±2.89; $Z=5.63$, $p<0.001$), on the 3/9 (USS JASON DUNHAM, USS NIMITZ, PSQI=8.11±3.02; $Z=3.02$, $p=0.010$), or on the 6/6 (USS JASON DUNHAM, PSQI=12.2±3.49; $Z=4.43$, $p<0.001$) – all comparisons based on the Dunn method for joint ranking with control (Shattuck & Matsangas, 2014, 2015b; Shattuck, Matsangas, & Brown, 2015; Shattuck, Matsangas, & Powley, 2015; Shattuck et al., 2014).

B. UTILITY AND ACCEPTANCE OF THE 3-3-3-15 AS COMPARED TO THE 3/9

Based on 16 factors associated watch schedule utility and acceptance, participants rated whether the novel 3-3-3-15 schedule was better, the same, or worse compared their previous schedule, i.e., the 3/9. Overall, approximately 84% of the responses noted that the 3-3-3-15 was either better (27.5%) or the same (56.1%) as compared to the 3/9 (better/worse ratio=1.7). As compared to the 3/9, crewmembers preferred the 3-3-3-15 because they had more time to complete off-watch duties and shipboard/departmental qualifications (41% positive responses, 18% negative), to sleep (40% positive responses, 22% negative), and to work out (40% positive responses, 16% negative). They also reported having more personal time when using the 3-3-3-15 (35% positive responses, 23% negative), were better able to plan daily activities (35% positive responses, 13% negative), and liked the predictability of the daily schedule (28% positive responses, 12% negative). Crewmembers preferred the 3-3-3-15 because they felt their sleep quality was improved (35% positive responses, 24% negative), and they felt more alert and able to

focus (31% positive responses, 18% negative). Weighted by section, these results are shown in Figure 8.

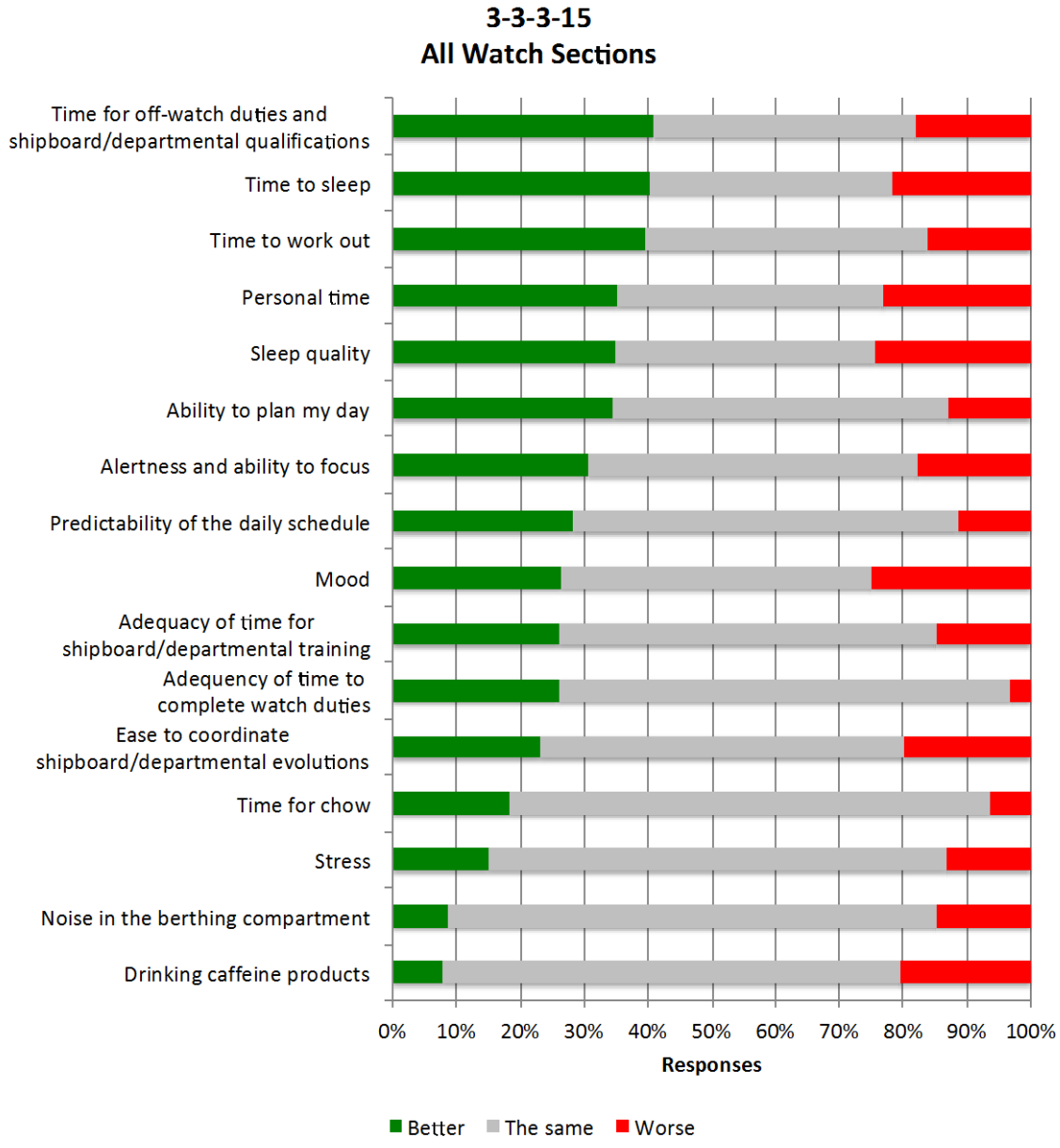

Figure 7. Responses about the utility and acceptance of the 3-3-3-15 as compared to the 3/9.

The utility and acceptance differed between watch sections. Specifically, only 20% of the responses from crewmembers on WS 2 (0300-0600 & 0900-1200) were clearly positive about the 3-3-3-15 as compared to the 3/9. In contrast, crewmembers working the other three watch sections provided on average 30% positive responses about the 3-3-3-15. Focusing on the clearly negative responses, WS 1 and WS 4 were the worse approximately 20% negative responses. These results are shown in Figure 9.

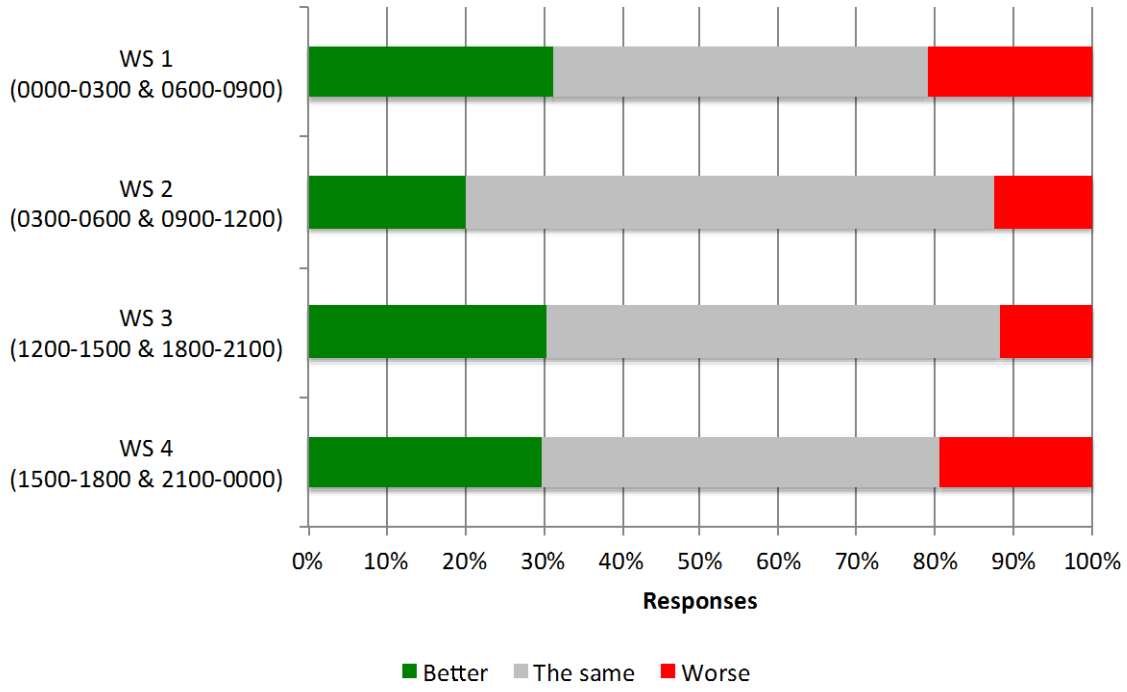

Figure 8. Aggregated acceptance responses.

The assessment of acceptance by watch section showed a number of interesting patterns.

Specifically, Sailors in WS 1 (0000-0300/0600-0900) preferred the 3-3-3-15 for having time to work out, probably between 0300 and 0600 (more information about this later in this section). WS 1 reported difficulty in coordinating shipboard/departmental evolutions, and problems with sleep quality/noise in the berthing compartment. Consequently, it is not a surprise that 29% of the Sailors in the WS1 prefer the 3/9 in terms of caffeine consumption (they drinking less coffee when working in the 3/9). The problems in sleep quality are also more evident in WS 4 (1500-1800/2100-0000). In

contrast, Sailors in WS 3 (1200-1500/1800-2100) have the most positive responses regarding sleep affordability and quality of sleep. These results are shown in Figure 10.

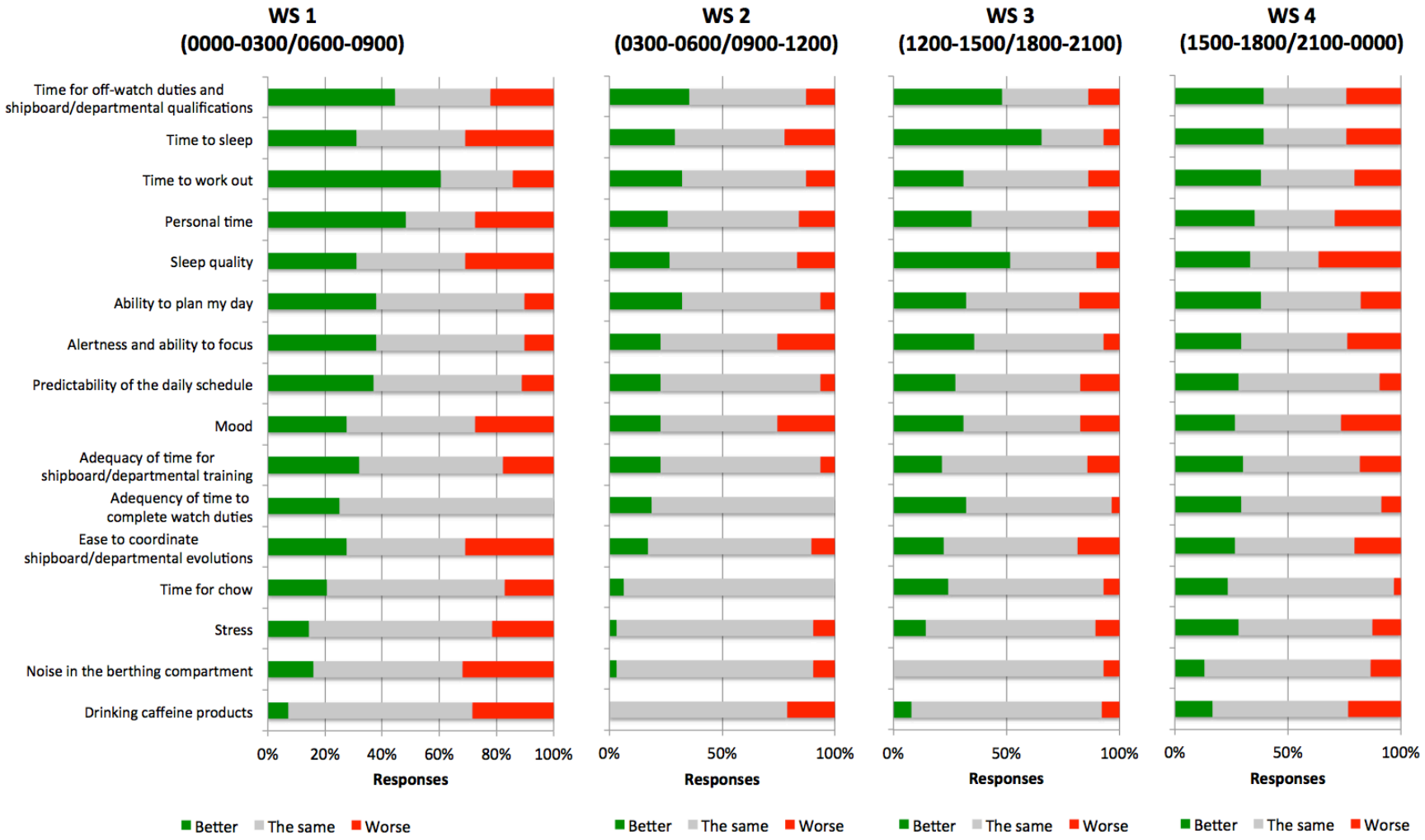

Figure 9. Responses on the factors contributing to acceptability of the 3-3-3-15 watch schedule by section.

Next, we assessed the 3-3-3-15 utility and acceptance by rank and department. To facilitate this analysis, we calculated the percentage of positive, neutral, and negative responses by participant. We also calculated the percentage-wise difference between positive and negative responses by participant. The larger the percentage-wise difference between positive and negative responses, the stronger the opinion the crewmember has about the 3-3-3-15.

To assess the factors associated with the positive, the negative, and the difference between positive and negative responses, we conducted multiple regression analyses with four predictor factors (gender, rank group, department, and watch section). In all three models, department was a statistically significant predictor (all $p<0.05$). Based on these results, we assessed the effect of department in the three acceptance metrics. Figure 12 shows the percentage of positive responses, negative responses, and the difference of positive minus negative responses (all metrics aggregated by participant) by department. The data presented in Figure 12 show that crewmembers in the Combat Systems Department are in general positive about the 3-3-3-15 as compared to the 3/9. The rest of the departments show a consistent rate of acceptance, but the percentage of negative responses increase in the Operations Department.

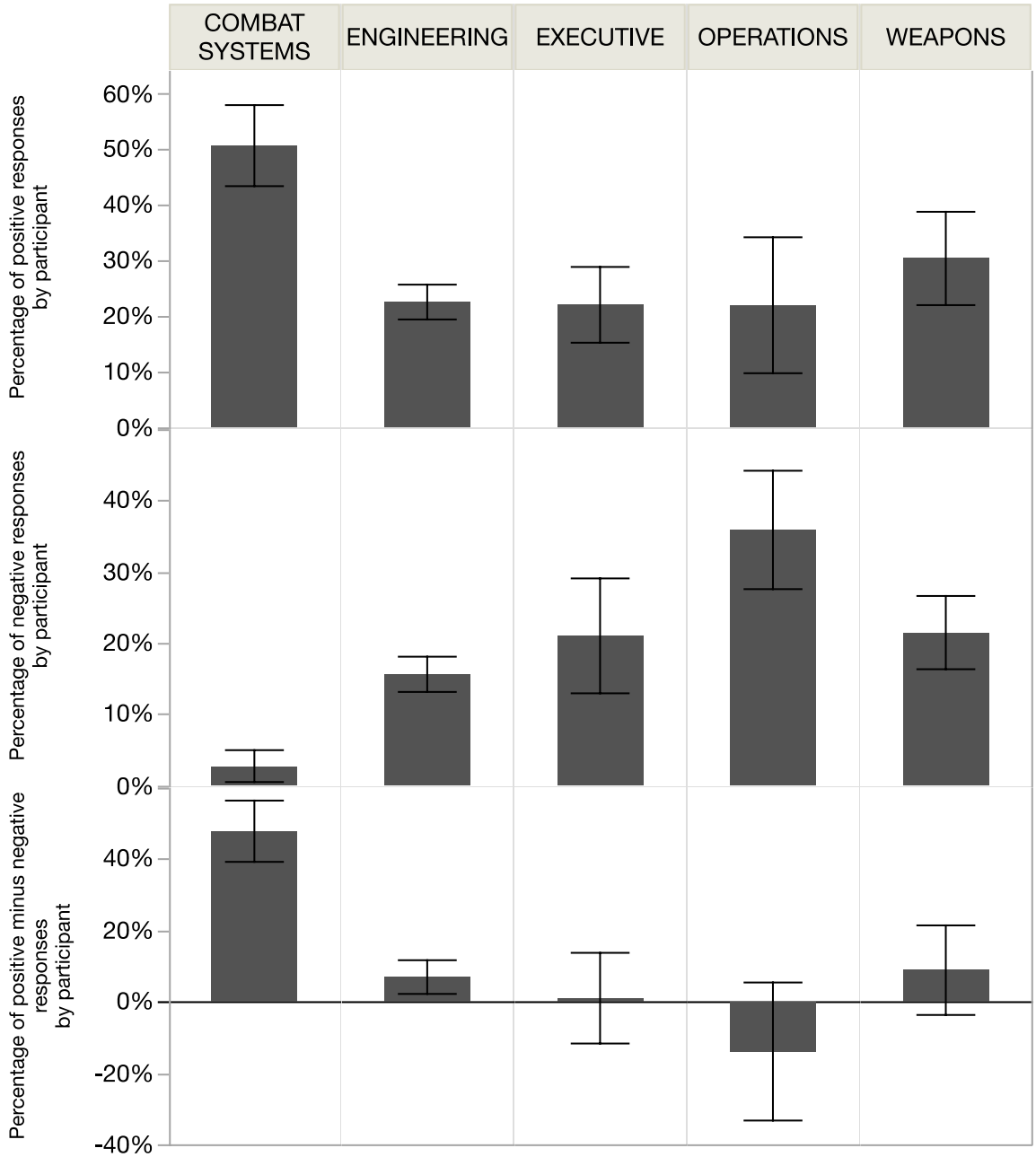

Figure 10. Average acceptance responses by department. Vertical bars denote the standard error of the mean.

Next, we assessed the effect of department and rank in the three acceptance metrics. Figure 12 shows the percentage of positive responses, negative responses, and the difference of positive minus negative responses (all metrics aggregated by

participant) by ran and department. The data presented in Figure 12 show a number of interesting patterns.

- The positive opinions of the 14 crewmembers in the Combat Systems Department are clearly emphasized by the positive ratings from enlisted personnel (n=12).
- The Engineering Department (n=78) has mixed opinions about the 3-3-3-15 as shown by ratings ranging from very strong positive to very strong negative opinions.
- Crewmembers in the Executive Department (n=10) also have mixed opinions.
- In the Weapons Department, the enlisted personnel (n=15) have mixed opinions, but the two officers prefer the 3-3-3-15 compared to the 3/9.
- Crewmembers in the Operations Department (n=10) are in general negatively disposed toward the 3-3-3-15. Notably, the officers' ratings are divided. Specifically, two officers have a strong positive opinion about the 3-3-3-15, but the other four officers prefer the 3/9 over the 3-3-3-15. These two officers with positive ratings both stood watch in WS 4 (1500-1800, 2100-2400).

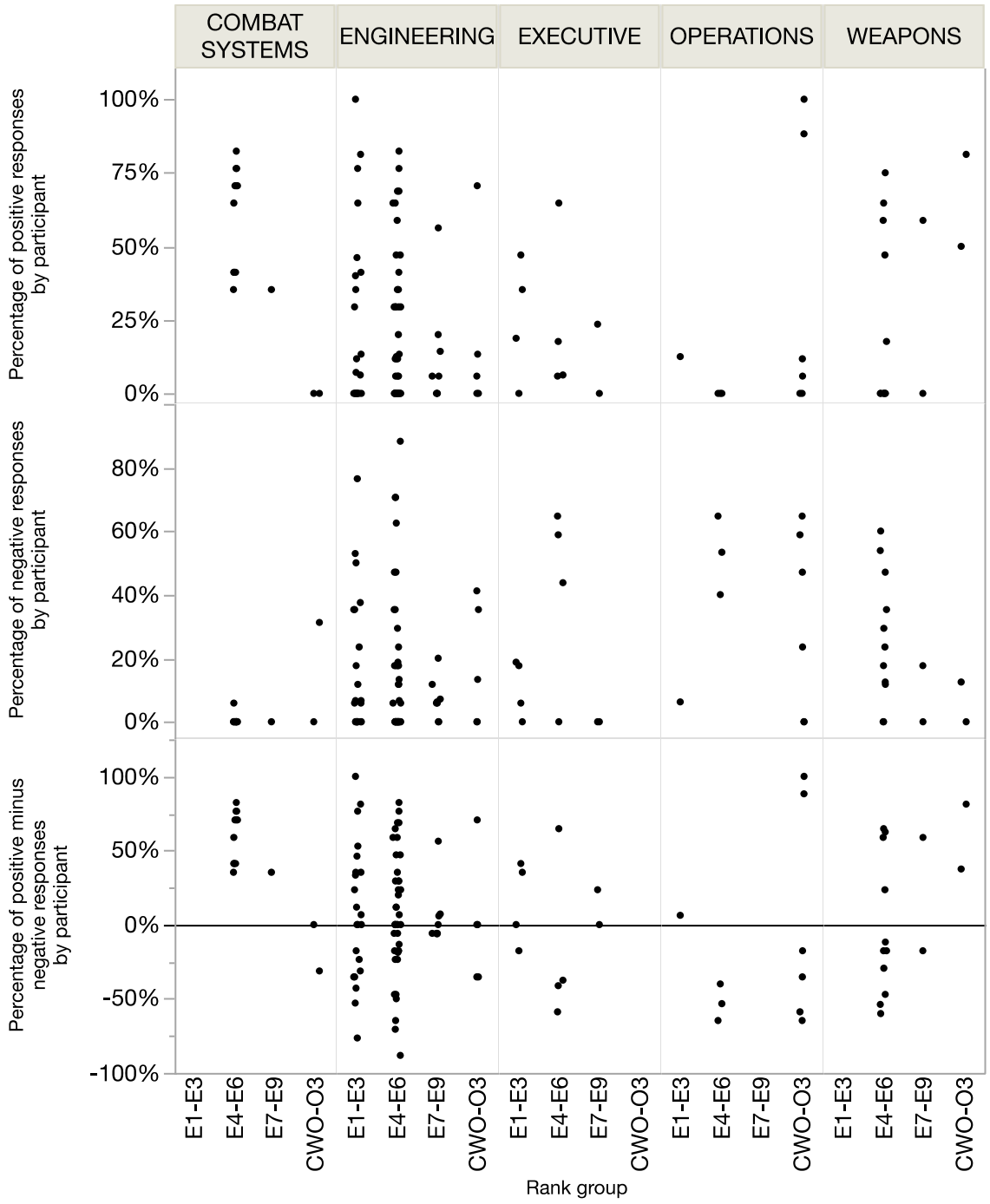

Figure 11. Acceptance responses by rank and department.

To further assess the impact of the 3-3-3-15 watchstanding schedule, we examined participant responses to two open-ended questions. From the 114 crewmembers answering the question "What did you like most about your current watch schedule?", approximately 32% responded that they liked the 3-3-3-15 because they had adequate personal time and time and work out, 26% responded that they had adequate time to sleep, 23% liked the 15 hours off between shifts, 18% noted that they had adequate time to complete their work duties between shifts, and 15% liked that the two 3-hours shifts were clustered together. Notably, approximately 60% of the positive responses regarding work out came from crewmembers from WS 1(0000-0300/0600-0900) with some of responses noting that the three hours were used for working out. These results are shown in Figure 13.

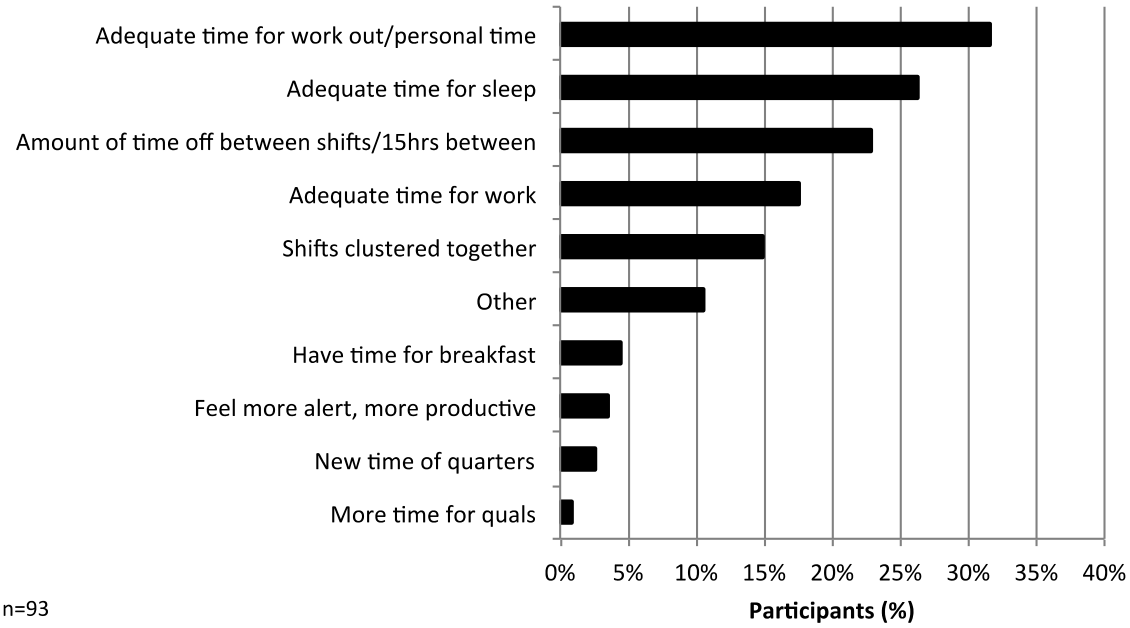

Figure 12. Responses to the question "What did you like most about your current watch schedule?"

From the 84 crewmembers answering the question "What did you like least about your current watch schedule?", approximately 30% identified conflicts between their sleep time and their other work duties. Approximately, 24% of the respondents noted that they did not like that the two shifts were clustered together with only a 3-hr break

between them, and the fact that they were working long hours. Eleven from the 62 crewmembers standing watch in night shifts noted that they did not like the night shifts, and the times they had to go to bed or wake up in the middle of the night. These results are shown in Figure 14.

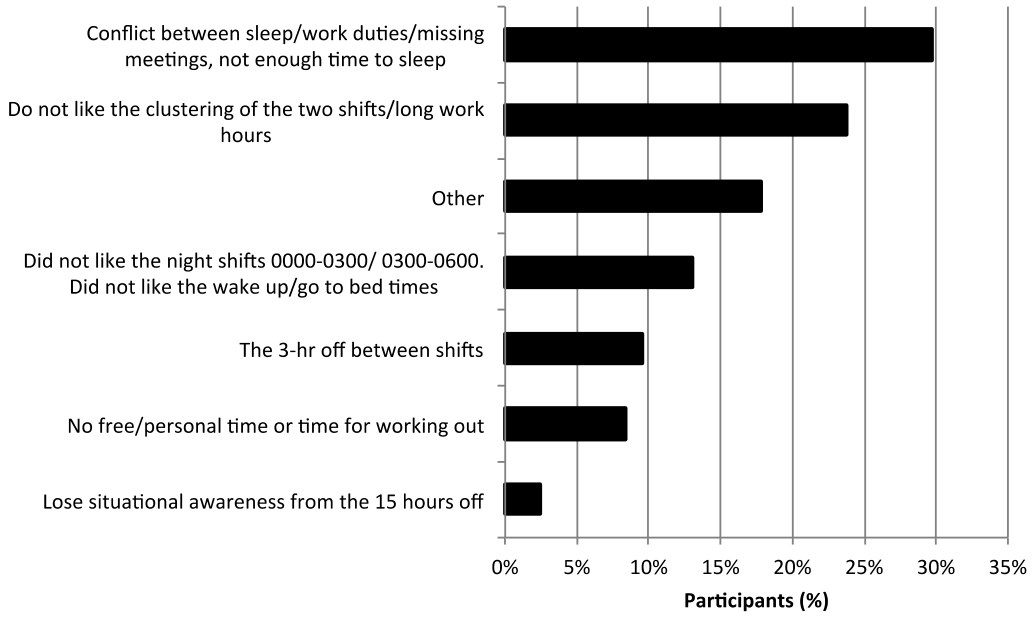

Figure 13. Responses to the question "What did you like least about your current watch schedule?"

We should also note comments by two officers reporting that the 15 hours between consecutive shifts led to losing situational awareness. Specifically, one officer from the Weapons Department on WS 4 (1500-1800 & 2100-0000) noted "It was difficult to get used to 15 hours off in terms of how much changes [have occurred]. With 9 hours off, turnovers held fewer surprises. It was just an adjustment that had to be made in terms of mindset coming on watch." Another officer from the Operations Department on WS 1 (0000-0300 & 0600-0900) noted "Lose situational awareness during 15 hours between watches, standing 6 hours of bridge watch in 9 hours can be strenuous."

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

We developed FAST schedules for the typical work and sleep patterns of crewmembers working the four sections of the 3-3-3-15. Based on data from various other sleep studies in the US Navy ships, the sleep patterns we modeled can be considered a "best case" scenario. Specifically, we assumed that the daily sleep amount was received in one single episode of excellent quality during evening or nighttime. Wake time was modeled between 30 and 60 minutes prior to shift. The same amount of time was allowed between shift end and sleep onset. The sleep duration was derived from the sleep responses in questions 4 of the PSQI. Under these assumptions, the times of sleep were modeled as follows.

- WS 1: 5.75 hours between 1715 and 2300.
- WS 2: 5.50 hours between 2030 and 0200.
- WS 3: 6.50 hours between 2330 and 0600.
- WS 4: 5.75 hours between 0100 and 0645.

Figures 15 to 18 show the FAST output of predicted effectiveness for the four watch sections of the 3-3-3-15. Work and sleep intervals are color-coded: black intervals indicate watch periods and blue intervals indicate sleep periods. The black line represents the predicted effectiveness of a person with average sensitivity to sleep loss. The dotted line represents the predicted effectiveness of a person with high sensitivity to sleep loss (10^{th} percentile). The FAST output indicates predicted effectiveness of individuals who have been given adequate time to fully adjusted to the work/rest cycle of their watch section.

The average predicted effectiveness was 86% during the shifts of WS 1 (0000-0300, 0600-0900), 84% in WS 2 (0300-0600, 0900-1200), 92% in WS 3 (1200-1500, 1800-2100), and 85% in WS 4 (1500-1800, 2100-2400). Visual inspection of the FAST diagrams shows that the predicted effectiveness of crewmembers working on WS 2/4, and who are sensitive to fatigue, may fall below the 77.5% criterion in the late evening/early night.

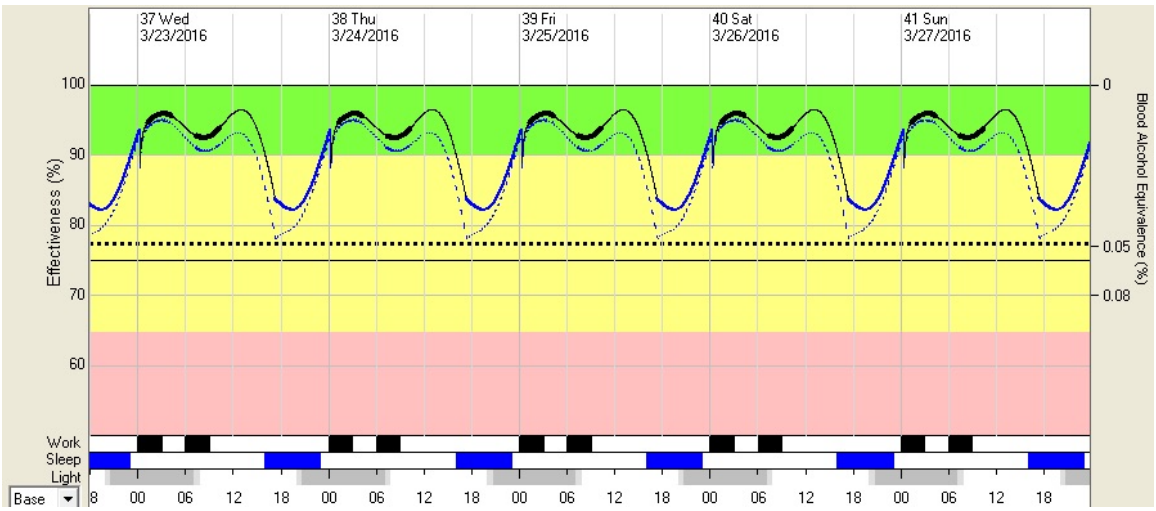

Figure 14. FAST predicted effectiveness in WS 1 (0000-0300, 0600-0900).

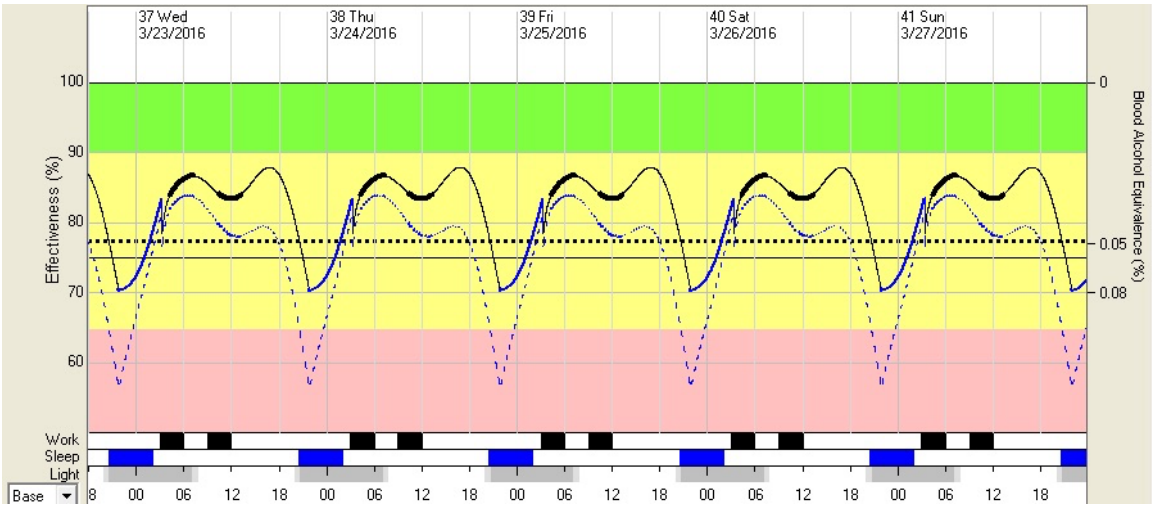

Figure 15. FAST predicted effectiveness in WS 2 (0300-0600, 0900-1200).

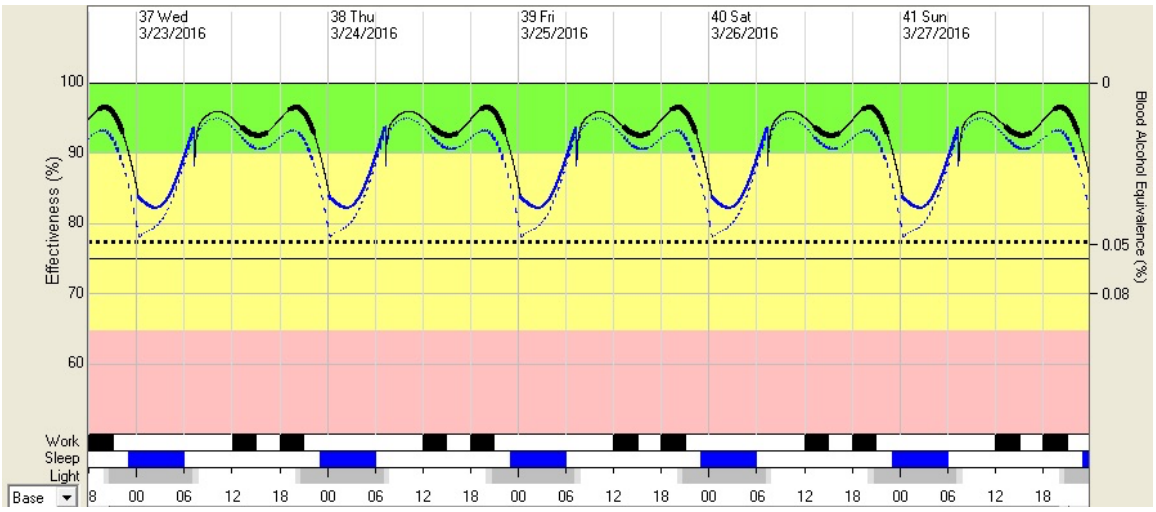

Figure 16. FAST predicted effectiveness in WS 3 (1200-1500, 1800-2100).

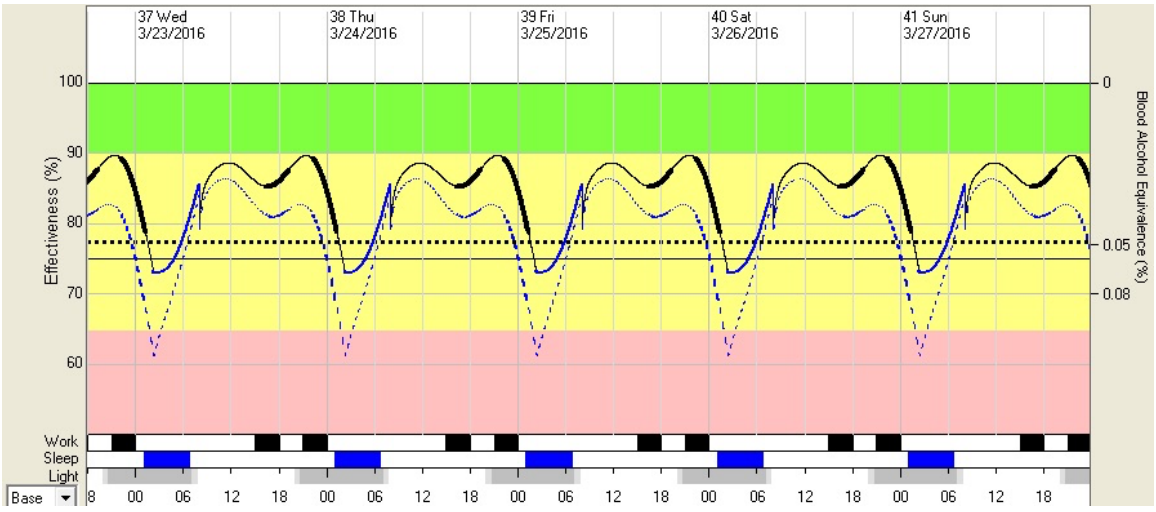

Figure 17. FAST predicted effectiveness in WS 4 (1500-1800, 2100-2400).

THIS PAGE INTENTIONALLY LEFT BLANK

IV. DISCUSSION

This study assessed the utility of the novel 3hrs-on/3hrs-off/3hrs-on/15hrs-off (3-3-3-15) watchstanding schedule on the USS STOCKDALE (DDG 106) while the ship was conducting underway operations. After working on the 3-3-3-15 for a month, crewmembers were asked to provide their opinion about the utility and the acceptance of the 3-3-3-15 as compared to the 3/9, which was the watchstanding schedule they had been using previously. In the 3-3-3-15, crewmembers stand watch in two 3-hours shifts every day. The novelty of the 3-3-3-15 lies in the clustering of the two shifts, which are divided by a 3-hour off period, and the long 15-hour off period after the second shift. The crewmembers had not experienced the clustering of the two shifts characteristic of the 3-3-3-15 because the typical watchbills used at sea distribute the watch shifts throughout the day.

In comparison to the 3/9, the average rate of non-negative responses of the 3-3-3-15 (to include positive and neutral responses) ranged from 80% (Sailors working on WS 1 and WS 4), to 90% for Sailors working on WS 2 and 3. Overall, the largest acceptance (positive) rates were identified in sleep affordability, the adequacy of time to complete off-watch duties and shipboard/departmental qualifications, to work out, to have more personal time, and to be able to plan daily activities. The pattern of acceptance, however, differed by watch section. WS 1 (0000-0300/0600-0900) was preferred for having time to work out (especially between 0300 and 0600), but it was characterized by low sleep quality and noise in the berthing compartments, and difficulty in coordinating shipboard/departmental evolutions. In contrast, crewmembers working on the WS 3 (1200-1500/1800-2100) preferred their new schedule due to its sleep affordability and quality of sleep as compared to the 3/9.

Crewmembers in the 3-3-3-15 report sleeping on average 5.80±1.23 hours; their satisfaction (72%) with the amount of sleep was equivalent to 3/9 ratings from the USS NIMITZ (Shattuck, Matsangas, & Brown, 2015; Shattuck, Matsangas, & Powley, 2015). Reported sleep quality in the 3-3-3-15, however, was considerably better than in the modified 6/18, the 5/10, the 3/9, or on the 6/6 (Shattuck & Matsangas, 2014, 2015b;

Shattuck, Matsangas, & Brown, 2015; Shattuck, Matsangas, & Powley, 2015; Shattuck et al., 2014).

The percentage of participants who reported drinking caffeinated beverages (approximately 89%) did not differ from earlier findings on the USS NIMITZ (Shattuck & Matsangas, 2015a; Shattuck, Matsangas, & Brown, 2015; Shattuck, Matsangas, & Powley, 2015). It should be noted, however, that the percentage of crewmembers on the USS STOCKDALE who reported drinking more coffee in the 3-3-3-15 compared to the 3/9 was three times higher (that is, 20% reported that the 3-3-3-15 was worse than the 3/9 as opposed to 8% who reported that the 3/9 was better).

It is notable that the acceptance of the 3-3-3-15 differed considerably by department with the Operations Department being in general negative to the new schedule. Even though the ratings of the other departments were in general positive, they showed a large spread from very positive to very negative. These results suggest that the 3-3-3-15 may be useful for some departments and watch duties but not for others. Evidence also suggests that the 3-3-3-15 may not be as good for officers whose duties demand high level of situational awareness about ship operations, for watchstanders in the Operations Department or for bridge watch duties.

Overall, our results suggest that the 3-3-3-15 has the potential to be a useful alternative to existing watch standing schedules in terms of crew fatigue levels, acceptance by the crewmembers, and workload management when working in a Navy vessel. Being a novel schedule, however, more effort should be focused on how to best implement the 3-3-3-15 on a ship, and determine the factors that affect the utility of the 3-3-3-15 at sea.

A. FUTURE RESEARCH

Based on the lessons learned from this study, we recommend that further assessment of the utility of the 3-3-3-15 is needed and more data should be collected on Navy ships while underway. Specifically, sleep quantity and quality should be assessed objectively with the use of actigraphy. Cognitive performance should also be assessed objectively with the use of computerized tests like the Psychomotor Vigilance Test (PVT)

(Basner, Mollicone, & Dinges, 2011; Dinges & Powell, 1985; Lamond, Dawson, & Roach, 2005; Thorne et al., 2005).

Lastly, it is important to assess the loss of situational awareness caused by having an extended off-watch period between consecutive shifts. To our knowledge, this is an issue which is yet to be investigated in the literature about shiftwork.

B. STUDY LIMITATIONS

This study had a number of limitations. We only collected subjective data about the utility of the 3-3-3-15 with the use of a survey. Future assessments should incorporate objective methods to assess sleep and cognitive performance. Subjective methods should be extended to include the assessment of daytime sleepiness, insomnia, etc. Lastly, because the study was cross-sectional, it was not possible to use a control group or collect data with the same crewmembers while using the 3/9 schedule.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A

USS STOCKDALE Questionnaire

Instructions: *Please answer ALL questions as accurately as possible. ALL information is confidential and will be used only for research purposes.*

1. What is your age: _____ years

2. What is your gender (Check one ☑) ☐ Male ☐ Female

3. What is your rate: (for example, FC, HT, OS, IT, GSE) _____

4. What is your rank: (for example, E4, O2) _____

5. What is your Department: (for example, Engineering, Operations, etc.) _____

6. Years on active duty: _____

7. What things affect your sleep? (Check ALL that apply ☑)

☐ Not enough time to sleep

☐ Noise: _____Other people _____ Noise inside berthing area _____ Noise outside berthing _____ 1MC

☐ Temperature: _____Too cold ____Too hot

☐ Light

☐ Motion

☐ Bedding Conditions: ____Bed size ____Mattress ____Pillow _____ Curtain

☐ Odors

☐ Other things that affect your sleep: _____

8. How many of the following caffeinated beverages do you drink **on average** each day? (Check ALL that apply ☑) and indicate daily amount)

☐ Tea Servings/Cups per day: _____

☐ Coffee Servings/Cups per day: _____

☐ Soda/pop/soft drinks Servings/Cups per day: _____

☐ Energy drinks (Monster/RedBull, etc.) Servings/Cups per day: _____

☐ Other (specify): _____ How often: _____ (Example: 4 times per day)

9. Do you use tobacco or tobacco products? (Check one ☑) ☐ Yes ☐ No

10. Do you take any prescribed or over-the-counter medications? (Check one ☑) ☐ Yes ☐ No

If **YES**, please list all medications you take:_____

_____

11. Do you have an exercise routine? (Check one ☑) ☐ Yes ☐ No

If **YES,** frequency: ____Daily ____Times per week (for example, 3 Times per week)
What kind of exercise routine do you do? (for example, cardio, weight lifting)

_____

How long does this routine take? (for example, 45 minutes) _____

12. Did you stand watch since your last port visit? **(**Check one ☑) ☐ Yes ☐ No

a. **If you stood watch**, which watchstanding schedule were you on? (hours on/ hours off) Check ALL that apply ☑

☐ NEW 3-3-3-15 schedule	☐ 6/12
☐ 3/9	☐ 6/18
☐ 5/10	☐ 6/12
☐ 5/15	☐ 12/12
☐ 6/6	☐ Other, describe _____

13. When did you stand watch? (For example, 0000-0300 and 0600-0900)

_____

14. The sleep I received since the last port visit was: **(**Check one ☑)

Much less than I needed	Less than I needed	About right	More than I needed	Much more than I needed
☐	☐	☐	☐	☐

15. The sleep received **by other Sailors** since the last port visit was: **(**Check one ☑)

Much less than needed	Less than needed	About right	More than needed	Much more than needed
☐	☐	☐	☐	☐

16. How did your workload for the past 2.5 weeks compare to your normal workload while underway? **(**Check one ☑)

Much less than usual	Less than usual	About the same	More than usual	Much more than usual
☐	☐	☐	☐	☐

17. What did you like most about your current watch schedule?

_____

_____

_____

18. What did you like least about your current watch schedule?

_____

_____

_____

19. What advice would you give to others who would like to improve their watchstanding schedules?

_____

_____

_____

Pittsburgh Sleep Quality Index Instructions: *The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days/nights since the last port visit. Please answer all questions.*

1.	In the past month, what time have you usually gone to bed at night?	Bed Time: _____
2.	During the past month, how long (in minutes) has it usually taken you to fall asleep each night	Number of Minutes:_____
3.	In the past month, what time have you usually gotten up in the morning?	Getting up time:_____
4.	During the past month, how many hours of actual sleep did you get at night? (this may be different than the number of hours you spent in bed.)	Hours of Sleep per Night:_____

Instructions: *For each of the questions, check the one best response.*

5. During the past month, how often have you had trouble sleeping because you…	Not during the past month	Less than once a week	Once or twice a week	3 or more times a week
a) Cannot get to sleep within 30 mins	○	○	○	○
b) Wake up in the middle of the night or early morning	○	○	○	○
c) Have to get up to use the bathroom	○	○	○	○
d) Cannot breathe comfortably	○	○	○	○
e) Cough or snore loudly	○	○	○	○
f) Feel too cold	○	○	○	○
g) Feel too hot	○	○	○	○
h) Had bad dreams	○	○	○	○
i) Have pain	○	○	○	○
j) Other reason(s), please describe: _____ How often during the past month have you had trouble sleeping because of this other reason?	○	○	○	○

6. During the past month, how would you rate your sleep quality overall?	Very Good ○	Fairly Good ○	Fairly Bad ○	Very Bad ○
7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter"?	Not during the past month ○	Less than once a week ○	Once or twice a week ○	Three or more times a week ○
8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	○	○	○	○
9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	Not a problem at all ○	Only a very slight problem ○	Somewhat of a problem ○	A very big problem ○

Instructions: *This list includes items that Sailors have indicated as important issues for watchstanding acceptability. Please rate the following items for the* ***NEW*** *(3-3-3-15) watchstanding schedule as compared to the one you used prior to this underway. For each of the items, check the one best response. Base your decision on* ***your experience since the last port visit.***

Issues	Compared to my **former** schedule, the **NEW** watchstanding schedule is…			
	Worse	The same	Better	N/A
a) Predictability of the daily schedule	○	○	○	○
b) Ease of coordinating Shipboard or Departmental evolutions	○	○	○	○
c) Alertness and ability to focus	○	○	○	○
d) Sleep quality	○	○	○	○
e) Time to sleep	○	○	○	○
f) Time for off-watch duties and Shipboard or Departmental qualifications	○	○	○	○
g) Ability to plan my day	○	○	○	○
h) Time to complete my watch duties	○	○	○	○
i) Time for chow	○	○	○	○
j) Mood	○	○	○	○
k) Drinking caffeine products	○	○	○	○
l) Stress	○	○	○	○
m) Drinking caffeine products	○	○	○	○
n) Time to work out	○	○	○	○
o) Personal time	○	○	○	○
p) Enough time for Shipboard or Departmental training	○	○	○	○
q) Noise in the berthing compartment	○	○	○	○

Other comments (either positive or negative) about the new (3-3-3-15) watch standing schedule:

_____
_____
_____
_____
_____

LIST OF REFERENCES

Basner, M., Mollicone, D., & Dinges, D. F. (2011). Validity and sensitivity of a brief psychomotor vigilance test (PVT-B) to total and partial sleep deprivation. *Acta Astronautica*, *69*(11-12), 949-959.

Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A New Instrument for Psychiatric Practice and Research. *Journal of Psychiatric Research*, *28*(2), 193–213.

Department of the Navy. (2014). *Naval Aviation safety management system - OPNAV Instruction 3750.6S*. Washington, D.C.: Office of the Chief of Naval Operations.

Dinges, D. F., & Powell, J. W. (1985). Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations. *Behavior Research Methods, Instruments, & Computers*, *17*(6), 652–655.

Hursh, S. R., Redmond, D. P., Johnson, M. L., Thorne, D. R., Belenky, G., Balkin, T. J., . . . Eddy, D. R. (2004). Fatigue models for applied research in warfighting. *Aviation Space and Environmental Medicine*, *75*(3 Suppl), A44–A53; discussion A54–A60.

Lamond, N., Dawson, D., & Roach, G. (2005). Fatigue Assessment in the Field: Validation of a Hand-Held Electronic Psychomotor Vigilance Task. *Aviaton Space Environmental Medicine*, *76*(5), 486-489.

Miller, N. L., Matsangas, P., & Kenney, A. (2012). The Role of Sleep in the Military: Implications for Training and Operational Effectiveness. In J. H. Laurence & M. D. Matthews (Eds.), *The Oxford Handbook of Military Psychology* (pp. 262–281). New York: Oxford University Press.

Miller, N. L., Matsangas, P., & Shattuck, L. G. (2008). Fatigue and its effect on performance in military environments. In P. A. Hancock & J. L. Szalma (Eds.), *Performance under stress* (1st ed., pp. 231–250). Burlington, VT: Ashgate Publishing.

Shattuck, N. L., & Matsangas, P. (2014). *Work and rest patterns and psychomotor vigilance performance of crewmembers of the USS Jason Dunham: A comparison*

of the 3/9 and 6/6 watchstanding schedules (Technical Report Report No. NPS-OR-14-004). Monterey, CA: Naval Postgraduate School.

Shattuck, N. L., & Matsangas, P. (2015a). Caffeinated beverage consumption rates and reported sleep in a U.S. Navy ship. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 59*(1), 696-700.

Shattuck, N. L., & Matsangas, P. (2015b). Operational assessment of the 5-h on/10-h off watchstanding schedule on a US Navy ship: Sleep patterns, mood, and psychomotor vigilance performance of crew members in the nuclear reactor department. *Ergonomics, 59*(5), 657-664. doi: 10.1080/00140139.2015.1073794

Shattuck, N. L., Matsangas, P., & Brown, S. (2015). *A comparison between the 3/9 and the 5/10 watchbills* (Technical Report Report No. NPS-OR-15-006). Monterey, CA: Naval Postgraduate School.

Shattuck, N. L., Matsangas, P., & Dahlman, A. S. (2018). Sleep and fatigue issues in military operations. In E. Vermetten, A. Germain, & T. Neylan (Eds.), *Sleep and Combat related PTSD*: Springer.

Shattuck, N. L., Matsangas, P., Mysliwiec, V., & Creamer, J. L. (In press). The role of sleep in human performance and well-being. In D. Schnyer & M. D. Matthews (Eds.), *The Cognitive and Behavioral Neuroscience of Human Performance in Extreme Settings*. New York: Oxford University Press.

Shattuck, N. L., Matsangas, P., & Powley, E. H. (2015). *Sleep patterns, mood, psychomotor vigilance performance, and command resilience of watchstanders on the "five and dime" watchbill* (Technical Report No. NPS-OR-15-003). Monterey, CA: Naval Postgraduate School.

Shattuck, N. L., Matsangas, P., & Waggoner, L. (2014, October 27-31). *Assessment of a novel watchstanding schedule on an operational US Navy vessel.* Paper presented at the Human Factors and Ergonomics Society (HFES) 58th Annual Meeting, Chicago, IL.

Thorne, D., Johnson, D. E., Redmond, D. P., Sing, H. C., Belenky, G., & Shapiro, J. M. (2005). The Walter Reed palm-held psychomotor vigilance test. *Behavior Research Methods, 37*(1), 111-118.

Troxel, W. M., Shih, R. A., Pedersen, E., Geyer, L., Fisher, M. P., Griffin, B. A., . . . Steinberg, P. S. (2015). *Sleep in the military: Promoting healthy sleep among U.S. servicemembers*. Santa Monica, CA: RAND.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Research Sponsored Programs Office, Code 41
   Naval Postgraduate School
   Monterey, California

4. Nita Lewis Shattuck……...1
   Operations Research Department
   Naval Postgraduate School
   Monterey, California

5. Panagiotis Matsangas…….1
   Operations Research Department
   Naval Postgraduate School
   Monterey, California

THIS PAGE INTENTIONALLY LEFT BLANK