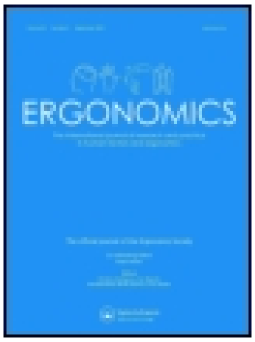

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Operational assessment of the 5-h on/10-h off watchstanding schedule on a US Navy ship: sleep patterns, mood and psychomotor vigilance performance of crewmembers in the nuclear reactor department

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ABSTRACT
We assessed sleep patterns, psychomotor vigilance performance, work demands and mood of 77 crewmembers of USS NIMITZ (CVN-68) on the rotating 5-h on/10-h off (5/10) watchstanding schedule. Within the 3-day cycle of the 5/10, sleep occurred at distinctly different times each day. On two of these days, sailors typically received only brief, 4-h sleep episodes followed by periods of sustained wakefulness (approximately 22 and 20 h). Crewmembers received approximately seven hours of sleep daily, but reported excessive fatigue and dissatisfaction with their schedule. Crewmembers' mood worsened significantly over the course of the underway phase. Psychomotor vigilance performance (reaction times, lapses) was significantly degraded compared to performance when working circadian-aligned schedules. Overall, standing watch on the 5/10 schedule, combined with other work duties, resulted in poor sleep hygiene. Crewmembers on the 5/10 experienced periodic bouts of sustained wakefulness and accrued a significant sleep debt due to extended workdays and circadian-misaligned sleep.

Practitioner summary: We assessed crewmembers' sleep patterns, psychomotor vigilance performance and work demands when working a rotating 5-h on/10-h off (5/10) watchstanding schedule. The 5/10, combined with other work duties, resulted in poor sleep hygiene. Crewmembers experienced periodic bouts of sustained wakefulness and accrued a significant sleep debt due to extended workdays and circadian-misaligned sleep.

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KEYWORDS
Shiftwork; sleep deprivation; fatigue; shiftworking; watchstanding schedules; work scheduling; circadian misalignment

1. Introduction

The maritime environment is notorious for inducing fatigue and sleep deprivation (Miller, Matsangas, and Kenney 2012). Shiftwork, reduced manning levels, extended workdays, austere berthing spaces and limited privacy are all factors that intensify the negative effects of life at sea (for example, Arendt et al. 2006; Åkerstedt and Wright 2009; Sallinen and Kecklund 2010). Since maritime processes use a system of shiftwork to enable continuous operations, it is not surprising that optimising shiftwork practices is a global concern for navies in general and the United States Navy (USN) in particular. Documented in a series of studies conducted at the Naval Postgraduate School over the last two decades, USN sailors are habitual shiftworkers, regularly working shifts that result in circadian misalignment (Colquhoun, Blake, and Edwards 1968). Instead of a 24-h day with opportunities to sleep about the same time each day, their work schedules result in an 18- or 20-h day that continuously cycles without weekends or time off for recovery. In the civilian population, working other than a 24-h day, especially shorter days that impose a type of chronic jet-lag, is a well-known contributor to fatigue (Wilkinson 1992). While some of the factors characterising shipboard life are hard to change, determining the daily work and rest schedules for crewmembers are typically under the control of the ship's commanding officer.

Researchers from the Naval Postgraduate School were contacted by the Commanding Officer of USS Nimitz (CVN-68) to assess the fatigue levels of crewmembers working on the 5-h on/10-h off (5/10) watchstanding schedule while conducting underway operations. The 5/10 is a 3-section watchstanding schedule in which a crewmember stands watch for five hours followed by 10-h off watch. These 5-h watches commence at 0200, 0700, 1200 and 1700, while the watch commencing at 2200 is only four hours in duration. Figure 1 shows two 3-day cycles of the 5/10 watchstanding schedule. The continual rotation of the 5/10 iterates every three days and results in work and rest occurring at different times each day and has long been associated with sleep problems and circadian dysyncrony (Colquhoun and Folkard 1985; Goh et al. 2000; Hakola and Härmä 2001).

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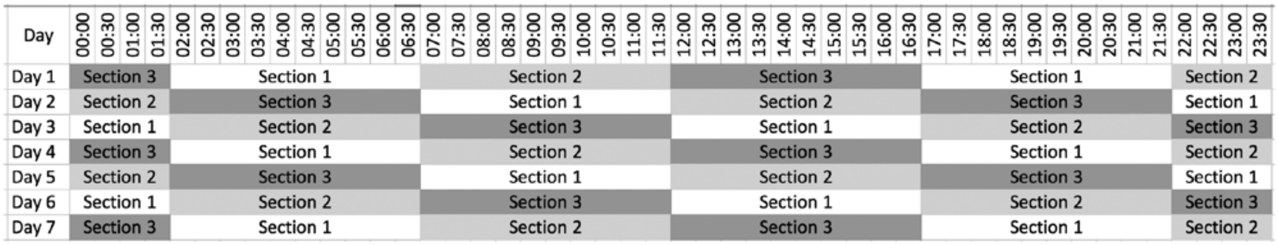

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Day 1	Section 3				Section 1										Section 2										Section 3										Section 1										Section 2			
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Day 7	Section 3				Section 1										Section 2										Section 3										Section 1										Section 2			

Figure 1. The 5/10 watch schedule.

The current study assessed the mood, sleep patterns, daytime sleepiness and psychomotor vigilance performance of a sample of USS Nimitz RX Department crewmembers over a 2-week underway period while they were working a 5/10 watchstanding schedule.

2. Methods

2.1. Equipment and instruments

The prestudy survey included demographic questions about age, gender, rate/rank, department, years on active duty, as well as three standardised fatigue-related questionnaires. The Epworth Sleepiness Scale (ESS) was used to assess average daytime sleepiness (Johns 1991). The ESS uses a 4-item Likert scale to rate the chance of dozing off or falling asleep in eight different everyday situations. Individual answers are scored from 0 to 3, with 0 being 'would never doze', 1 being 'slight chance of dozing', 2 being 'moderate chance of dozing' and 3 denoting a 'high chance of dozing'. Respondents were instructed to rate each of the eight items according to his/her usual way of life in recent times. Individual item responses were summed to arrive at a total score. A total score of 10 or more reflects above normal daytime sleepiness and indicates a need for further evaluation (Johns 1992). The ESS questionnaire has a high level of internal consistency (Cronbach's α ranging from 0.73 to 0.88), and a high test–retest reliability ($\rho = 0.82$, $p < 0.001$) (Johns 1992). Total ESS scores are negatively correlated with mean sleep latency in the multiple sleep latency test (e.g. $\rho = -0.37$, $p = 0.004$) (4, 7) (Johns 2002).

To measure mood states and assess changes in mood, participants filled out the profile of mood state (POMS) questionnaire (McNair, Lorr, and Droppelman 1971). The POMS is a standardised, 65-item inventory originally developed to assess mood state in psychiatric populations. The questionnaire assesses the dimensions of the mood construct using six subscales: anger–hostility (12 items; range 0–48), confusion–bewilderment (7 items; range 0–28), depression (15 items; range 0–60), fatigue (7 items; range 0–28), tension–anxiety (9 items; range 0–36) and vigour–activity (8 items; range 0–32). Total mood disturbance (TMD) score ranges from 0 to 200 and is derived by subtracting the vigour subscale score and summing the scores of the remaining five subscales. Normalised scores (*T*-scores) are based on norms for adults (Nyenhuis et al. 1999). The POMS was administered using the instruction set: 'Describe how you felt during the past two weeks'. Positive mood has been associated with better within-team communication behaviours and enhanced team awareness (Pfaff 2012). In addition to administering the ESS and POMS again, the post-test survey also asked participants to verify the watchstanding schedule they used and to indicate the adequacy of their own and their peers' sleep using a 5-point Likert scale: 'Much less than needed'; 'Less than needed'; 'About right'; 'More than needed' and 'Much more than needed'. Reliability coefficients for all six POMS scales are near 0.90 or more, whereas POMS scores are positively correlated (range = 0.42–0.86) with the Hopkins Symptom Distress Scale (McNair et al. 1971).

Two brands of actigraphic devices were used to assess crewmembers' sleep, the Motionlogger Watch (Ambulatory Monitoring, Inc.; Ardsley, New York), referred to as 'AMI', and the Spectrum (Philips-Respironics; Bend, Oregon) actiwatch, referred to as 'PR'. Data for both devices were collected in 1-min epochs. AMI data were collected in the zero-crossing mode and 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-min period. All values are the defaults for this software. PR data were scored using Actiware software version 6.0.0 (Phillips Respironics; Bend, Oregon). The medium sensitivity threshold (40 counts per epoch) was used, with 10 immobile minutes as the criterion for sleep onset and sleep end. Again, all values are the defaults for this software. Previous research assessed total sleep time over an approximate 8-h night sleep episode yielded 3-min precision for AMI data analysed with Cole–Kripke and PR data analysed with medium sensitivity parameters (average results compared to polysomnographically derived 436 min of sleep) (Meltzer et al. 2012). Furthermore, a comparison failed to identify significant differences in 3/9 daily rest and total sleep time duration between AMI and PR actiwatches (Wilcoxon Rank Sum test, $p > 0.10$).

All participants were asked to complete an activity log, documenting their daily routine in accordance with Navy Standard Workweek categories. The activity logs covered a 24-h period in 15-min intervals. Operational demands precluded the use of the standard 10-min version of the psychomotor vigilance test (PVT) (Dinges and Powell 1985), so we used a 3-min version of the PVT (Loh et al. 2004; Basner and Dinges 2011) which was installed on the AMI motionloggers (PVT-192). A red backlight appeared for one second and the letters 'PUSH' were used as visual stimuli; the response time was then displayed in milliseconds. The PVT interstimulus interval ranged randomly from 2 to 10 s. Shortened versions of the PVT have been used effectively by other researchers to detect the effects of sleep deprivation (Loh et al. 2004). The 3-min PVT has been validated against the standard 10-min PVT with good results in total and partial sleep deprivation conditions (Basner, Mollicone, and Dinges 2011).

2.2. Procedures

This study was a naturalistic observation rather than a designed experiment. Participants were volunteers from the Reactor (RX) Department of USS Nimitz (CVN-68) aircraft carrier. The study protocol was approved by the Naval Postgraduate School Institutional Review Board. Data were collected from 10 June to 27 June 2014. The ship was in port from 10 to 15 June, with a brief underway during the daytime hours on 13 June. The ship was at sea from 15 to 27 June. During the entire study period, however, the RX Department was in a simulated underway environment due to reactor plant startup, shutdown and run procedures.

Personnel wishing to volunteer signed consent forms and received further training prior to being issued equipment for the study. The participants filled out the prestudy questionnaires upon receipt of their sleep watches and activity logs. All participants were instructed to fill out their activity logs daily and, at a minimum, complete a PVT prior to and after standing watch. Upon completion of the study, participants returned their equipment and filled out an end-of-study questionnaire.

2.3. Analytical approach

Statistical analysis was conducted with a statistical software package (JMP Pro 10; SAS Institute; Cary, North Carolina). Data are presented as mean (*M*) ± standard deviation (SD) or median (MD), as appropriate. Significance level was set at $p < 0.05$.

All variables underwent descriptive statistical analysis to determine demographic characteristics of the study population. The data were assessed and rejected for normality using the Shapiro–Wilk W test; therefore, further comparisons were based on nonparametric methods. Correlation analysis was based on Spearman's ρ.

Based on the Dunn method for joint ranking accounting for family wise error, daily rest/sleep and PVT metrics in the 5/10 were compared with the sleep and PVT results obtained from two previous studies of USN Sailors. The first study included 34 crewmembers from various departments of a US Navy Arleigh Burke class destroyer during a transit from Hawaii to San Diego between 24 May and 30 May 2013 (Shattuck, Matsangas, and Waggoner 2014). The participants were performing their daily duties while standing watch on a modified 6-h on/18-h off (6/18) watch schedule. The second study was conducted on another Arleigh Burke class destroyer ($N = 52$ crewmembers) during independent steaming in forward deployment. The participants were performing their daily duties while standing watch on two schedules; one group ($n = 41$ from various departments) on the 3-h on/9-h off (3/9), and one group ($n = 11$ from the Operations department) on the 6-h on/6-h off (6/6) schedule (Shattuck and Matsangas 2014).

The change in ESS and POMS scores between the beginning and end of each study was assessed using pairwise Wilcoxon Rank Sum tests. To account for multiple comparisons in POMS scores, statistical significance was adjusted by applying the Benjamini–Hochberg false discovery rate controlling procedure (Benjamini and Hochberg 1995).

Analysis included actigraphy data collected from 10 June to 27 June 2014. From the 2391 rest intervals, 71 (2.97%) were missing and their values were interpolated. From the rest/in-bed intervals (identified as DOWN in the AMI software, and REST in Phillips–Respironics software), the time in-bed and sleep amounts were calculated.

PVT data were analysed based on the metrics proposed by Basner and Dinges (2011) for individuals with chronic sleep deprivation. Responses without a stimulus or with RTs < 100 ms were identified as false starts. Lapses were defined as RTs equal to, or greater than, 355, and 500 ms. Psychomotor vigilance performance analysis was based on nine PVT metrics: mean reaction time (RT), mean 1/RT (i.e. reciprocal reaction time, also called response speed), fastest 10% RT, slowest 10% 1/RT, percentage of false starts within each PVT trial (i.e. number of false starts divided by the number of stimuli), percentage of 355 ms lapses, percentage of 500 ms lapses, percentage of 355 ms lapses combined with false starts, percentage of 500 ms lapses combined with false starts. For calculating mean 1/RT and slow-est 10% 1/RT, each RT (ms) was divided by 1000 and then reciprocally transformed. For all metrics, the response values were aggregated by trial. For more information on data reduction and processing, please refer to the technical report (Shattuck, Matsangas, and Powley 2015).

3. Results

From the initial 110 volunteers, 77 crewmembers from the Reactor Department working on the 5/10 watchstanding schedule participated in the study (63 males, 76 enlisted and one officer). Participants were 25.3 ± 3.17 years in age, and had 4.87 ± 2.65 years of active duty. The factor affecting sleep most frequently reported by sailors was lack of adequate time to sleep (88%), followed by noise (73%) and temperature in the berthing compartment (56%). Participants on the 5/10 schedule were dissatisfied with the amount of sleep they received. Approximately 21% rated their amount of sleep as about right, whereas 79% found their sleep amount less (71.4%) or much less (7.80%) than was needed. The sleep of other sailors was also rated as less (62.2%) or much less (16.2%) than was needed.

As assessed by ESS scores, average daytime sleepiness of participants on the 5/10 intensified by the end of the study. Specifically, the average ESS score increased from 9.66 ± 4.07 (MD = 10) at the beginning of the study to 10.8 ± 4.65 (MD = 11) (matched pairs Wilcoxon Rank Sum test, $S = 392$, $p = 0.011$). ESS scores indicate that 39% of the participants had elevated daytime sleepiness (ESS score > 10) (Johns, 1991) at the beginning of the underway period. By the conclusion of the study, 52% of the participants had ESS scores indicative of excessive daytime sleepiness.

3.1. Sleep

The daily rest and sleep durations of crewmembers from the Reactor Department working the 5/10 were compared with sleep data from crewmembers from three other ships. As assessed by actigraphy, average rest and sleep of crewmembers on the 5/10 were similar to the patterns of sailors on the 3/9 schedule, but was significantly higher than crewmembers on the 6/6 and on the modified 6/18 watch schedules. Crewmembers working on the 6/6 schedule were in the Operations (OPS) Department. These results are shown in Table 1 and Figure 2.

It is interesting to note that that on average, participants slept more than one episode per day (mean = 1.55 ± 0.282 episodes), which suggests that they slept whenever possible (i.e. they frequently engaged in napping). Furthermore, daily rest and sleep duration were positively correlated with the number of rest episodes per day (Rest: $\rho = 0.388$, $p < 0.001$; Sleep: $\rho = 0.352$, $p = 0.003$). Consequently, participants who napped more accumulated more sleep during the day. This result illustrates the beneficial effect of napping in an operational environment where opportunities for lengthy sleep episodes are limited.

3.2. Psychomotor vigilance performance

The PVT analysis reveals a consistent trend: participants on the 5/10 watchstanding schedule had the worst PVT performance among the four schedules, followed by their counterparts on the 6/6. The best performance was seen in the crewmembers on the 3/9, which is followed by the modified 6/18. Specifically, performance on the 5/10 was significantly worse than the modified 6/18 in eight PVT metrics (i.e. reaction time, response speed, fastest 10% RTs and slowest 10% 1/RTs, lapses, and lapses combined with false starts). Performance on the 5/10 was significantly worse than the 3/9 in six PVT metrics (i.e. reaction time, response speed, fastest 10% RTs and slowest 10% 1/RTs, 500 ms lapses, and 500 ms lapses combined with false starts). These results are shown in Table 2.

3.3. Mood

Sailor mood, as measured by POMS TMD scores, deteriorated significantly during the underway period. From an average

Table 1. Daily sleep by watchstanding schedule as assessed by actigraphy.

Variable	5/10 ($n = 70$)	6/6 ($n = 9$)	Mod. 6/18 ($n = 34$)	3/9 ($n = 24$)
Daily rest (hours)	7.52 ± 0.909^{a,b}	6.54 ± 0.944	6.62 ± 1.66	7.25 ± 0.781
Daily sleep (hours)	6.88 ± 0.894^{a,b}	5.90 ± 0.898	5.65 ± 1.63	6.54 ± 0.800
Number of rest episodes per day	1.55 ± 0.282	–	1.86 ± 0.518	–

Note: Data presented as M ± SD. Sleep assessed by actigraphy.

[a] Statistically different from the 6/6 (Dunn method for joint ranking, $p < 0.05$).

[b] Statistically different from the modified 6/18 (Dunn method for joint ranking, $p < 0.05$).

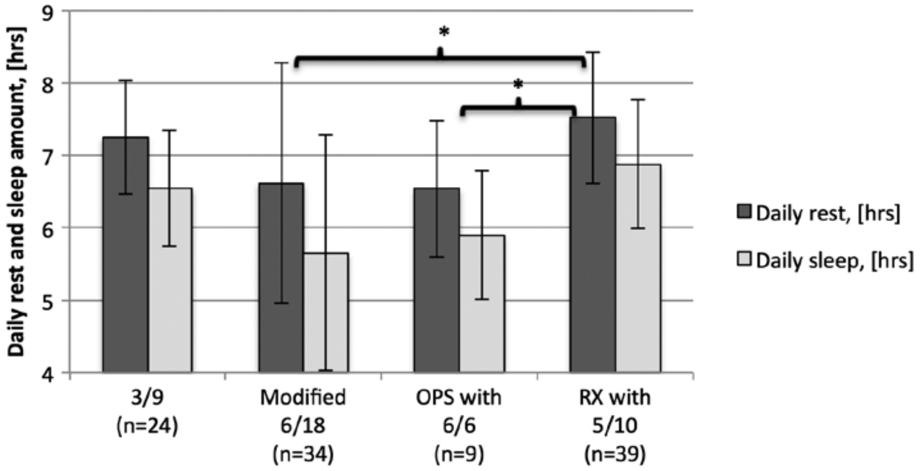

Figure 2. Daily rest and sleep amount assessed by actigraphy.
Note: The asterisk denotes a statistical significant difference at the $a = 0.05$ level.

Table 2. PVT metrics.

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

Note: Data presented as *M* ± SD.

[a] Statistically different from the modified 6/18 (Dunn method for joint ranking, $p < 0.05$).

[b] Statistically different from the 3/9 (Dunn method for joint ranking, $p < 0.05$).

Table 3. Profile of Mood State subscale scores.

POMS scales	Beginning	End	*p*-value
Tension–anxiety	11.0 ± 5.52	11.5 ± 5.92	0.265
Depression	11.2 ± 9.22	13.6 ± 11.1	0.026*
Anger–hostility	13.8 ± 9.14	18.2 ± 9.86	<0.001*
Vigour–activity	11.5 ± 5.21	9.18 ± 4.79	<0.001*
Fatigue	12.5 ± 4.84	13.8 ± 5.71	0.009*
Confusion–bewilderment	9.04 ± 4.55	9.08 ± 4.75	0.708

Note: Data presented as *M* ± SD.

Comparisons with the two-tailed matched pairs Wilcoxon Signed Rank test.

*Statistical significance assessed with the Benjamini–Hochberg false discovery rate controlling procedure for the six POMS subscales.

of 46.0 ± 27.4 at the beginning of the study, the TMD scores of crewmembers on the 5/10 increased to 57.0 ± 31.1 by the end of the study ($p < 0.001$). The same pattern of deterioration was evident in four of the POMS subscales: depression, anger–hostility and fatigue were significantly worse, while vigour–activity scores were significantly lower, all indications of worsening mood. Table 3 shows all the POMS scores and compares scores between the beginning and end of the study.

3.4. Daily activity

The analysis of daily activity was based on 652 days of data derived from 64 participants from the RX Department on the 5/10 watchstanding schedule (on average, 9.82 days of activity data per participant). These data did not include information from 13th June to 15th June when the ship was in port at Victoria, British Columbia, Canada. Interpolation was required and applied to 459 15-min intervals (0.73%) in which the data were missing. On average, crewmembers in the Reactor Department working on the 5/10 watch schedule were on duty for 12.2 ± 1.85 h per day, i.e. they stood watch, participated in training, work/maintenance, meetings, etc. Approximately 55% of these participants reported being on duty for more than 12 h per day whereas 15% of the participants reported being on duty, on average, more than 14 h per day.

Figures 3–5 show the distribution of time in terms of time on duty, watch and reported sleep. Each diagram shows one full day of activity distributed into 96 15-min time bins. In terms of sleep distribution and the interaction between work/watch and sleep, there are several important points to consider. First, watchstanding comprised approximately 60% of the daily work activity. The remaining 40% was distributed among other work commitments. Second, approximately 15% of the crewmembers were working, on average, 14 h or more per day.

Analysis of activity distribution shows that, over an entire 3-day rotation circle, a crewmember on the 5/10 watch schedule faces two periods of extended wakefulness. On the first day of the rotation (Figure 3), crewmembers experience a period of sustained wakefulness of approximately 22 h (i.e. 0100–2300). The second extended wakefulness period, 20-h in length,

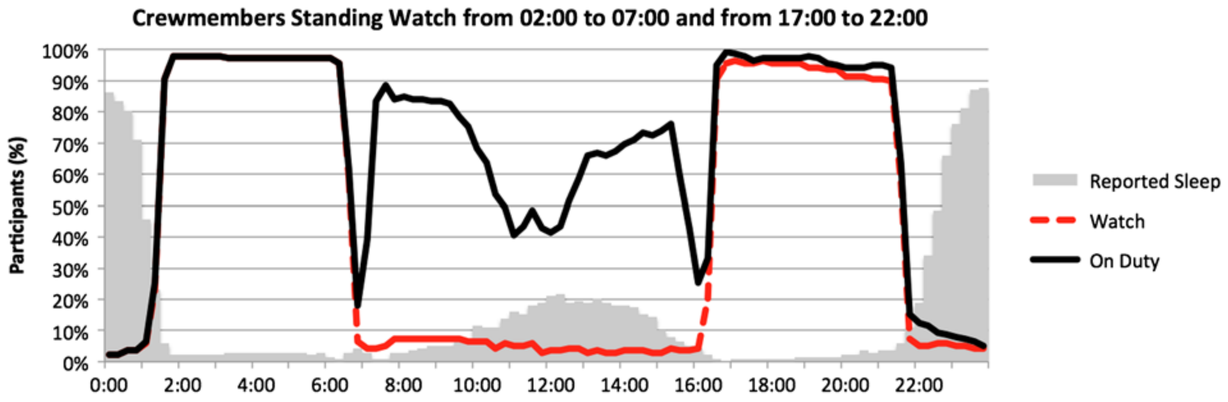

Figure 3. Reported activity time distribution for crewmembers standing watch from 02:00 to 07:00 and from 17:00 to 22:00.

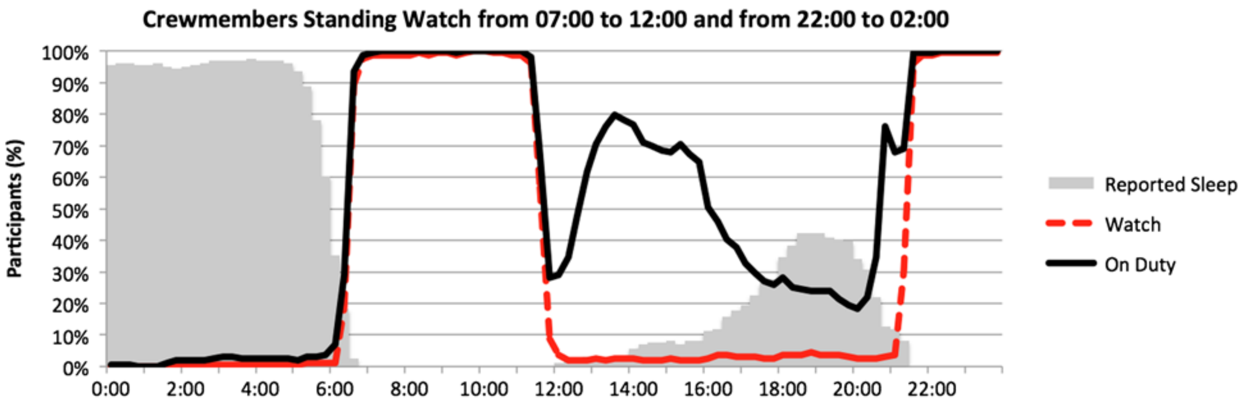

Figure 4. Reported activity time distribution for crewmembers standing watch from 07:00 to 12:00 and from 22:00 to 02:00.

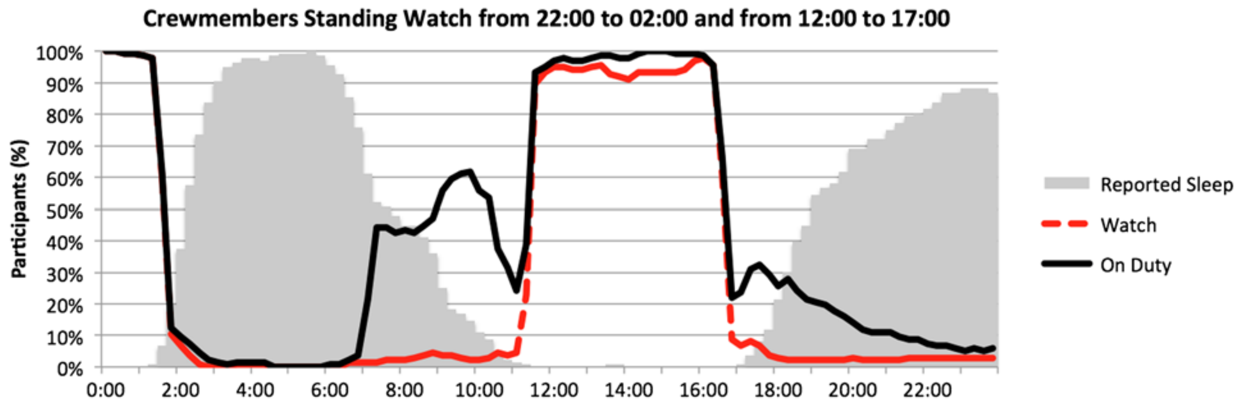

Figure 5. Reported activity time distribution for crewmembers standing watch from 22:00 to 02:00 and from 12:00 to 17:00.

begins at approximately 0600 of the second day (Figure 4), continuing until after 0200 on the third day (Figure 5). During these two periods, the fatigue experienced due to the sustained wakefulness is only partially ameliorated by napping during the day. Furthermore, there is one night of short sleep (Figure 5). This sleep episode terminates early, being only 4 h in length, because of daily work commitments. It also notable that some crewmembers on the 0200–0700 night watch do not start their sleep as early as necessary the evening before the watch. This decision can potentially be attributed to a need to attend to other duties, for personal time after work, and to the improper timing of this sleep period because of circadian misalignment. Vertical axes in Figures 3–5 mark the percentage of participants on the 5/10 schedule in each activity; reported sleep is on the right axis, while duty and watch times are on the left axis.

4. Discussion

This study focused on the assessment of the 5/10 watchstanding schedule. Results show that the 5/10 is problematic compared to other watch schedules in terms of amounts of rest and sleep, subjective levels of fatigue and psychomotor vigilance performance. In terms of daily sleep duration, crewmembers on the 5/10 received approximately seven hours of sleep per day on average, which is significantly more than US Navy personnel on other watchstanding schedules (Miller, Matsangas, and Kenney 2012; Shattuck, Matsangas et al. 2014; Shattuck, Waggoner et al. 2014). The amount of daily sleep obtained on the 5/10 was significantly more than that obtained on the modified 6/18 and the 6/6 schedules, but was comparable to the sleep received by participants on the 3/9 schedule.

The crewmembers on the 5/10, however, reported elevated levels of fatigue. In fact, almost all of them (88%) indicated that they did not have adequate time to sleep and they did not like their watch schedule. The contradiction between the amount of daily sleep and crewmembers' negative opinions of their schedule may be explained when we consider the timing of the sleep they received. Over an entire 3-day rotation cycle, a crewmember on the 5/10 watchstanding schedule sleeps at three distinctly different times on subsequent days. Our findings suggest that the 5/10 schedule yields poor quality sleep that has less recuperative value. These results are aligned with earlier research showing that the timing of sleep affects its physiological expression, and hence, its subjective impression (Åkerstedt et al. 1997). By the end of the underway phase, crewmembers' moods were significantly worse compared to the beginning of the study. Specifically, participants' POMS scores for depression, anger–hostility, fatigue and TMD increased, while vigour–activity scores decreased – all indications of degradations in mood. Deteriorations in mood and negative affect may produce considerable effects not only at an individual level, but also in team cognition and awareness (Pfaff and McNeese 2010; Pfaff 2012).

In addition to the problems in sleep quality, we also found that crewmembers on the 5/10 had worse psychomotor vigilance performance than crewmembers on the modified 6/18 and the 3/9 schedules. Specifically, participants on the 5/10 had 21.4% longer PVT reaction times and 71.5% more errors (i.e. lapses combined with false starts) than participants on the 3/9 schedule. However, performance on the 5/10 was comparable to the performance of their counterparts on the 6/6 schedule.

The disruption of the internal circadian rhythm (Colquhoun et al. 1968), referred to as circadian desynchrony, provides one possible explanation for our findings. Irrespective of the departmental work shifts, late night and early morning shifts, accompanied by sudden returns to work, are associated with short sleep and increased sleepiness (Sallinen and Kecklund, 2010). A fast-rotating watch schedule disturbs the sleep-wakefulness cycle (Åkerstedt 2003) and does not allow for the circadian clock to realign, due to the continuously changing cycle. Research has shown that adjustment of the circadian diurnal rhythm to a nocturnal rhythm may take at least a week (Monk 1986), although reports of 12 days or more have also been reported for circadian realignment to occur (Colquhoun, Blake, and Edwards 1969; Hockey 1983).

The findings of this operational study suggest that the rotating 5/10 watchstanding schedule, combined with other work duties, leads to poor sleep hygiene. Initially introduced in 1864 (Gigli and Valente 2013), the concept was formally developed by Hauri (1977) to denote a set of behavioural practices promoting good sleep. However, crewmembers are, in general, not in control of their watch and work schedule. Specifically, crewmembers on the 5/10 schedule experience sustained wakefulness due to extended workdays and sleeping during circadian-misaligned times. Our results also suggest that some crewmembers do not make the best use of sleep opportunities when offered. Therefore, in the context of this study, sleep hygiene refers to the actual level (which is dynamic) of sleep-promoting behaviours in the everyday life of the crewmembers, which is impacted both by operational/organisational factors (watch/work schedule) and personal factors (non-optimised use of personal time to rest). Hence, sleep hygiene is a goal in the operational environment.

Excessive work commitments and collateral duties, combined with restricted opportunities for sleep, result in decreased alertness, deteriorated mood and degraded psychomotor vigilance performance. This study further illustrates the beneficial effect of napping in an operational environment, where opportunities for lengthy sleep episodes are limited (Åkerstedt 2003; Åkerstedt and Torsvall 1985). Crewmembers in this study who had the opportunity to nap – and availed themselves of that opportunity – received significantly more sleep across 24 h than those who did not nap. That being noted, however, napping can also be considered a negative outcome of shift working. Åkerstedt and Torsvall (1985) showed that, in general, shift workers nap when they cannot get adequate night sleep because of work commitments and the shift schedule on which they are working.

Overall, our results suggest that, when possible, the use of the rotating 5/10 should be avoided. This conclusion aligns with previous research showing that rotating watch schedules inevitably produce fragmented sleep and disrupt physiological rhythms (Colquhoun et al. 1968; Colquhoun 1985). Watchstanding schedules that take human physiology into account may lead to better performance in the operational environment (Miller 2006). For example, shift schedules leading to circadian-aligned 24-h day and allowing watchstanders to sleep at the same time every day are more tolerable from a circadian rhythm perspective (Colquhoun et al. 1968; Colquhoun 1985). Lastly, we should emphasise the need to educate crewmembers on healthy sleep habits. With a proper appreciation of the negative consequences of sleep deprivation, sailors will be motivated to reconsider whether sleeplessness is a badge of honour (Davenport 2007) and will manage their schedules more wisely.

4.1. Study limitations

This study had a number of limitations. The 5/10 assessment was based on participants from one department. Future efforts should include a sample representing more ship departments. Furthermore, officers were underrepresented (i.e. only 2% of the study samples were officers) in our sample of the Reactor Department.

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