A 6-Month Assessment of Sleep During Naval Deployment: A Case Study of a Commanding Officer

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BACKGROUND: Sleep deprivation is known to be a common problem in the U.S. Navy and has been documented using wrist-worn actigraphy in various operational studies that typically span 2 to 4 wk in duration. However, sleep patterns over an extended period of time have not been objectively measured.

CASE REPORT: This 6-mo study used actigraphy and the Fatigue Avoidance Scheduling Tool (FAST) to quantify the sleep patterns of a 39-yr-old Commanding Officer (CO) of an Arleigh Burke class destroyer while the ship was forward-deployed. On average, the CO received 5.2 h of sleep daily and averaged 6 h time in bed each day. The participant received more than 8 h of sleep for only 2% (N = 3) of the study days; for 17% (N = 27) of the days, he received less than 4 h of daily sleep. For 15% of waking time, the CO had a predicted effectiveness of less than 70% on the FAST scale, equating to a blood alcohol equivalent of 0.08%—or legally drunk. The CO's predicted effectiveness was below 65% approximately 10% of waking time.

DISCUSSION: Results from this study are aligned with earlier research showing that crewmembers on U.S. Navy ships suffer from chronic sleep restriction. During a typical deployment, personnel accrue a considerable sleep debt even during normal operations. Should critical events with additional sleep restriction occur, the ship has limited reserve capacity, potentially placing her crew and their mission in grave jeopardy.

KEYWORDS: fatigue, actigraphy, field studies, naval environments, sleep debt, maritime sleep, sleep at sea, predicted effectiveness.

Sleep deprivation is a well-recognized problem in the naval environment.[10] However, the objective assessment of sleep patterns in operational environments, especially for long periods of time, poses a considerable challenge. To our knowledge, operational studies using actigraphy to assess sleep patterns in the naval environment typically last less than a month in duration.[1,10] Although useful, sleep studies of only days or weeks in duration may give an inaccurate portrayal of the long-term sleep patterns of crewmembers on naval vessels, appearing either artificially higher or lower than actuality due to spikes in operational tempo or other reasons. Hence, the external validity of their results may be compromised. To gain a better appreciation of long-term sleep patterns during operational commitments, we collected actigraphy data from the commanding officer (CO) of an Arleigh Burke class destroyer during a 6-mo forward deployment.

The CO has the absolute responsibility for his/her ship. While at sea, the CO must exert every effort to maintain the ship in a state of operational readiness for all conditions, up to and including war. Although the CO does not stand watch, s/he is continuously accessible for issues that may arise and need his/her attention. Given his/her responsibilities and position in the command structure of a ship, the CO should be able to maintain alertness levels necessary to operate effectively. In other words, the CO must manage his/her own schedule, balancing the demands of command with his/her own need for rest and relaxation. Unfortunately, commanders may forego self-care, thinking that they are sacrificing for the good of their crew. Shay[12] speaks eloquently of this phenomenon in his essay entitled, "Ethical Standing for Commander Self-Care: The Need for Sleep." The assessment of the sleep patterns of a commanding

officer for a 6-mo operational deployment can provide valuable insight regarding fatigue and alertness levels over the course of the deployment.

CASE REPORT

This observational study was conducted onboard a 9300-ton Arleigh Burke class destroyer (Bath Iron Works, Bath, ME) from June (when the ship was at home port) to November 2012 during a forward deployment. Activity and sleep were recorded using the Spectrum actiwatch (Phillips Respironics, Bend, OR). Data were collected in 1-min epochs and scored using Actiware software version 6.0.0. The medium sensitivity threshold (40 counts per epoch) was used with 10 immobile minutes as the criterion for sleep onset and sleep end (all values are default for this software). To minimize the impact on the participant's workload, a sleep log was not used, although the event button was often used to indicate bedtime. The Fatigue Avoidance Scheduling Tool (FAST), which is based on the Sleep and Fatigue Task Effectiveness (SAFTE) model, was used to estimate predicted effectiveness from the actigraphically scored sleep.[8] All sleep episodes were assumed to be of excellent quality, perhaps overly optimistic given the nature of life on a warship. Hence, the FAST output should be considered as a best-case scenario for the CO's predicted effectiveness.

From the 274 rest intervals, 9 (3.28%) were imputed. Analysis focused on the rest intervals, the actigraphically scored sleep within each rest interval, and on the number of sleep episodes per 24-h period. Sleep episodes were classified into two categories: "major/night" sleep episodes ($N = 156$) and "naps" ($N = 117$). The night sleep episodes were identified as such based on their time of occurrence. Naps were the sleep episodes occurring other than nighttime and were of shorter duration than the major night sleep episodes. The daily sleep amount for each 24-h period was calculated from 18:00 to 17:59 local time.

Time zones were adjusted according to the ship's schedule. The ship began her mission from an area with Coordinated Universal Time (UTC) −4 during Daylight Saving Time. From the first week of July until the end of November 2012, the ship remained on local time (LT) = UTC +3.

This 6-mo study assessed the sleep patterns of the CO of the ship (39 yr old with 17 yr in service), who volunteered to participate. From all indications, at the start of the deployment, he was in excellent physical health, typical for a Navy Commander who is deemed "fit for sea duty." During the 157-d period, the ship was at sea approximately 125 d (80%) while spending 32 d in port (20%). On average, the CO received 5.19 h of sleep per day (SD = 1.25) and averaged 6.02 h time in bed (SD = 1.50; range = 1.45 to 10.1 h) each day. The participant received more than 8 h of sleep for only 2% ($N = 3$) of the study days; for 17% ($N = 27$) of the days, he received less than 4 h of sleep per day. No significant differences were identified between sleep patterns while at sea and in port (Wilcoxon rank sum test, $P > 0.50$). The CO's rest and sleep opportunities were distributed into
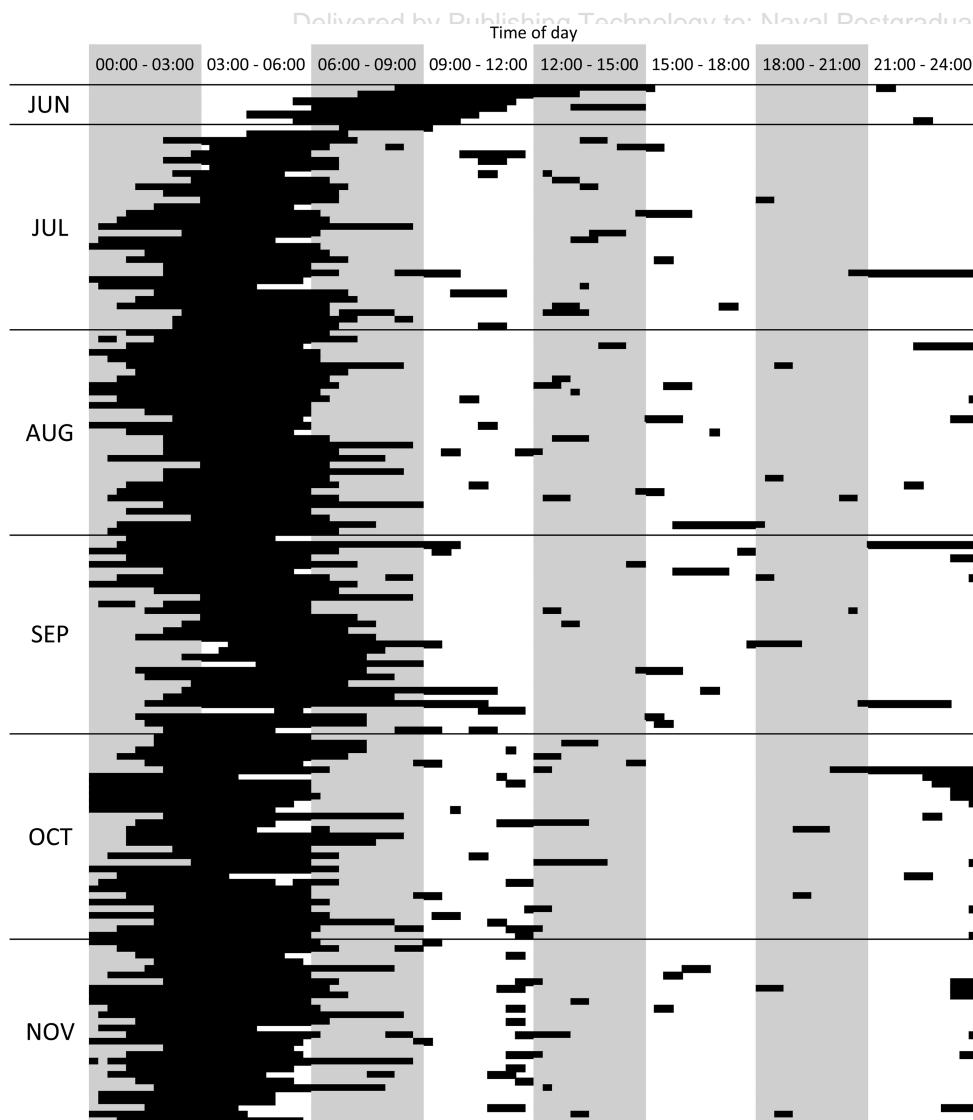

Fig. 1. Time-in-bed episodes in 15-min time bins represented by black bars.

157 major night sleep episodes with a mean duration of 4.76 h (SD = 1.24, minimum = 0.45, maximum = 8.05), and 117 naps with a mean duration of 0.582 h (SD = 0.348, minimum = 0.233, maximum = 2.03). On average, the CO split sleep into 1.75 sleep episodes per day. Specifically, napping was apparent on 94 d (60%): 71 d with one nap, and 23 d with two naps. Excluding the first few days of the deployment when the ship was transiting time zones, the major night rest episode occurred between 01:07 (SD = 1:18 h) and 06:35 (SD = 1:15 h) local time. **Fig. 1** shows the occurrence of time-in-bed (TIB) night episodes and naps. The horizontal axis is divided in 15-min interval bins representing time of day. On the vertical axis, each row represents a day. Black cells denote a 15-min period of TIB. Local time of day is assumed to be UTC+3 throughout the data collection period. For this reason there is a shift in TIB from the beginning of the deployment at LT = UTC−4 until 6 July, after which the ship remained at LT = +3. **Fig. 2** depicts the amount of daily sleep as distributed in the major sleep episodes and naps.

We assessed the association between napping and the duration of prior and subsequent night sleep. A nonparametric correlation analysis showed that the sleep received on the previous night is inversely correlated with the duration of all naps on the following day (Spearman's rho = −0.326, P = 0.001). However, the duration of all naps during a given day is positively correlated with the subsequent night's sleep (rho = 0.208, P = 0.044). These results suggest that napping was restorative (i.e., addressing an existing sleep debt) rather than prophylactic in nature. The participant was chronically sleep-deprived, and when he experienced a foreshortened night sleep, he experienced an increased incidence of naps on the subsequent day. However, these naps were not long enough to restore the participant to a fully-rested condition, evidenced by the fact that even though he napped during the day, he also tended to sleep more the subsequent night.

The FAST tool was used to predict effectiveness using the sleep data obtained with actigraphy. The average predicted effectiveness while awake was 80.8% (SD = 8.84%). For 15% of

waking time, the CO had a predicted effectiveness of less than 70% on the FAST scale, equating to a blood alcohol equivalent of 0.08%—legally drunk. The predicted effectiveness was below 65% approximately 10% of waking time and was less than 90% predicted effectiveness for 99% of the time. These results are shown in **Fig. 3**, the actual FAST graph.

During the 6-mo period of the study, the ship was involved in an operationally critical event occurring on 11 September 2012. The CO had received approximately 5.12 h (SD = 0.96) of sleep per night the week before the event, but received only 4.75 h (SD = 0.80) of sleep per night for the week following the event. The average predicted effectiveness for the week following the event was 80% (SD = 1.5), ranging from 57 to 89%. The daily fluctuation in predicted effectiveness is shown in **Fig. 4**. The gray area represents the daily range of predicted effectiveness. Vertical lines represent daily standard deviation of predicted effectiveness.

DISCUSSION

The CO was chronically sleep-deprived; he received on average 5.19 h of sleep per day during the 6-mo deployment. For the entire study period, he almost never slept more than 8 h per day, while for 20% of the observation period, he received less than 4 h of sleep per day. These results are consistent with earlier research showing that senior military leadership is chronically sleep-deprived.[7] Huffman and colleagues showed that senior U.S. Army officers (Lieutenant Colonels and above) in staff positions received on average 7.3 h of daily sleep. However, our results differ in that the CO was unable to recover from the sleep debt during weekends. In contrast to the staff leaders, who slept an average of 8.3 h on weekends, due to the 24/7 nature of naval operations, the CO did not have this opportunity.

Receiving 5 h of sleep per night for 6 mo raises two issues of concern. First, there is the issue of the effect of chronic sleep restriction on overall health. Epidemiological studies have shown that short sleep duration (defined as less than 5 to 7 h of sleep) is associated with a higher risk for diabetes[13] and increased mortality.[5]

A second area of concern is the effect that the chronic sleep restriction could have on the CO's performance. Although the CO does not stand watch, s/he is continuously accessible and should be able to maintain alertness levels necessary to operate effectively when needed. However, sleep deprivation impairs decision making involving the unexpected, innovation, revising plans, competing distractions,
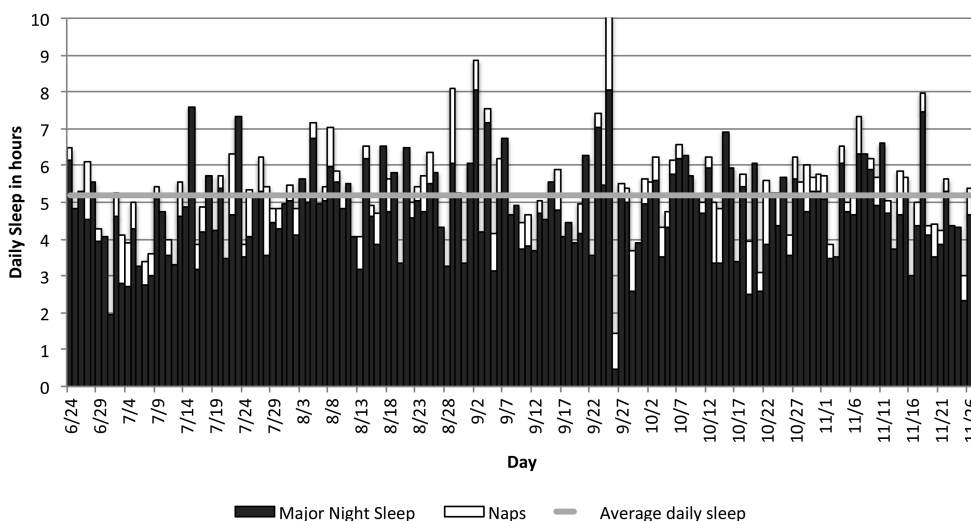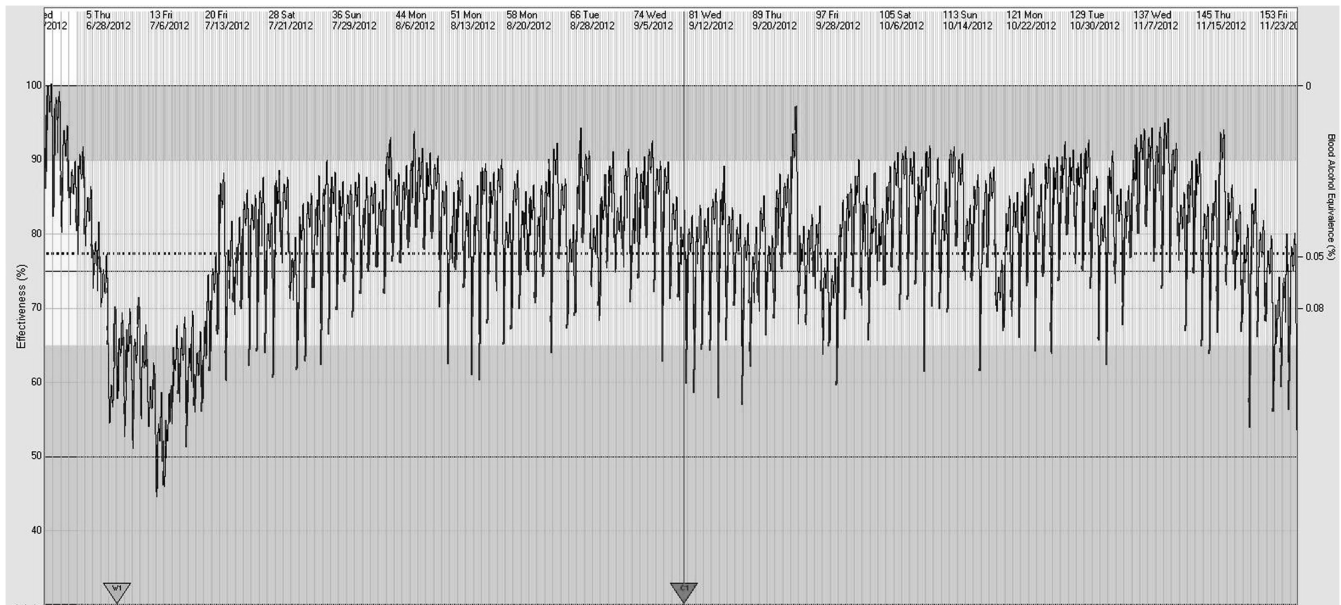

Fig. 2. Major sleep episodes and naps by day.

Fig. 3. FAST graph of 6 mo of actigraphically scored sleep.

and effective communication.[6] Restricting sleep to approximately 5 h for seven consecutive nights has been shown to have a significant negative effect on alertness in terms of sleepiness, fatigue, mood disturbance, stress, and psychomotor vigilance performance.[4] Another study showed that after restricting sleep to 5 and 7 h TIB for a 7-d period, psychomotor vigilance performance initially declines and then appears to stabilize at a lower-than-baseline level for the remainder of the sleep restriction period.[2] Even after a 3-d sleep recovery period, performance for the sleep-restricted participants did not fully recover. Sleep-deprived humans are prone to make more risky decisions,[14] demonstrate

impaired ability to integrate emotion and cognition to guide moral judgments,[9] and have more difficulty foreseeing potentially critical problems.[11] However, we do not know what happens in terms of performance deterioration if sleep restriction occurs for an extended period of time. It is notable that in our data, we identified seven 7- to 17-d periods of consecutive days of sleep restriction (i.e., days with sleep less than 7 h TIB).

Furthermore, the additional drop in daily sleep observed after a critical event had occurred raises the question of limitations of spare capacity. If the CO is already chronically sleep-deprived, when a critical event occurs, his/her ability to
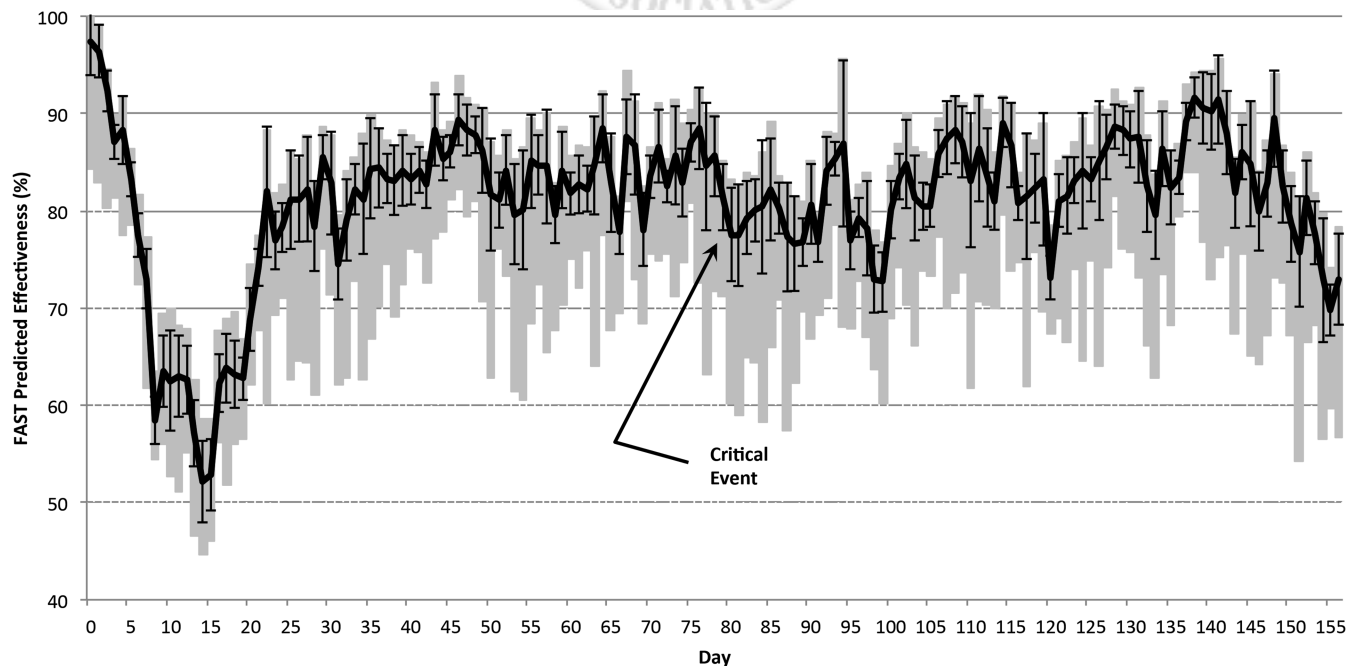

Fig. 4. Daily fluctuation in FAST predicted effectiveness levels.

react may be undermined by the chronic sleep restriction prior to the event. Moreover, the critical event itself often leads to further reductions in sleep, becoming a "vicious circle" of degraded performance, especially if the critical events are clustered in time. In such a case, operational commitments may not allow for adequate restoration of sleep reservoirs since operational environments have even less opportunities to get recovery sleep.

Future investigations of sleep at sea should be of longer duration, mirroring operational deployments, to increase their validity. This study has a number of caveats. In the absence of a sleep log, TIB episodes were identified based on the pattern of actigraphic activity, i.e., periods of low activity were identified as TIB. Therefore, the amounts of sleep and TIB reported may be overestimated and should be evaluated as a best-case scenario. Furthermore, actigraphic data were collected in a moving environment. Being omnidirectional accelerometers, actigraphs cannot distinguish when motion originates from the human or from the ship. During the 6-mo data collection period, it is reasonable to expect that on occasion, certain types of ship motion could interfere with actigraphic recordings, especially in rough sea states. However, there is, as yet, no analytical procedure to identify ship motion interference in wrist-worn actigraphic output. In conclusion, the results of this case study highlight Davenport's[3] sage observation: "Fatigue is so prevalent and such a part of our culture we scarcely see or recognize it. It's the big gray elephant we muscle out of the cockpit when we fly, step around when we enter the bridge, and push aside when we peer into the periscope."

ACKNOWLEDGMENTS

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