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Sleep Patterns of Naval Aviation Personnel Conducting Mine Hunting Operations

ABSTRACT

Detailed research conducted over the past forty years has conclusively determined that varying degrees of sleep loss, shifts in sleep cycle, increased stress and even changes in time zone with respect to daylight transition result in a myriad of physiological and psychological degradations. Fatigue affects human performance adversely, resulting in predictable changes, not only on the individual level, but also on the system as a whole.

This descriptive study investigates the amount of sleep and predicted performance of aviation personnel assigned to an operational squadron conducting mine hunting operations. Wrist activity monitors (actigraphs) were used as objective assessments of sleep quantity. Demographic variables and additional measures such as reported sleepiness, fatigue ratings, caffeine and alcohol use, were also collected. Significant differences in amount of sleep and predicted effectiveness of personnel by officer-enlisted status were identified.

INTRODUCTION & BACKGROUND

The aviation environment is challenging and unforgiving, requiring aircrew and maintenance personnel to maintain a high degree of vigilance. As Helmreich and Davies (2004) demonstrated, fatigue due to disrupted sleep patterns can result in diminished mental capacity, slowed reaction time, increased spatial disorientation, propensity for miscommunication, sensory misperception and slowed cognitive capacity. These symptoms have been cited as causative factors contributing to aviation mishaps, jeopardizing personnel, aircraft and mission success (Yacavone, 1993; Erwin, 2000). Fatigue affects human performance, resulting in predictable changes not only on the individual level but also on the system as a whole. An examination of the health hazards associated with fatigue and its detraction from aviator performance encompasses several domains within Human Systems Integration. Our goal is to better understand fatigue, error, safety, and organizational culture as it relates to aviator performance, specifically those in the MH-53E helicopter community.

The mission of the US Navy HM (Heavy-lift Airborne Mine Countermeasures) community consists of long periods of low-intensity workload accompanied by intermittent high intensity/high workload conditions requiring high levels of skill and coordination. The MH-53E helicopter is the largest and arguably the most complex helicopter in the US Navy. Crews typically fly four-hour missions towing a "sled" deployed from the rear of the aircraft. The sled is pulled along the water’s surface via a several thousand foot long cable that passes dangerously close to the tail rotor. Once the sled is deployed, the aircrew must remain vigilant throughout a long and detailed search pattern. This sustained vigilance results in high levels of fatigue-related errors, particularly when coordinating launch and recovery operations. Captain Neubauer, from the Navy Safety Center, recently noted that aircrew fatigue has proven to be a critical factor in several recent accidents experienced by the aviation community.

Research demonstrates that individuals are not able to accurately predict their own performance impairment during a week of alternating shift schedules (Dorrian et al., 2003). To compensate for changing schedules, military requirements mandate eight hours of uninterrupted rest prior to pilot flight operations, with a maximum twelve flight-hour duty days, as well as weekly, monthly and yearly flight hour maximums. Chronic sleep restriction over an extended period results in a condition known as sleep debt (Hardaway & Gregory, 2002). Individual performance does not return to normal levels even after three days of rest (Belenky et al, 2003; Lenne, Triggs, & Redman, 1998).

Porcu, Bellatreccia, Ferrara, and Casagrande (1998) found that shift workers, who are often involved in night-time operations and irregular work schedules, frequently complain of nocturnal sleepiness. The work schedules of military pilots mirror those of shift workers in that their schedules operate 24 hours a day and are subject to wide fluctuation due to operational requirements. The added demands placed on military pilots due to multiple time zone shifts and irregular scheduling undoubtedly result in decreased performance and increased sleep debt. Additionally, deployments for military pilots may result in an increase in preparation duties during both arrival and departure for home; each deployment requires additional tasking that may further add to pilot stress and fatigue. The ability to objectively assess fatigue levels both at home and when deployed is essential to avoid catastrophic systems failure due to unrecognized fatigue (Hardaway & Gregory, 2002).

There have been great strides forward in flight scheduling proficiency, but it is still difficult to account for the anomalies that often arise due to the changing nature of flight operations. Sleep debt, jet lag, stress-induced fatigue, short notice emergency flights for medical evacuation and search and rescue are all situations that undermine even the best scheduling algorithms. Delays due to maintenance failure or operational issues further complicate the situation by pushing individual crew-day limits. During a normal briefing time, the schedule may be optimized for an aviators' performance only to have the schedule slide into an unsafe flight window as a result of unforeseen delays.

Research has demonstrated the general inability of humans to assess their own fatigue level (Dorrian et al., 2003). Often, aviators will opt to accept missions with a higher purpose, such as medical evacuation flights or operationally significant missions. The level of motivation and arousal inherent to the mission can further cloud their judgment when making a personal fatigue assessment. Technology, though, in the form of wrist activity monitors (actigraphs) may assist researchers and the aviation community in making objective assessments of sleep quantity and allow for predicted performance using the Fatigue Avoidance Scheduling Tool (FAST).

Actigraphy has been shown to adequately discriminate between states of wakefulness and sleep (Jean-Louis, Kripke, Mason, Elliott, & Youngstedt, 2001). It is also a valid and reliable estimate of sleep when compared to polysomnographic measures of sleep in various groups of research participants (r=.93 to .99) (Ancoli-Israel, Clopton, Klauber, Fell & Mason, 1997; Brown, Smolensky, D'Alonzo, & Redman, 1990). Output from wrist activity monitors may be utilized in the FAST software program as a means to predict performance. Much of the research incorporating the use of the FAST software program has focused on the corroboration of subjective assessments. Typically, researchers study the extent of sleepiness or fatigue experienced by subjects using the FAST to provide a quantifiable measurement to predict performance under varying states of fatigue.

FAST output is a graph of predicted task performance, based on sleep and naps obtained by the participant. FAST output also may include a blood alcohol content equivalence on the right side of the output; this scale is designed to equate the level of individual sleep deprivation with the equivalent performance typically experienced by a person following alcohol ingestion. FAST displays individual predicted effectiveness in terms of green, yellow and red bands. The green band represents acceptable predicted effectiveness associated with a blood alcohol equivalency range from 0.00 to 0.06 and indicates little or no decrement in predicted effectiveness. When individuals receive eight hours of sleep per night, their waking predicted effectiveness stays in this zone. The yellow or cautionary band indicates some decrement in predicted effectiveness and is associated with a blood alcohol equivalency range between 0.06 and 0.12. The red or danger band indicates substantial loss of predicted effectiveness due to fatigue and is associated with impairment equivalency of blood alcohol greater than 0.12. FAST output of 78% effectiveness is the minimum accepted level used by the USAF when calculating work/rest regimens on their long-duration missions, e.g., B-2 missions of 40 hours in length; during these missions, the pilot in command must have a predicted effectiveness greater than 78%. During all mission critical phases of the flight (e.g., take-off, air-refueling, ordnance delivery, and landing), the predicted effectiveness level must be in the green band.

METHODS

This cross sectional study used actigraphy and survey data to describe the sleep differences between enlisted and officer participants and their associated predicted performance using the FAST. Command staff of an operational MH-53 helicopter squadron provided a pool of potential study participants. A screening survey was administered to collect the age, gender, sleep history, caffeine intake, and the ability to complete the approximately two-week study without substantial interruption of each potential participant. Participants in this study were 26 naval aviators and air crewmen assigned to a Helicopter Squadron located in Norfolk, VA. Participants were Aviation Warfare qualified pilots and aircrew assigned to the squadron and fully qualified for mine hunting duties. All aircrew and pilots received rigorous medical screening examination prior to and throughout their tenure on aviation duty as required by

US Navy standards; since all participants were cleared for flight duty, it was assumed that this group was healthy.

Participants in the study received a battery of tests including a demographic survey, the Epworth Sleepiness Scale, and a screening test for sleep apnea. Additionally, they received wrist activity monitors (WAMs)—along with instructions for their use and care. One WAM malfunctioned early in the study, reducing the sample from 26 to 25. Data collection time ranged from 10 to 21 days. Activity and sleep logs were used during the data collection period to capture data regarding naps, sleep/wake times, participant affective mood, and exercise periods. At the end of the data collection period, the data were downloaded from each actigraph and analyzed using commercial sleep and statistical analysis software.

Rest and activity levels were measured using a small wrist worn ambulatory activity monitor (MotionLogger Actigraph, Ambulatory Monitoring Inc, Ardsley, NY). Activity level was measured in 1-minute intervals over the period of the study and stored in memory for subsequent computer retrieval and analysis. The activity device detects movements through a piezoelectric accelerometer and is capable of detecting accelerations greater than 0.01g (up to 10 counts per second). The accelerometer generates a voltage during each movement, which is amplified and band pass filtered. The resulting signal is compared to a reference signal to determine if it exceeds a threshold for quantification and storage. Actigraphs in the current study are set to record in proportional integrating mode, as this setting has been shown to be the most sensitive in previous research (Jean-Louis, Kripke, Mason, Elliott, & Youngstedt, 2001).

Additionally, participants were asked to record their activity during the duration of the study using a paper and pencil activity log. The activity log consists of a chart broken down into quarter hour intervals with space for participants to record the type of activity performed during each period. Participants were instructed to record all activities performed throughout the day in 30-minute increments. They were also asked to note in the log the times at which they went to sleep, woke up, or removed the actigraph.

The demographic survey utilized included the Epworth Sleepiness Scale, which determined the participant's usual level of daytime alertness or chronic sleepiness. Information was gathered on hours of sleep and sleep patterns immediately before flying. Usual patterns of sleep and work were also reported. Gender, race, rank, age, operational experience, general health status including caffeine intake, number and age of family members residing with participant, and physical fitness scores were used as covariates. Affective measures such as feelings of stress, alertness, irritability, and mood state were also collected through self-report responses on a Likert-type scale. Sea state, wind and other pertinent meteorological data were collected and included in the analysis to rule out possible confounding due to differences in weather during testing.

Participants were instructed to maintain a regular sleep–wake-cycle (bed- and wake-times within ± 30 min of self-selected target time), which was verified by wrist activity monitors and sleep logs. The sleep–wake schedules were calculated by centering the 8-hour sleep episodes at the midpoint of each individual's habitual sleep episode as assessed by actigraphy and sleep logs. When participants returned the actigraph, the data were downloaded into a computer for analysis with ActME, and FAST software.

RESULTS

We were able to collect data on the sleep patterns and the predicted performance of enlisted and officer personnel in the squadron and the results of this work are presented here. Table 1 displays the demographics and other related variables for the study participants.

Table 1. Summary of Demographic and Other Variables

		Frequency	Percent	Valid Percent
Gender				
	male	20	76.9	90.9
	female	2	7.7	9.1
	Total	22	84.6	100
Marital Status				
	single never married	6	23.1	24
	married	15	57.7	60
	divorced	4	15.4	16
	Total	25	96.2	100
Education				
	high school graduate	4	15.4	16
	attended or attending college	6	23.1	24
	graduated college	12	46.2	48
	graduate school or more	3	11.5	12
	Total	25	96.2	100
Race/Ethnicity				
	Caucasian/European American	24	92.3	96
	Hispanic/Hispanic American	1	3.8	4
	Total	25	96.2	100
NEC/Designator				
	1310	8	30.8	34.8
	1315	7	26.9	30.4
	7886	6	23.1	26.1
	8226	1	3.8	4.3
	8236	1	3.8	4.3
	Total	23	88.5	100
Experience				
	less than 6 months	1	3.8	4
	1-3 years	8	30.8	32
	3-5 years	4	15.4	16
	5-10 years	2	7.7	8
	more than 10 years	10	38.5	40
	Total	25	96.2	100
Smoker				
	moderate smoker	2	7.7	8
	light smoker	1	3.8	4
	social smoker	1	3.8	4
	non smoker	21	80.8	84
	Total	25	96.2	100
Alcohol				
	moderate drinker	1	3.8	4
	light drinker	8	30.8	32
	social drinker	9	34.6	36
	non drinker	7	26.9	28
	Total	25	96.2	100

Sleep patterns of officer and enlisted participants were examined. The average amount of nightly sleep in minutes for each participant was used for the statistical analysis. On average, participants in the study received approximately 7hrs, 28min (*s.d.* = 1hr, 39min) of sleep per night. A histogram of the study sample, using 20-minute bins from four hours to seven hours of sleep per night showed a relatively normal distribution of minutes slept among total study population. Sleep quantity was assessed between enlisted and officers in the study. T-test results, $t(243) = -3.208$, $p = 0.002$, indicated that the officers in the study got significantly more sleep (on average, approximately 42 minutes per night) than did the enlisted personnel in the study.

Since there were differences in the sleep received by officers and enlisted study participants, daily sleep averages were stratified by day of the week. Mann-Whitney U statistic was used to determine differences in daily average sleep by day of the week and by officer-enlisted status. The results of Mann-Whitney U showed that on Monday and Wednesday there were significant differences in the amount of sleep between officers and enlisted personnel, with enlisted personnel getting significantly less sleep than their officer counterparts. For the study period, officers received an average of 45 minutes more sleep than enlisted members on Mondays; on Wednesday, officers received an average of 1 hr., 42 min. more sleep than the enlisted study participants.

Study participants were sorted by officer-enlisted status. A correlation matrix across all of the demographic variables, categorized by officer-enlisted status, is shown in Table 2.

Table 2. Correlation Matrix of Demographic and Sleep as Dependent Variables by Officer-Enlisted Status

Correlations Between Demographic and Sleep as Dependent Variable

Question — Enlisted (n = 10)

Question		1	2	3	4	5	6	7	8	9	10	11	12	13
Activity Mean	Corr		-0.60	-0.07	-0.25	-0.85	0.61	-0.32	0.18	-0.14	0.00	-0.33	-0.76	-0.52
	Sig.		0.00	0.87	0.55	0.01	0.15	0.44	0.68	0.74	1.00	0.42	0.03	0.19
Sleep Minutes	Corr			-0.26	-0.25	0.55	-0.33	-0.15	-0.79	-0.33	-0.22	0.58	0.59	-0.20
	Sig.			0.53	0.55	0.16	0.46	0.72	0.02	0.42	0.60	0.13	0.12	0.64
Age	Corr				0.58	0.20	-0.18	0.91	0.31	0.52	0.00	0.21	-0.03	0.48
	Sig.				0.13	0.64	0.70	0.00	0.45	0.18	1.00	0.62	0.94	0.23
Marital Status	Corr					0.45	0.11	0.53	0.44	0.41	0.08	-0.26	-0.22	0.60
	Sig.					0.26	0.81	0.18	0.28	0.31	0.84	0.54	0.61	0.12
Education	Corr						-0.51	0.29	-0.27	0.18	-0.07	0.05	0.68	0.39
	Sig.						0.24	0.49	0.52	0.67	0.88	0.90	0.06	0.35
NEC	Corr							-0.05	0.07	0.45	-0.57	-0.55	-0.52	0.19
	Sig.							0.91	0.88	0.31	0.18	0.20	0.24	0.68
Experience	Corr								0.30	0.73	-0.20	0.22	0.22	0.75
	Sig.								0.46	0.04	0.64	0.59	0.61	0.03
# Children in household?	Corr									0.25	0.44	-0.29	-0.42	0.40
	Sig.									0.55	0.28	0.49	0.30	0.33
Total Caffine	Corr										-0.61	-0.38	0.26	0.80
	Sig.										0.11	0.35	0.53	0.02
Epworth Risk	Corr											0.21	-0.32	-0.22
	Sig.											0.61	0.44	0.61
Apnea Risk	Corr												0.19	-0.15
	Sig.												0.65	0.73
Smoker	Corr													0.29
	Sig.													0.48
Drinker	Corr													
	Sig.													

Officer (n = 15)

Question		1	2	3	4	5	6	7	8	9	10	11	12	13
Activity Mean	Corr		-0.51	-0.17	-0.37	-0.03	-0.07	0.24	-0.05	-0.19	-0.10	-0.48	0.22	-0.29
	Sig.		0.00	0.62	0.24	0.93	0.82	0.45	0.89	0.55	0.76	0.11	0.50	0.37
Sleep Minutes	Corr			0.06	0.20	0.17	0.15	0.18	0.29	0.19	-0.40	-0.14	0.22	0.71
	Sig.			0.86	0.54	0.60	0.65	0.59	0.37	0.55	0.19	0.66	0.49	0.01
Age	Corr				0.62	0.55	-0.46	0.81	0.23	0.15	-0.23	0.34	-0.26	0.08
	Sig.				0.03	0.06	0.13	0.00	0.46	0.63	0.47	0.28	0.41	0.80
Marital Status	Corr					0.21	-0.11	0.23	0.15	0.35	-0.29	-0.05	-0.37	0.12
	Sig.					0.49	0.72	0.45	0.63	0.25	0.33	0.88	0.21	0.70
Education	Corr						-0.51	0.28	-0.48	-0.12	-0.20	0.13	-0.53	0.10
	Sig.						0.08	0.36	0.10	0.69	0.52	0.68	0.06	0.74
Designator	Corr							-0.26	0.27	-0.21	-0.10	-0.19	0.27	0.18
	Sig.							0.40	0.37	0.50	0.74	0.53	0.38	0.57
Experience	Corr								0.27	0.07	-0.51	0.10	0.28	0.12
	Sig.								0.38	0.82	0.07	0.75	0.36	0.71
# Children in household	Corr									0.30	0.13	0.08	0.25	0.12
	Sig.									0.33	0.66	0.79	0.40	0.71
Total Caffine	Corr										-0.04	0.17	-0.08	-0.32
	Sig.										0.90	0.58	0.80	0.29
Epworth Risk	Corr											0.55	-0.19	-0.18
	Sig.											0.05	0.52	0.56
Apnea Risk	Corr												-0.04	-0.08
	Sig.												0.90	0.80
Smoker	Corr													0.33
	Sig.													0.27
Drinker	Corr													
	Sig.													

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Significance is two-tailed

Spearman correlations were computed to determine if relationships existed among demographic and sleep outcome measures. Statistically significant relationships are presented in Table 3.

Table 3. Significant Spearman Correlations Between Variables

Grade	Pair-wise relation			Rho	Sig
Officer	Activity mean	vs	Sleep minutes	-0.51	0.00
	Sleep minutes	vs	Alcohol	0.71	0.01
	Designator	vs	Smoking	-0.58	0.06
	Epworth	vs	Apnea	0.55	0.05
Enlisted	Activity mean	vs	Sleep minutes	-0.60	0.00
	Activity mean	vs	Education	-0.85	0.01
	Activity mean	vs	Smoking	-0.76	0.03
	Sleep minutes	vs	Number of children	-0.79	0.02
	Experience	vs	Caffine	0.73	0.04
	Experience	vs	Alcohol	0.75	0.03
	Caffine	vs	Alcohol	0.80	0.02

Mean activity, or the average number of movements exceeding threshold per 60 second epoch during the data collection period, is negatively correlated with sleep minutes for both the Officer *P*(.00) *Rho*(-0.51) and Enlisted *P*(.00) *Rho*(-0.60) sample. Within the enlisted sample, mean activity was found to be significantly and negatively correlated to smoking *P*(.03) *Rho*(-0.76) indicating that those who smoke are less active. Additionally, a significant correlation within the enlisted sample between mean activity and education *P*(.01) *Rho*(-0.85) suggests that the more educated the enlisted person is, the less activity they engage in during waking hours. Further, a significant negative relationship was observed between the number of sleep minutes and the number of children at home *P*(.02) *Rho*(-.76) indicating that the amount of sleep decreases as the number of children increases.

Significant and positively correlations were observed among the enlisted participants. There was a significant relationship between participant experience – in terms of years within job classification - and use of caffeinated products (including soft drinks, coffee, chocolate and dietary supplements) *P*(0.04) *Rho* (0.73). Similarly, experience was also significantly and positively correlated with alcohol use *P*(0.02) *Rho* (0.75). Lastly, the use of caffeine was positively and significantly correlated to alcohol use *P*(0.02) *Rho*(0.80). All these results confirm that as the enlisted participants' experience on the job increases, so does also their use of caffeine and alcohol.

Although fewer in number, significant findings among the officer participants include positive and significant correlation between the number of minutes slept and alcohol use *P*(0.01) *Rho*(0.71) as well as an expected but significant correlation between sleep apnea score and score of the Epworth Sleepiness Scale *P*(0.05) *Rho*(0.55). This finding suggests that participants using alcohol among the officer study population received more sleep. The moderate positive correlation between the officer's score on the sleep apnea screening score and the Epworth Sleepiness Scale indicates that those participants scoring higher for sleep apnea risk indicate being more sleepy during the course of the day.

We looked at nightly sleep averages to identify squadron personnel who received the most, the least, and the closest to average nightly sleep amounts. We used the FAST software program to calculate predicted effectiveness for these participants. Tables of predicted effectiveness were generated by day, officer-enlisted status and grand mean effectiveness and are presented in Table 4. Over all participants, the average predicted effectiveness during working hours was 87.9%. The difference between groups was surprisingly large with the mean of 80.34% for the enlisted participants while officers had an average of 91% predicted effectiveness. For the enlisted participants, their average daily mean decreases significantly over the course of the week. Their average predicted effectiveness on Thursday was 70.04% and Friday was 73.79%. The lowest daily average predicted effectiveness for officers occurred on Friday with 85.93% level.

Table 4. Mean Predicted Effectiveness from FAST

		Predicted Effectiveness					
Grade	**Day**	**Min**	**Max**	**Daily Mean**	**Std. Dev**	**Grade Mean**	**Grand Mean**
Enlisted	Mon	73.01	93.14	87.48	6.23	80.34	87.90
	Tue	56.20	95.58	85.03	11.01		
	Wed	53.56	95.73	83.49	12.76		
	Thu	56.22	88.96	70.04	11.42		
	Fri	57.36	88.10	73.79	8.69		
Officer	Mon	83.51	96.81	91.74	3.57	91.00	
	Tue	78.50	97.93	90.57	5.60		
	Wed	77.10	98.16	92.11	4.92		
	Thu	84.95	98.82	93.78	3.86		
	Fri	72.12	100.65	85.83	11.35		

These results support the previous observations regarding the difference in average sleep between officers and enlisted on Wednesdays, as there is a marked decrement in enlisted predicted efficiency observed on the following Thursday (x=70.04, s.d.=11.0).

FAST output analysis showed that the squadron enlisted person with the highest amount of average nightly sleep received an average of approximately 8 hours 5 minutes per night throughout the course of the data collection period. This participant's mean waking effectiveness (as calculated by the FAST software) is 88.19%. In general, this individual is operating along the border of "yellow" and "green" for most of the study period. The squadron officer with the highest average nightly sleep received an average of approximately 9 hours, 42 minutes per night throughout the course of the data collection period. This participant's mean waking effectiveness (as calculated by the FAST software) is 92.58%, In general, this individual was operating "in the green" for most of the data collection period.

The median squadron member slept an average of approximately 7 hours, 25 minutes nightly. Based on FAST output, this participant's mean waking effectiveness was 87.80%. For most of study period, this participant was operating in "yellow" band, with some daily circadian peaks exceeding the 90% level. Using the blood alcohol equivalent scale, this individual's mean waking effectiveness was comparable to a blood alcohol content of slightly under 0.05%.

The Officer with the least amount of mean sleep per night was getting approximately 6 hrs, 14 min sleep per night. A scalloping pattern seen in his data illustrate how he was getting more sleep on weekends. Based on the FAST output, this participant's mean waking effectiveness was 84.01%. For most of study period, this participant was also operating in the "yellow" band, with some daily peaks exceeding the 90% level. Due to this individual's chronic sleep debt, however, using the blood alcohol equivalent scale, this individual's mean waking effectiveness was comparable to a blood alcohol content of slightly under 0.08%. While not over the legal BAC limit, this fatigue level indicates a level of impairment unacceptable in a high reliability organization. The FAST output for the enlisted participant receiving the least sleep indicated a mean effectiveness, excluding the first three days of the study, of only 75.01%. The blood alcohol equivalence for this study participant was just slightly less than 0.10%. The FAST results show that a number of study participants operate in a state of chronic sleep deficiency. It would be potentially dangerous for such individuals to participate in any high reliability operations, including maintenance of aircraft or participating in flight operations.

The FAST analyses showed a high level of degradation, as indicated by reduced predicted effectiveness, experienced by study participants. This degradation was most evident in the enlisted personnel in the study. Daily mean predicted effectiveness of the enlisted participants ranged from 70.04% to 87.48%. The largest sleep differential was observed on Wednesday nights, leading to the 13.45% decrement in predicted effectiveness of enlisted personnel on Thursdays.

DISCUSSION

This study reports the findings of a 10 to 21 day cross sectional study undertaken to assess the amount of sleep attained and the predicted performance of aviation crew and pilots of a mine hunting helicopter squadron stationed in Norfolk, Virginia. Actigraphy data showed that during the study period, enlisted personnel received significantly less nightly sleep than the officers of the same unit. During the study period, the participants, on average, received less sleep than recommended for their age group. Officers received on average 42 minutes more sleep per night across the entire study period. On Mondays and Wednesdays the enlisted population received significantly less sleep than the officers. This sleep differential manifest as a decrement in predicted effectiveness on the Thursdays.

The ability to correlate sleep with data such as officer-enlisted status, years of service, gender, and designator among such a small population was useful. Examination of the results reveals a number of expected as well as unexpected and surprising relationships. Mean activity was negatively correlated with sleep minutes for both groups. Additionally, results suggest that the amount of sleep decreases as the number of children increases. Although not surprising to anyone who comes from a large family, the implications for aviation safety may be important.

Within the enlisted sample, results indicated that those who smoke are less active. More surprising, however, is the finding that suggests that the more educated the enlisted person is, the less activity they engage in during waking hours.

A sleep hygiene education program could benefit the entire squadron. Knowing the signs and dangers of sleep deprivation, as well as using fatigue countermeasures, may assist in both increased performance and increased safety of operations.

This study utilized FAST output as a proxy for predicted task performance. Unfortunately, maintenance requirements during the study precluded the collection of actual operational performance data. MH-53E pilots on minesweeping missions must fly straight tracks back and forth, often for miles at a time, so that every inch of a suspected minefield may be covered. Wind and the motions of the sled in the waves below, however, often buffet the helicopter. Towing a sled on a straight path in these conditions requires constant vigilance and attention. When one track is completed, the helicopter executes a turn to proceed down the next. Nearly 1,000 feet of flying and floating machinery has to be kept as straight as possible. A properly executed turn is like a pivot on a point, with the helicopter slowly slewing around like the hand on a clock. Deviations from the ideal track are measured by global positioning system navigation equipment onboard the helicopter. Inability to execute track navigation with precision results not only in errors of mine detection and blank areas in the search grid known as “holidays”, but also endangers the aircraft and crew. Hence, the dependent performance measure proposed for future studies is deviation from the two dimensional search track during simulated mine sweeping operations, calculated as the root mean squared (RMS) distance from the planned flight path. This dataset would be in the form of GPS data captured as a standard performance metric by the squadron’s tactical analysis branch. Unfortunately, due to mechanical issues in the squadron aircraft at the time of data collection, these data were not available to be included in the study.

CONCLUSIONS

The cumulative effects of fatigue on performance are well established. Significant differences were observed between the average nightly sleep of officer and enlisted personnel. This analysis showed that the predicted effectiveness (using the Fatigue Avoidance Scheduling Tool) of enlisted members was clearly degraded. Further study is needed to determine if this reduction in predicted effectiveness manifests in operational performance. If validated, this finding demonstrates an important issue to the safety and operational success of aviation mine hunting capabilities.

This study sample is neither by intent nor design representative of the entire population of aviators and aircrew of the U.S. Navy. Broad generalizations concerning the entire aviation warfare community should not be made based on the results of this study. However, the fact that a large portion of study participants were functioning under impairment due to a state of chronic sleep deprivation should not be dismissed out of hand.

Although not specifically addressed in this research, it is important to note some possible effects due to chronic sleep deprivation. Other studies have shown that sleep-deprived participants select less-demanding problems and significantly less-demanding tasks. Increased sleepiness, fatigue, and reaction time were associated with the selection of less difficult tasks. Sleep-deprived participants were often unaware of their condition, and did not perceive a reduction in effort (Engle-Friedman et al., 2003). These studies suggest that sleep loss may result in low-effort behavior that runs counter to the requirements of successful military operations. Within the military—and during combat in particular—sleep-deprived people are faced with a myriad of decisions. The selection of the least demanding option in complex situations may negatively affect safety, reliability, and the effective integration of multiple facets of tasks (Hockey et al. 1998). Ultimately, this tendency toward less demanding options may result in serious, perhaps even life-threatening, consequences.

The results of this study are consistent with the assertion that there is an urgent need to improve how we address sleep and fatigue of our military personnel. Sleep deprivation and fatigue, particularly in the enlisted personnel, was a problem for the participants in this study and is a major cause for concern. We hope that these findings will serve as a catalyst for others to examine these issues further.

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