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and Operational Efficiency**

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SUMMARY

Naval Surface Fleet and Marine Corps members serving in the Persian Gulf were monitored for at least two consecutive 24-hour periods using Sleep Logs to obtain information on work-rest cycles, fatigue and sleep problems in this population. The overall results show that the personnel evaluated were able to get an adequate duration of not overly fragmented sleep. However, there is evidence of lower quality and more fragmented sleep in some ratings. Therefore, a larger, longer, and more detailed survey is required to better assess the adequacy of sleep among shipboard personnel in the Gulf. The advantages of the paper-and-pencil sleep log technique used in this study are discussed as a way of developing the database needed for effective application of sleep logistics.



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INTRODUCTION

During a low intensity, long-term mission, regardless of whether it is civilian or military, effective completion of a task depends on successful logistical support. For military missions to be successful, logistics for water, food, communications, oil, and ammunition, to mention a few, are critical. The relatively new discipline of sleep logistics (Military Sleep Management), however, appears to be often assigned a low priority.

Sleep logistics are based on scientific knowledge of how sleep loss influences human performance, and provides techniques to assure that every member of a group receives sufficient sleep at appropriate times so that serious sleep loss does not interfere with mission completion. First mentioned by Halord Williams (1964), sleep logistics require careful measurement of the amount and pattern of sleep each group member can obtain during a given mission scenario. There are many tools for measuring amounts and patterns of sleep. Portable brain wave recording systems, for an example, have frequently been used to obtain objective measures of sleep (e.g., Bandaret, Stokes, Francesconi, Kowal, and Naitoh, 1981). However, sleep recorders are cumbersome and expensive, and not suitable for monitoring large numbers of subjects or for use in many field situations. A wrist watch size device called an actigraph that records movements of the wrist, arm, and other parts of the body has also been useful (Webster, Kripke, Messing, Mullaney, and Wyborney, 1982). It can be used easily in the field to separate periods of rest/sleep (minimal activities, presumably asleep) from physically active periods. However, such actigraphic units are relatively expensive.

The most economical and preferred method to study sleep, especially in a large group of individuals, has been the "sleep log (diary)," first created and used by Hartman and Cantrell (1967). In addition to quantifying sleep, the sleep measures produced from sleep logs have been found useful in predicting task performance and mood (Beare, Naitoh, Bjesner, and Bond, 1981; Bricton, McHugh, and Naitoh, 1974; Hall, Townsend, and Knippa, 1979; Naitoh, Beare, Bjesner, Bondi, and Englund, 1983). Thus, sleep logs appear to contribute beyond a description of sleep patterns by providing a clue for predicting individual and group effectiveness in mission completion. It has been suggested by Harris and O'Hanlon (1972) that sleep log data can be used to estimate manpower resources for developing optimal sleep/wake schedules (or maximal organizational efficiency) in a sustained military operation.

This paper presents the results of measuring sleep patterns in a small group of Naval/Marine Corps personnel during an at-sea operation in the Persian Gulf, using sleep logs.

METHODS

Thirty-seven Navy and Marine Corps personnel who had served in the Persian Gulf area for more than three months completed two 24-hour sleep log sheets over two consecutive days. Two additional crew members completed sleep logs during four consecutive days. A total of 39 respondents completed 82 sleep log cards.

The sleep log used is that shown in Figure 1. In addition to sleep pattern and duration, subjects were asked to complete a Stanford Sleepiness Scale and eight additional questions regarding sleep. The Stanford Sleepiness Scale (Hoddes, Zarcone, Smythe, Phillips, and Dement, 1973) is printed on the back side of each sleep log sheet. It is a self rating scale which measures sleepiness by having subjects choose one of the seven statements shown at the lower half of Figure 1.

Sleep logs asked eight questions (see the upper half of Figure 1):

- (1) How much trouble did you have going to sleep last night?
- (2) How long did it take to fall asleep?
- (3) How many times do you recall waking up last night?
- (4) How rested do you feel?
- (5) Do you feel that you could have used more sleep?
- (6) How is your mood today?
- (7) Number of dreams you recall?
- (8) How many hours did you work in the last 24 hours?

The sleep measures derived from the sleep logs were: (1) Estimated time to fall asleep (in minutes), (2) Need for more sleep, (3) How well rested after awakening, (4) Stanford Sleepiness Scale, (5) Hours of work past 24 hours, (6) Estimated total sleep duration (in hours), (7) Sleep episode duration (or uninterrupted sleep; in hours), and (8) Intersleep interval (in hours).

NAME	AGE	SEX	OCCUPATION
1. On the clock below draw a horizontal line through the squares corresponding to the half hour periods during which you were asleep during the last 24 hours. Put an X in the squares corresponding to any half hour period during which you awoke (keeping up for 15 to 30 minutes).			
DAYTIME			
NIGHTTIME			
2. How much trouble did you have going to sleep last night?		Time to fall asleep _____ MINUTES	
<input type="checkbox"/> NONE <input type="checkbox"/> SLIGHT <input type="checkbox"/> MODERATE <input type="checkbox"/> CONSIDERABLE			
4. How rested do you feel?		5. Do you feel that you could have slept more sleep?	
<input type="checkbox"/> WELL RESTED <input type="checkbox"/> MODERATELY RESTED <input type="checkbox"/> SLIGHTLY RESTED <input type="checkbox"/> NOT AT ALL		<input type="checkbox"/> YES <input type="checkbox"/> NO	
6. Today's mood		7. Hours of work in last 24 hours?	
<input type="checkbox"/> VERY POOR <input type="checkbox"/> POOR <input type="checkbox"/> AVERAGE <input type="checkbox"/> GOOD		Number of dreams recalled _____	

SLEEP LOG (1967-02-08) (REV. 6-72)

STANFORD (11-73)

Circle one of the seven statements below which best describes your present feelings. How you feel right now.

- (1) Feeling active and vital; alert; wide awake.
- (2) Functioning at a high level, but not at peak; able to concentrate.
- (3) Relaxed; awake, responsive, but not at full alertness.
- (4) A little foggy; let down; out of peak.
- (5) Foggy; slowed down; hard going to keep interest in remaining awake.
- (6) Sleepy; weary; prefer to be lying down; fighting sleep.
- (7) Almost as nervous; sleep onset time; having struggle to remain awake.

Figure 1 Sleep logs card modified from Hartman and Cantrell (1967). The upper half of Figure 1 shows Hartman-Cantrell sleep logs which is printed on the front side of the sleep logs card. The lower half shows Stanford Sleepiness Scale (Hoddes et al. (1973)) and it is printed on the backside of the card.

Sleep logs were sorted according to the rating of respondents to determine whether sleep patterns of a particular job rating differed from those of others. Only those ratings with more than three respondents were used in the analysis rating. Four Navy job ratings satisfied this criterion: Boiler Technician (BT), Electrician's Mate (EM), Machinists's Mate (MM), and Signalman (SM). Five Marine respondents (junior enlisted or NCO) in this study were also grouped for additional analysis. Statistical tests were not used, because there were too few data points to warrant statistical evaluation of differences between one rating and another. Therefore, only trends are reported.

RESULTS

A graphic plot of the sleep/wake pattern of all subjects in this study is shown in Figure 2. Each sleep episode is represented by connecting the starting and ending point with a solid horizontal line. The X-axis shows the time of day, starting arbitrarily at 0900 and ending at 0900 of the next morning. The Y-axis shows the identification (ID) number of each sleep log sheet, starting from zero. The sleep/wake pattern of the sleep log ID# 0 is placed at the top of the plot, the sleep/wake pattern of sleep log #1 on the second line, etc.

A more easily understood way of presenting such data is to plot "sleep fraction," the percent of crew members in bed asleep at any given time of day. This technique was developed by Lewis and Masterson (1957). The sleep fraction plot for this study is shown in Figure 3. The X-axis shows Time of Day, starting at 0900. The Y-axis shows the percent of individuals in bed, most probably asleep.

The duration of sleep periods reported in our survey ranged from 2 - 13 hours (Figure 4). The average for all respondents was 6.55 hours. Intersleep interval, the time from the end of one sleep period to the start of the next, ranged from 1-24 hours (Figure 5). The average was 13.9 hours with a large standard deviation.

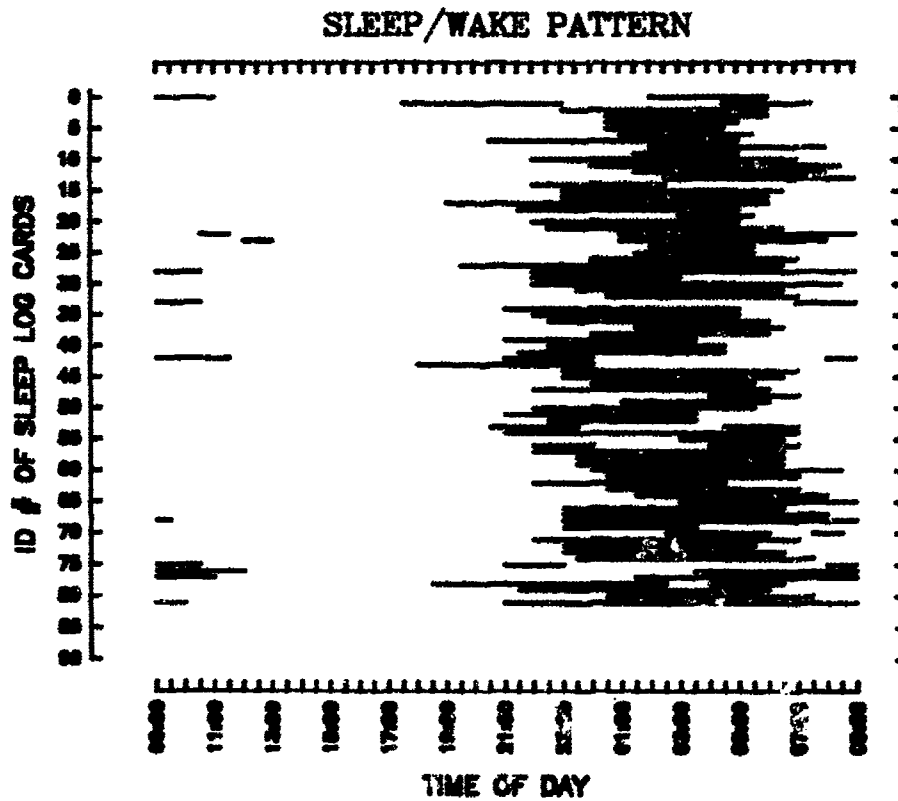


Figure 2 Sleep/Wake Pattern. Each horizontal line represents a time period spent sleeping, as indicated in a sleep log card. The first sleep log card (card ID# 0) shows three sleep periods. Sleep periods from 82 sleep log cards are plotted.

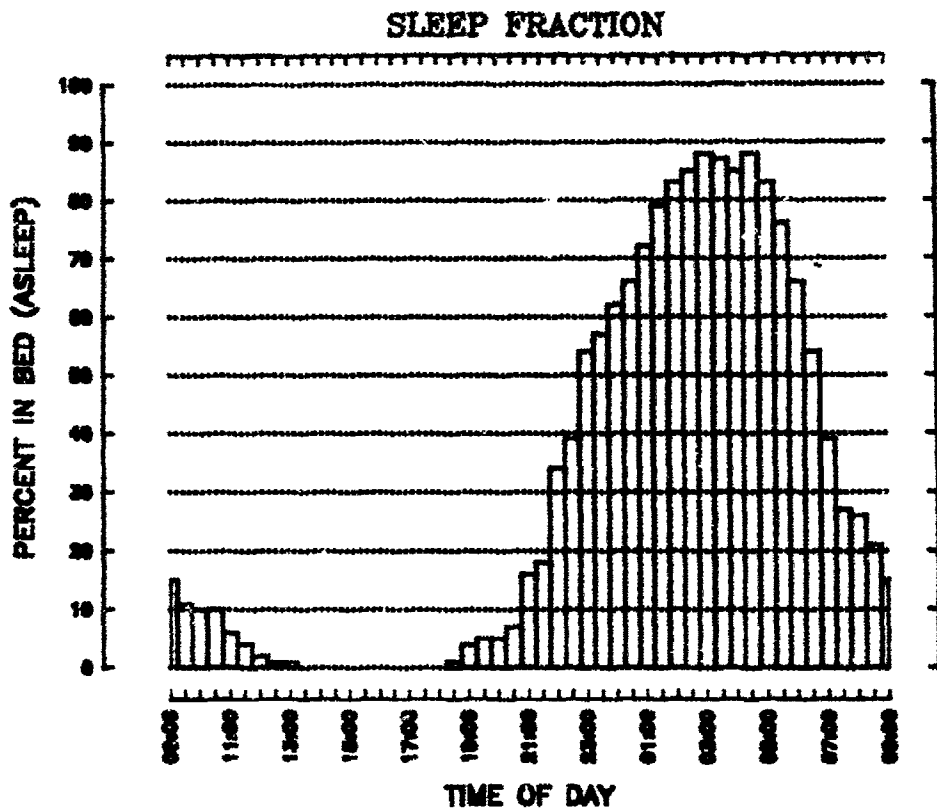


Figure 3 Sleep fraction: Percentage of crew members in bed. The information displayed in Figure 1 is replotted to show more clearly the proportion of the group asleep at each hour during a 24-hour period.

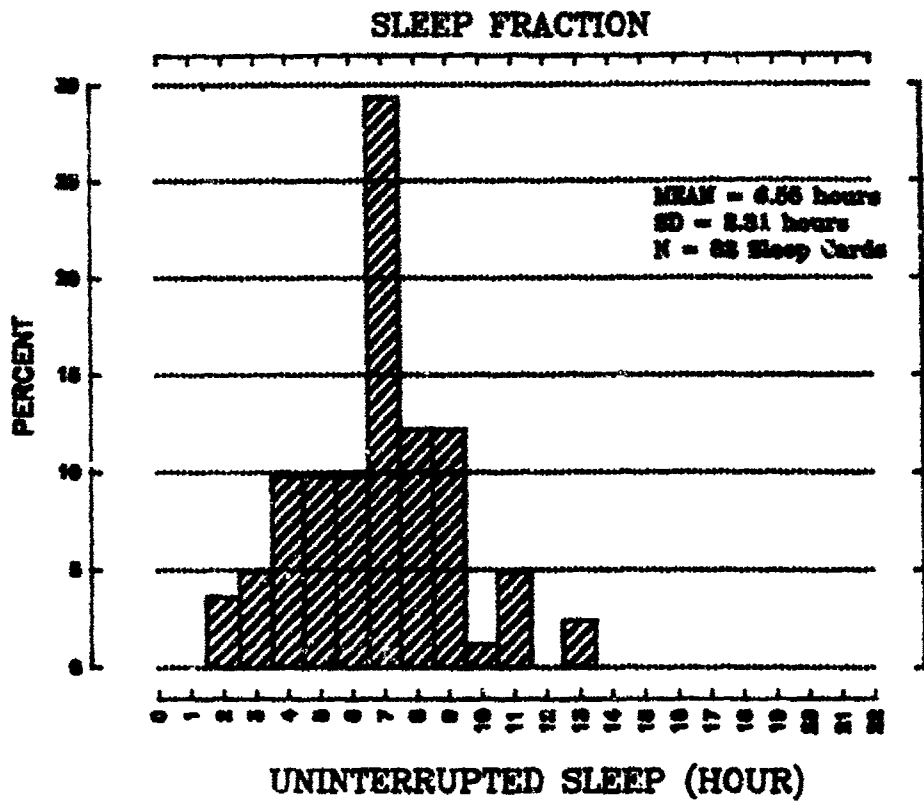


Figure 4 Sleep Episode Duration: Length of uninterrupted sleep periods. Under a normal shore duty office routine of 8 hours sleep/16 hours awake, uninterrupted sleep durations are clustered closely around 8 hours.

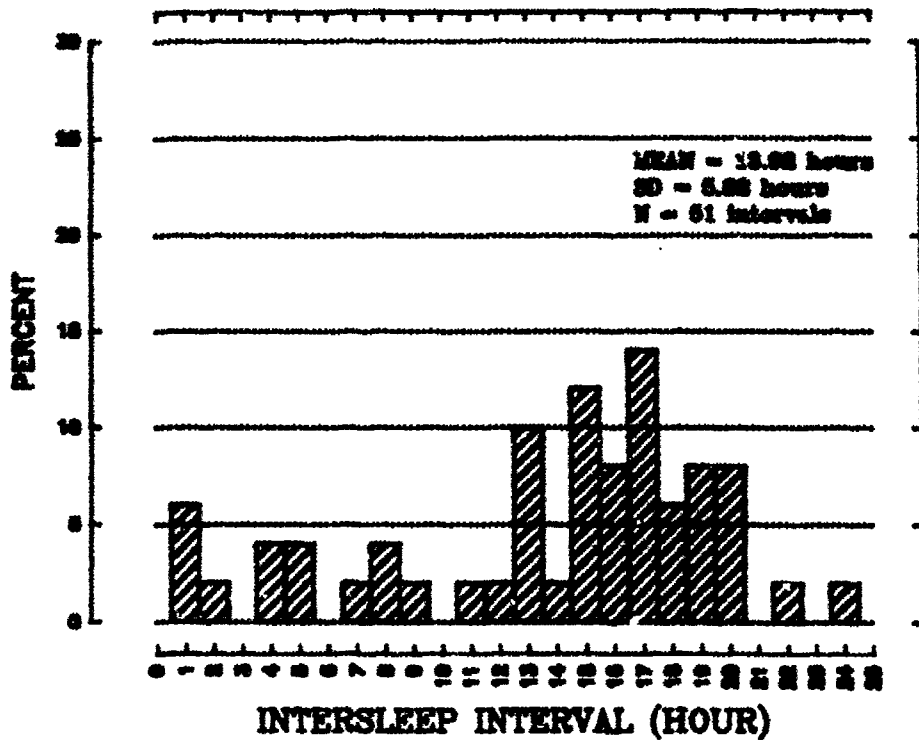


Figure 5 Intersleep interval: Hours since the last sleep. Under a normal shore duty office routine of 8 hours sleep/16 hours awake, the duration of intersleep intervals is clustered closely around 16 hours.

Table 1 shows the eight measures of sleep extracted from the sleep logs. These measures are: (1) sleep latency, (2) "Need more sleep?" (3) "How well rested?", (4) Stanford Sleepiness Scale, (5) "Work/last 24 hours,", (6) Total sleep duration, (7) Sleep episode duration, and (8) Intersleep interval. The results are explained in the following.

Sleep Measure 1: Time to fall asleep (sleep latency). The five Marines took on the average, an appreciably longer time (42.5 min) to fall asleep than the other groups (12.7 to 23.0 minutes).

Sleep Measure 2: Need More Sleep? The answer of "Yes, I need more sleep" was assigned a score of 1; the score of 2 was assigned to an answer of "No, I do not need more sleep." BT's (N=4) indicated that they needed more sleep, (i.e., an average of 1.0 with zero standard deviation). Other job ratings showed lower prevalence of needing more sleep.

Sleep Measure 3: How Well Rested? The answers to this question were scored using the weights of: 1 point for "Well Rested," 2 points for "Moderately Rested," 3 for "Slightly Rested," and 4 for "Not At All." The higher the score, the lower value a sleep period had in restoring restfulness. Average for the 39 subjects was 2.1, close to "moderately rested." The Marine Corps personnel reported feeling less completely rested (2.5) compared to all the other groups.

Sleep Measure 4: Stanford Sleepiness Scale (SSS). The SSS has a 7 point range: from "Feeling active and vital: wide awake" (the scale point 1) to "Almost in reverie: sleep onset soon; losing struggle to remain awake" (the scale point 7). Average scale score was 2.5 which is between "Functioning at a high level" and "Relaxed; awake, responsive, but not at full alertness." Again, the Marines reported feeling sleepier (3.6) than the other groups (2.5).

Sleep Measure 5: Work/24 Hours. Average work duration was 10.6 hours per 24-hour period for the entire group, with MM's working for the longest period of time: 11 hours.

Sleep Measure 6: Total sleep duration. People who are not required to work under unusual work schedules, including Naval personnel stationed on shore duty, will sleep once each 24-hour period during the nighttime for an uninterrupted duration of about 8 hours. BT's had the shortest total sleep duration of 5.8 hours and SM's had the longest at 7.3 hours. A minimum total sleep duration of 4-5 hours is the recommended amount per 24-hour period (Naitoh, Englund and Ryman, 1986).

TABLE 1: Means (\bar{X}) and Standard Deviations (SD) for Sleep Characteristics as measured by Sleep Log.

Measures*		1	2	3	4	5	6	7	8	
Job Class**	# of Subj	Time to fall Asleep (min)	Need More Sleep	How Well Rested	SSS	Work/24 Hrs Duration (Hrs)	Total Sleep Duration (Hrs)	Sleep Episode (Hrs)	Intersleep Interval	
		\bar{X} SD	\bar{X} SD	\bar{X} SD	\bar{X} SD	\bar{X} SD	\bar{X} SD	\bar{X} SD	\bar{X} SD	
<u>Navy</u>										
BT	4	18.1 8.4	1.0 0.0	2.0 0.8	2.4 0.8	10.5 4.2	5.8 1.5	4.2 2.1	11.8 6.0	
EM	4	14.6 9.1	1.4 0.5	1.6 0.5	2.2 0.8	10.5 5.1	7.0 1.1	6.2 2.3	17.5 0.7	
PM	7	23.0 19.3	1.3 0.5	2.1 0.9	2.3 1.0	11.0 4.7	6.4 2.7	5.3 2.9	10.1 6.8	
SM	3	12.7 18.1	1.5 0.6	1.8 0.8	2.8 1.3	10.3 3.0	7.3 2.1	7.3 2.1	14.8 2.1	
<u>Marine</u>										
Enl/ACD	5	42.5 53.2	1.2 0.4	2.5 0.8	3.6 1.6	10.3 5.1	6.7 2.4	6.7 2.4	16.8 2.2	
<u>All</u>	39	23.0 27.4	1.3 0.5	2.1 0.9	2.5 1.2	10.6 4.2	6.8 2.1	6.6 2.3	13.9 5.8	

* For an explanation of the unit of measures, 2, 3, and 4, refer to text.

** Only those job categories where there were more than 3 respondents are shown in this table.

SSS = Stanford Sleepiness Scale

(\bar{X}) = Means and Standard Deviations (SD)

Sleep Measure 7: Sleep episode duration. With increased workload onboard ship (i.e., watchstanding, collateral duties, General Quarters, and other events), sleep becomes interrupted. To compensate for interrupted sleep, the ships crew tend to take short naps. For example, if an individual had a main sleep period of 4 hours, supplemented by a 1 hour nap, and a second nap of 30 minutes, that would give an average sleep episode duration of 1.83 hours $[(4 \text{ hrs} + 1 \text{ hr} + .5 \text{ hr})/3 = 1.83 \text{ hrs}]$. The current survey shows the average sleep episode duration is 6.6 hours, suggesting that once crew members had an opportunity to go to sleep, they were most likely to sleep uninterrupted for 6.6 hours. BT's had the shortest sleep episode duration of 4.2 hours.

Sleep Measure 8: Intersleep interval. Because the usual sleep pattern in normal work/rest cycles is a single 8-hr period, the intersleep interval between the end of one sleep period and the start of the next, is about 16 hours, Nelson (1982). The job ratings of BT and MM exhibited the largest deviations from the normal 16-hour intersleep interval of the monophasic sleep pattern (11.8 and 10.1, respectively).

DISCUSSION

Subjective estimates of sleep duration and timing, using sleep log (or sleep diary) have been acquired previously by Lewis and Masterton (1957), Lewis (1961), Hartman and Cantrell, (1967), Nicholson (1970), Atkinson, Borland, and Nicholson (1970), and Nitch et al., (1971). The sleep log method continues to be used both to survey large numbers of individuals (e.g., Ursin, Lingjaerde and Wilk, 1987) and in research on clinical sleep disorders (e.g., Mullington, Spielman, Wells, and Hoffman, 1988).

The validity and reliability of sleep logs in estimating true sleep measures were determined by comparing sleep log data with measures obtained from polysomnographic records of sleep (Lewis, 1969). One of the most important questions for sleep logistics is whether a subjective estimate of awakening during sleep, using a sleep log, is valid and correlates highly with an EEG-recorded estimate for awakenings. Schneider-Helmert and Kumar (1986) correlated subjective with objective measures of awakenings in 15 normal subjects (average age 47 years). The correlation between subjective

and objective sleep measures was 0.47, for sleep latency, and 0.89 for awakenings after sleep onset (WASO). These correlations were significant. Webb and Schneider-Helmert (1984) compared a Post-sleep Inventory with a sleep log with polysomnographic recordings in a group of elderly (50-70 years) healthy men and women. They found, contrary to the findings of Schneider-Helmert and Kumar, no substantial correlation between the subjective and objective measures of awakenings. However, they did not interpret this lack of correlation as a sign of low validity. Instead, they suggested that the subjective and objective measures each reflect important unique aspects of awakening during sleep. They felt that both measures are needed to accurately determine whether awakenings took place, and how individuals perceive these awakenings.

Sleep logs seem to produce reliable sleep measures (Ursin, Lingjaerde and Wilk, 1987). The most pertinent reliability study was reported by Mullington, Spielman, Wells and Hoffman (1988). They asked graduate students (average age 27 years) to complete sleep logs for 42 consecutive nights. They found that 7 to 10 consecutive days of sleep log data provided sufficient stability. For example, the average of 7 nights of nocturnal sleep time correlated at 0.85 with the 42 nights average. In the present study, where a maximum of four consecutive nights were available, reliability would be approximately 0.7.

Brooks, Shergold, Angus, Heslegrave and Redmond (1988) compared actigraphic sleep-wakefulness measures with sleep log measures (see, also, Webster et al., 1982). They found that actigraphic estimates of the quantity of sleep were significantly longer than the sleep durations reported in the sleep logs. Some slight differences in the start and stop times of the sleep periods and an occasional mismatch in terms of presence of short sleep/rest periods were observed. However, the actigraphic and sleep logs identified similar sleep periods. It was felt that inconsistencies between actigraphic and sleep log measures of sleep were caused by (1) inaccurate recall of the exact periods of sleep when completing sleep logs, (2) low activity wake periods, being misinterpreted as sleep by the actigraph, and (3) failure to record napping in sleep logs. Brooks, et al. (1988) recommended the continued use of both techniques.

The sleep data from the present survey indicate that a sample of 39 naval crew members aboard ship during an active naval at-sea operation

slept, on the average, 6.8 hours per 24-hour period. This total sleep duration is sufficiently long enough to sustain job performance at a high level for several months. Sleep was not seriously fragmented. Once crew members seized an opportunity to sleep, they were most likely allowed to sleep uninterrupted for 6.6 hours. This 6.6 hours of uninterrupted sleep is long enough to capture the minimum necessary sleep defined as "core sleep" by Horne (1989). However, the average intersleep interval deviates from the typical monophasic sleep patterns, which suggest naps were taken.

Although average sleep patterns in this study are acceptable and would not cause serious sleep logistic concerns, an analysis of individual crew members revealed that for some personnel, major sleep periods were consistently less than 4 hours. This was especially true of the BT and to a lesser degree the MM job ratings (Table 1). Although their total sleep time might have added up to 5.8 to 6.4 hours daily through nappings, a short main sleep episode duration signifies a loss of sleep continuity. A continuous sleep period of 4.5-5 hours duration is needed to provide efficient core sleep. Those individuals with the BT and MM ratings are possibly accumulating sleep debt which may interfere with performance of jobs requiring sustained attention and situational awareness.

On shore duties, a sleep fraction generally shows almost 100% of the crew asleep from 0100 to 0700 (Naitoh, 1982). In contrast, Figure 3 reveals that 10-20% of the crew remain awake between 0200 and 0500. However, previous studies of crews on naval ships found at least 30% of the crew to be awake at any time day or night (Naitoh, 1982), as might be anticipated from a 3-section watch schedule where the 1/3 of the crew would be on duty at any time. The 10-20% awake between 0200 and 0500 is less than expected. This is probably an artifact due to the short duration of data collection and the small portion of the crew that were surveyed. Figure 3 also shows that more crew members remained awake during the daytime than would be expected from the 3-section watch standing (again, roughly 30%). The crew in this survey as well as the shipboard subjects in the previous study (Naitoh, 1982) were awake for longer hours than those on shore duty.

A more advanced type of analysis than those used on the present data is available, if each respondent completes sleep logs for at least five, and preferable 7 to 10, consecutive 24-hr periods.

The application of this methodology is presented using data from a previously conducted sleep survey, to demonstrate another effective utilization of sleep logs (Figure 6, Naitoh (1982)).

The analysis consists of integrating information from two graphic representations: one plot with total sleep time on the X-axis and its associated standard deviation on the Y-axis. Another plot with the intersleep intervals on the X-axis and its standard deviation on the Y-axis. The integration of information from these two graphic representations is critical for identifying those individuals whose sleep patterns suggest insufficient and non-optimal sleep. From the total sleep graph, individuals who have short total sleep of less than 6 hours regularly (i.e., a small standard deviation) over at least 5 consecutive 24-hour periods can be identified. Those identified can then be looked up on the intersleep interval graph to see if they also show evidence of non-optimal timing of sleep, (i.e., a short intersleep interval with a large standard deviation). Individuals who fit these criteria need remedial intervention by sleep logistics to improve their sleep.

The data in Figure 6, originates from 31 shipboard personnel each of whom completed 5 consecutive sleep logs (Naitoh, 1982).

Individuals whose total sleep duration is either extremely short or long within this group are identified by ratings or positions. Smaller standard deviations represent individuals who have stable amounts of total sleep over each of the 5 nights. For example, the Executive Officer (XO) had a stable, but short, total sleep duration of close to 6 hours during each of the 5 consecutive 24-hour periods. The right-hand plot in Figure 6 plots intersleep interval against its standard deviation. Again, those individuals whose intersleep interval is either extremely long or short within this group are identified by their ratings. The XO shows a relatively long intersleep interval of about 14 hours, but his "bedtime" was observed as irregular which was indicated by the large standard deviation. When the two sleep measures are combined for the XO, it reveals that his sleep was consistently short with no compensatory short naps. "Bedtime" varies a great deal from one sleep episode to another, but once he had the opportunity to sleep, his sleep was uninterrupted for almost 6 hours. The sleep logs indicate that the XO was getting minimal sleep and timing was not optimal to assure superior sleep quality.

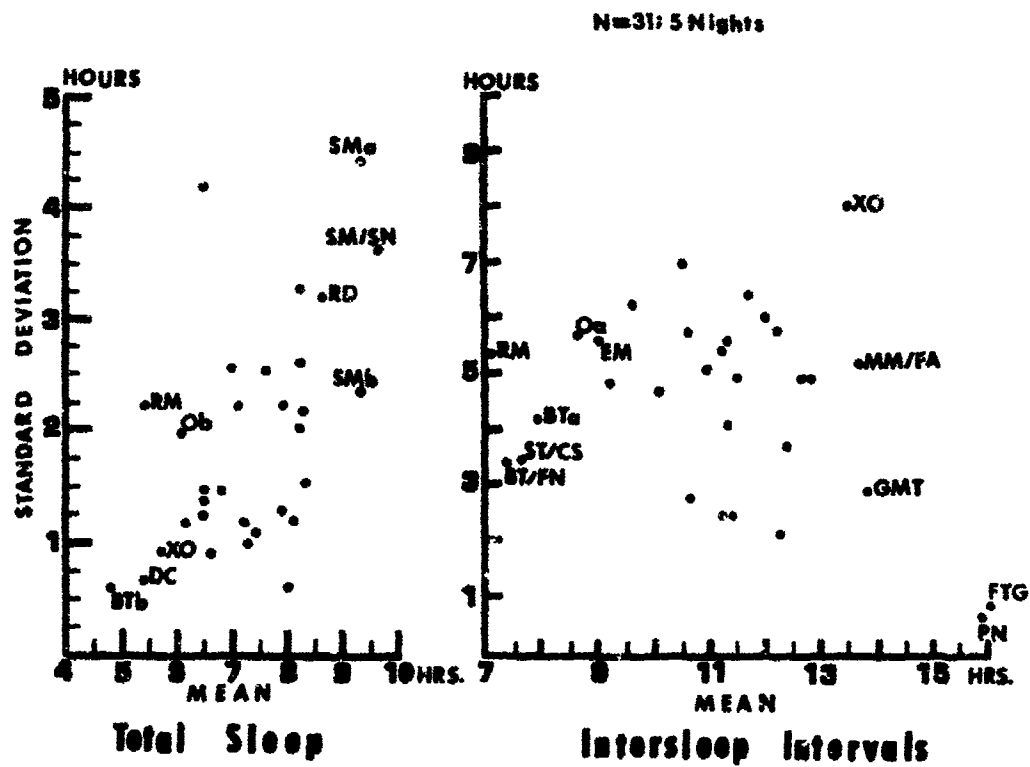


Figure 6 Integrating information of total sleep durations with intersleep intervals. See text for details.

A radarman (RM) was also selected as a case requiring careful analysis. This man was identified as having a brief total sleep duration and very short intersleep intervals. This individual did not have consistently short sleep over five 24-hour periods, but he had more than one sleep episode per a 24-hour period. Sleep logs indicated that this RM had minimal sleep, but compensated by taking short naps.

Sleep logs provide the information required to determine how well rested individual Naval personnel are for continuing optimal performance, and how effective a group will be in a sustained operation. Consistently completed sleep logs, over at least 7-10 consecutive 24-hour periods during various phases of Naval exercises (e.g., steaming into port, inport activities, etc.) within critical ratings are required to obtain a comprehensive view of how the Navy rests onboard ships and copes with demands of low intensity conflicts involving extended missions. The future use of the actigraph will complement information gained from the sleep log. Sleep Questionnaires, which provide information on an individual's "normal" pre-deployment sleep pattern compared to his shipboard pattern are also valuable adjuncts. The technique of time-lapse photography of groups of sleepers (e.g., Hobson, Spagna and Malenka, 1978) would be desirable to accurately capture another aspect of sleep in the field in conjunction with sleep quality and quantity.

The primary use of sleep logs has been to determine the sleep pattern of each crew member and assuring them of no severe sleep deprivation. However, Harris and O'Hanlon (1972) expanded the function of sleep log data by recommending their use to produce a measure of group efficiency in job accomplishment. Knowing the work/rest schedule and the recuperative power of recovery sleep, Harris and O'Hanlon were able to calculate a "Force Effectiveness" index. Force effectiveness shows us the number of individuals that are well rested (slept) and ready to resume working towards meeting group goals. Sleep fraction (as in Figure 3) can be used as an index to provide information on how to achieve optimal ship function (i.e., balancing the fact that the more people awake at a given time, the more effectively a ship will operate against the fact that the more people awake at a given time, the more people must subsequently be taken out of the work place to sleep and recuperate, because sleep deprived personnel do not function properly). Measuring sleep fraction also determines whether more people are awake onboard ship than are required by work to be done. The long term "survival" of a ship may be ensured by a careful application of sleep logistics.

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