

ON VARYING WORK/SLEEP SCHEDULES:
ISSUES AND PERSPECTIVES AS SEEN BY A SLEEP RESEARCHER

Laverne C. Johnson
Naval Health Research Center
San Diego, California

The published works of many of you attending this symposium indicate that the major issue for most workers with varied work/sleep schedules is sleep. Your subjects have complained about both the quantity and the quality of their sleep. In a paper on shift work and sleep, Foret and Benoit (1977) state, "As far as we know, no survey has ever found day sleep duration as long as night sleep duration." Foret and Lantin (1972), by use of both questionnaires and electroencephalogram (EEG) recordings, have documented the reduced sleep of shift workers. Their data show that train drivers sleep an average of 6 hours 22 minutes on working days and 7 hours 59 minutes on rest days. Foret and Lantin also found that these workers tended to make up their reduced sleep with naps during the day and prolonged night sleep on rest days, and wondered whether this variable kind of sleep was equivalent to regular and unbroken sleep. That is still an unanswered question.

In addition to the social factors that reduce sleep (e.g., meals with the family and leisure-time activities), noise is also a problem for the day sleeper. Sixty-three percent of 171 oil refinery shift workers reported noise as a sleep problem (Koller, Kundi, & Cervinka, 1978). Rutenfranz and Knauth (1970) have also emphasized the importance of noise in complaints about sleep, reporting that 78% of those sleeping during the day were bothered by noise. Along with the complaint of inadequate sleep is the feeling of fatigue. Kogi (1971), in a questionnaire study of oil refinery shift workers, found that 82% stated that they suffered from lack of sleep, 58% said they felt very tired, and 37% rather tired after a night shift.

Numerous published articles detail the problems of sleep and fatigue, and, in several review articles, Rutenfranz and his colleagues have summarized the sleep problems of shift- and night-workers (Rutenfranz, Knauth, & Colquhoun, 1976; Rutenfranz, Colquhoun, Knauth, & Ghata, 1977). Noting the consensus that night work usually results in sleep less than 7 hours and in some groups as low as 2.5 hours, they comment, "It is, therefore, understandable, that sleep disturbances are the principal symptom amongst the complaints of night-workers, and that the quality of sleep is one of the deciding factors, whether a worker can or cannot adapt to night- and shift-work" (Rutenfranz et al., 1976, p.335).

For sleep researchers, then, the issue is inadequate sleep, poor sleep quality, and fatigue. In this session, we are charged not only with stating the issues but also with discussing perspective. One definition of perspective is "the true relationship of objects or events to another." This definition is quite appropriate, for the question yet to be answered is: What is the relationship of sleep *per se* to the complaints of shift workers? Is the reduced amount of sleep they obtain the cause of their fatigue; is the quality of their sleep inferior; is there a chronic sleep deficit? Is sleep the focus of general dissatisfaction with the work schedule and, as Dr. Wedderburn would remind us, interacting with social factors? While I have referred to shift workers, the flight schedules of aircrew members not only cause sleep rever-

sals but they also involve travel across several time zones. The presence of a representative from the Air Line Pilots Association at this symposium, Dr. Masters, attests to the concern of aircrew members. Dr. Endo has previously presented quantitative data on the effects of eastbound and westbound flights on sleep (Endo, Yamamoto, & Sasaki, 1978), and will be discussing his work on Saturday.

Later in our program, there will be reports of new sleep research pertinent to the issues of sleep quality, quantity, and fatigue. I would like, in this presentation, to briefly summarize previous work, with the goal of trying to narrow the number of questions I have posed. I will explore the research concerned with sleep quality, sleep quantity, and the fragmentation of sleep, to see if these factors could account for shift workers' sleep complaints and feelings of fatigue.

Research Issues

Sleep Quality

A primary goal of sleep research has been to determine what is good sleep and to obtain an objective measure of sleep quality. Perhaps because of the initial enthusiasm and excitement of our ability to chart a night of sleep by use of the EEG and to divide the EEG waves into sleep stages, much work has been oriented toward sleep stages as an index of sleep quality.

The EEG studies of sleep have added to our knowledge of the changes in sleep structure with variations in work/sleep schedules. We now know what happens to rapid eye movement (REM) latency, whether percent Stage REM increases or decreases, and what happens to slow wave sleep (SWS). While early laboratory studies varied sleep schedules of non-shift workers, recent work has focused on the recording of shift workers and the changes in EEG sleep measures of aircrew members following flights across several time zones. Though the search has been both extensive and intensive, the early expectations that sleep stages were the key to the mysteries of sleep have not been supported. The amount of REM sleep one gets is not the key to emotional well-being and time in SWS is not the crucial factor for "knitting up the raveled sleeve of care." In the past few years, most sleep researchers who previously suffered from REM tunnel vision or slow wave myopia (the former could only see REM during a night of sleep and the latter could not see beyond the first third of the night) have had their visual problems partially alleviated by overwhelming negative data (Johnson, Naitoh, Lubin, & Moses, 1972). I think that it is time to stop wondering whether REM latency is 60 or 90 minutes, or whether we have 30 or 40 minutes of SWS or a decrease or increase in REM sleep. In the evaluation of hypnotic drugs, perhaps a reflection of the failure of EEG sleep stages to quantify drug effectiveness and the finding that most hypnotics reduce either Stage REM or SWS, there is renewed interest in subjective estimates of sleep quality. More attention also is now being given to the effect of hypnotic drugs on daytime performance. It is unfortunate that those earlier studies concerned with alterations in sleep schedules did not ask their subjects how they felt after the shift in their sleep times. While there are numerous tables and figures on sleep stage amounts, percents, latencies, eye movements and REM periods, most researchers did not ask "How was your sleep?" If they did ask, they did not report the answer. There are also little performance data in the early shift-work studies.

I don't expect the sleep researchers to abandon their EEG machines--nor should they. As with many physiological measures, such as heart rate for example, extreme deviations from the norm, either in rate or rhythm, deserve further study and evaluation. Heart rate, like REM or SWS percent, however, can vary from person to person and within a single subject depending on the circumstances with minimal relation to performance or feeling of well-being. But I don't believe we will find the relationship of sleep to shift-work complaints by scoring EEG sleep stages alone. Although I am not impressed with stages of sleep as a measure of sleep quality, for those who do not agree with me and to summarize the major findings, I will briefly review the most consistent findings.

As is often the case, our Keynote Speaker has had a major impact, both in terms of quantity and quality of work, on research in the areas of altered sleep schedules and sleep structure (Webb & Agnew, 1971; Webb, Agnew, & Williams, 1971; Webb & Agnew, 1977). Webb and his associates believe that three variables are associated with the EEG sleep measure in split periods and altered sleep regimes: (1) the time interval between sleep periods, (2) the sidereal time of sleep onset, and (3) the length of the periods. The most consistent finding by Webb, and by others, has been the direct relationship of time between sleep periods and the amount of Stage 4 occurring in each sleep period. The longer the time awake, the greater the increase in SWS. There have also been consistent results with respect to time-of-day effects on sleep latency and length. As illustrated in Figure 1, Foret and Lantin (1972) found that, as the time of sleep onset was delayed after midnight, the total sleep duration decreased. The authors thus summarize their finding, "the duration of unbroken sleep periods...is an inverse function of bedtime, and an almost linear one at that" (p. 278).

In our nap studies (Moses, Hord, Lubin, Johnson, & Naitoh, 1975; Moses, Lubin, Naitoh, & Johnson, 1978), we have found more rapid sleep onset and more total sleep time (TST) when the time for a 1-hour nap fell in the last third of the night when body temperature was low (Figure 2). Webb also believes that there is a clear circadian effect in sleep stages since the displacement of the sleep period shows a tendency to reduce the amount of Stage 4 and increase the amount of REM. Morning sleep onset is usually associated with a shorter REM latency.

In contrast to the general support of the relationship between sleep loss and an increase in Stage 4, the association of REM sleep with time of day is less clear. Several have reported REM onset in morning sleepers (Decoster & Foret, 1979), but sleep-onset REM has been found in both morning and afternoon naps (Weitzman, Nogueira, Perlow, Fukushima, Sassin, McGregor, Gallagher, & Hellman, 1974; Carskadon & Dement, 1975; Moses et al., 1975). Instead of time of day or the awake time since last sleep, we believe REM latency is related to amount of total sleep since last REM onset, regardless of how fragmented the sleep; i.e., the REM cycle is a sleep-dependent rhythm while Stage 4 may be more wake-dependent (Moses, Lubin, Johnson, & Naitoh, 1977; Moses, Naitoh, & Johnson, 1978).

The duration of the sleep period is, of course, directly related to amount of time spent in each stage. In Figure 2, the amounts of Stage 2, Stage 4, and REM increase with TST in the 1-hour nap which, as we have seen, is in-

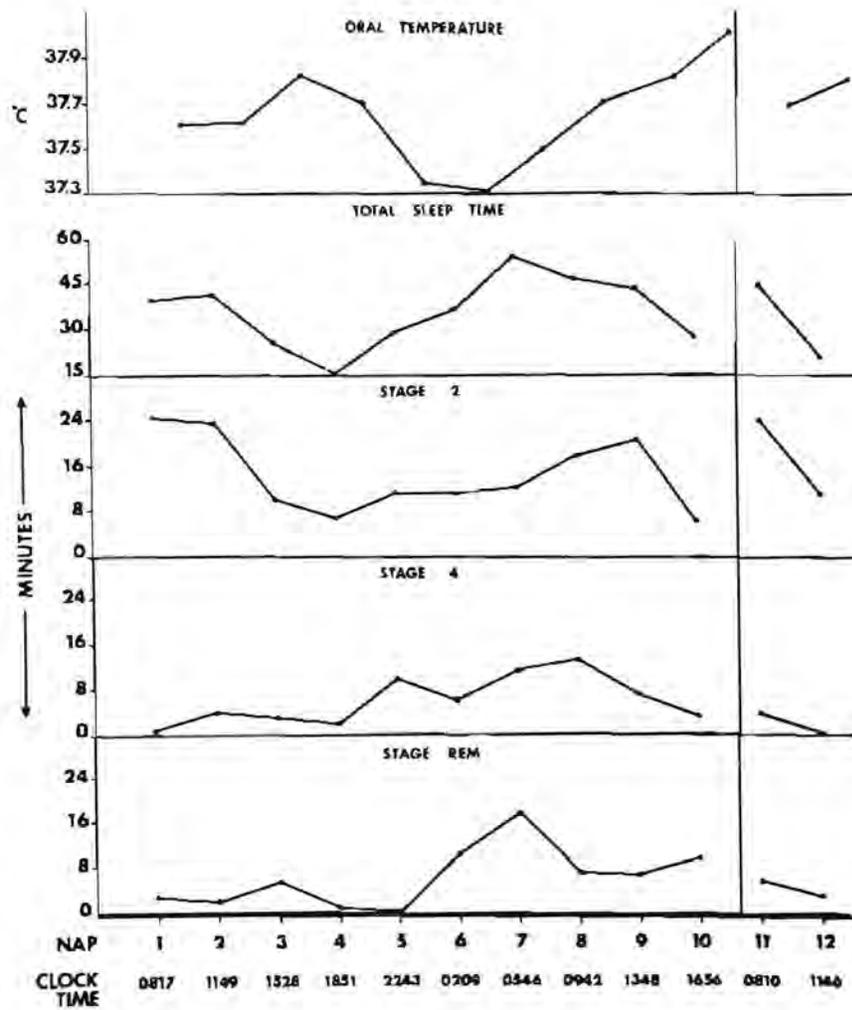


Figure 2. Distribution of sleep, sleep stages, and oral temperature during naps (N = 8) [from Moses et al., (1975), with permission].

versely related to body temperature. Regardless of the length of the nap, however, when sleep in each nap is averaged over a 24-hour period, all stages of sleep are present.

To illustrate the similarity of the structure of sleep in various sleep regimens, in Table 1 are data comparing the sleep measures for our nap sleepers and our gradual sleep reduction subjects. The baseline sleep for both groups was very comparable, even though the nap subjects were 8 male sailors and the gradual sleep reduction subjects were 3 male and 3 female graduate students. The 366 minutes of TST for the nap subjects were obtained in 10 naps over a 40-hour period, while the 346 minutes of TST for the sleep reduction subjects were obtained during a single uninterrupted sleep period. There was less stage REM in the nap sleepers, but the similarities in sleep stages were more striking than the differences. Note, however, the marked differences in total wake time and percent Stage 1. The nap sleep was clearly less efficient, with a 61% TST, than that of the gradual sleep reduction subjects whose percent sleep time was 96%.

Table 1
Sleep Measures for Nap Sleepers (N = 8) and
Gradual Sleep Reduction Subjects (N = 6)

Measure	Nap Sleepers	Gradual Sleep Reduction Subjects
	Naps 1-10	6-Hour Phase
Total bed time (minutes)	600	360
Total sleep time (minutes)	366	346
Percent total sleep time	61	96
Percent wake time	38	3
Percent Stage 1	20	4
Percent Stage 2	39	38
Percent Stage 3	7	10
Percent Stage 4	17	15
Percent Stage REM	17	25

Sleep Efficiency

If the stages of sleep do not relate to sleep quality, were there any findings from the sleep studies that do relate to sleep quality? Yes. In both the altered sleep schedules and in the nap studies, as seen in Table 1, there was more awake time and more Stage 1, the transition period between awake and sleep (Stage 2). In a study of the acute reversal of the sleep-waking cycle, (Weitzman, Kripke, Goldmacher, McGregor, & Nogueira, 1970) noted a significant increase in waking immediately after reversal; the awake time, though decreased, was still higher than baseline, 2 weeks after reversal. Before reversal, Stage W occurred predominantly in the first hour of sleep. After reversal,

the amount of Stage W decreased significantly in the first hour and increased significantly in the last 3 hours. After reversal, their subjects fell asleep more quickly, but tended to awaken intermittently in the latter half of their daytime sleep period. Stage 1 followed a similar pattern. Matsumoto (1978) found a similar increase in number of awakenings and in Stage 1, in hospital nurses during day sleep. He also found an increase in Stage 1 in the third period of sleep.

In a discussion of the motivation of day sleepers, Foret and Benoit (1977), noting Weitzman et al.'s (1970) finding of increased waking in the latter part of the sleep period, wondered if "the sleeper is likely to think that he is wasting his time (psychosociological pressure) and feels that he is too much aroused (physiological pressure) to sleep. So he makes the choice of getting up" (pp. 83-84).

A series of shorter sleep, or naps, does not appear to be the answer. As noted earlier, the efficiency of a nap depends upon its time of occurrence, but, over the 24-hour period, nap sleep is not as efficient as a single period of nocturnal sleep. As in our nap study (Moses et al., 1975), Weitzman et al. (1974) reported low sleep efficiency; 56% sleep time during 3-hour sleep-wake schedules over ten 24-hour periods. In the 90-minute day--30 minutes sleep/60 minutes awake, which lasted 5 days--Carskadon and Dement (1975) reported 62.1% TST.

Thus, the answer to Foret and Benoit's question as to whether fragmented sleep is equivalent to unbroken sleep is "No" -- if we use percent time asleep as our measure.

Reduced Sleep

The question of whether there is a change in sleep quality is still unanswered, but reversed and fragmented sleep are less efficient resulting in decreased TST. Reduced sleep, thus, is present in both field and laboratory studies of altered sleep. Is the reduced amount of sleep the explanation for the sleep complaints and feelings of fatigue? It probably contributes but very likely is not the only cause. The average TST of shift workers appears to be between 6 and 7 hours. This is below the average day sleeper's 7.5-8.5 hours, but 30-40% of the 20-40 year olds sleep 7 hours or less with no complaints. There are about 1-2% who sleep less than 5 hours. You are quite correct if you are thinking: Yes, the amount of sleep a person needs varies, but shift work brings about sleep reduction. Abrupt and gradual sleep reduction studies have been done. Again, Dr. Webb and his associates were among the first to report quantitative sleep reduction data. In one study, they abruptly reduced sleep from 7.5-8 hours to 5.5 hours for 60 days (Webb & Agnew, 1974). Using tests sensitive to sleep loss, they found no performance decrement over the 60 days. There were also no significant changes in mood or affect during the study.

In gradual sleep reduction studies (Johnson & MacLeod, 1973; Friedmann, Globus, Huntley, Mullaney, Naitoh, & Johnson, 1977), subjects reduced their sleep by 30 minutes every 2-4 weeks until their sleep was reduced from 1-4 hours. A follow-up one year later indicated the subjects were still sleeping 1-2.5 hours less than before the study began. There were no significant per-

formance decrements in school work or on tests sensitive to sleep loss. However, as indicated in Table 1, as sleep was reduced, the sleep time was used more efficiently; awakenings and Stage 1 were decreased. The subjects ended their sleep reduction due to feelings of fatigue and sleepiness. But, as shown in Figure 3, the sharp increase in fatigue did not appear until TST was 5.5 hours and sleepiness started to increase more rapidly after a TST of less than 6.5 hours. Sleep reduction of 1 to 2 hours thus occurred with no marked changes in performance or mood.

Many night sleepers obtain less sleep than shift workers, and greater sleep reduction than that experienced by most shift workers does not lead to major behavioral changes. These data suggest that reduction in sleep quantity per se should not be the major factor in sleep complaints by shift workers. Pollak, McGregor, and Weitzman (1975) came to the same conclusion after using Dalmane to decrease the awakenings and thus increase TST in day sleepers. Though TST was increased, Pollak et al. noted there was no decrease in complaints in the drug takers, suggesting that the timing of sleep may be as important as its quantity.

The findings of Pollak et al.'s study were confounded by possible drug hangover effects, but support for their conclusion comes from studies by Åkerstedt (1976), Taub and Berger (1974, 1976), and from our laboratory. In a questionnaire study, Åkerstedt compared the well-being of 3-shift, 2-shift, and day workers. As indicated in Figure 4, the TST followed a pattern similar to that of the complaint scores. The afternoon shift for both second- and third-shift workers had the longest sleep and fewer complaints, but the sleep on the morning shift did not exceed that on the night shift. In spite of the similar quantity of sleep for the morning and night shifts, Åkerstedt found that complaints by the morning shift workers were significantly higher. For Åkerstedt, this suggested that factors other than quantity of sleep may be important in determining good sleep.

Taub and Berger (1974, 1976) have investigated the effects of shifts in the sleep-wakefulness cycle in a series of laboratory studies. They investigated the effects of shortening or lengthening habitual sleep and by displacing the sleep time. These studies have involved subjects whose usual sleep times varied from 7-10.5 hours. Taub and Berger reported both sleep data as well as mood and performance data. Based upon the results of their studies, they concluded that acute disruption of the 24-hour sleep-wakefulness cycle produces degradations in performance, largely independent of TST. Taub and Berger found no relationship between sleep stage amounts and mood and performance.

Changing the time of sleep thus appears to be more important than the type or quantity of sleep. It is, thus, not surprising that night work produces the largest number of sleep complaints. These workers usually sleep in the morning after work. For these night workers, morning sleep, regardless of quantity, does not appear to provide the same benefits as night sleep. Dr. Naitoh, in his presentation, will discuss work from our laboratory that documents the ineffectiveness of an early morning 2-hour nap, 0400 to 0600, in overcoming sleep loss. In contrast, a 2-hour nap from 1200 to 1400 was more effective.

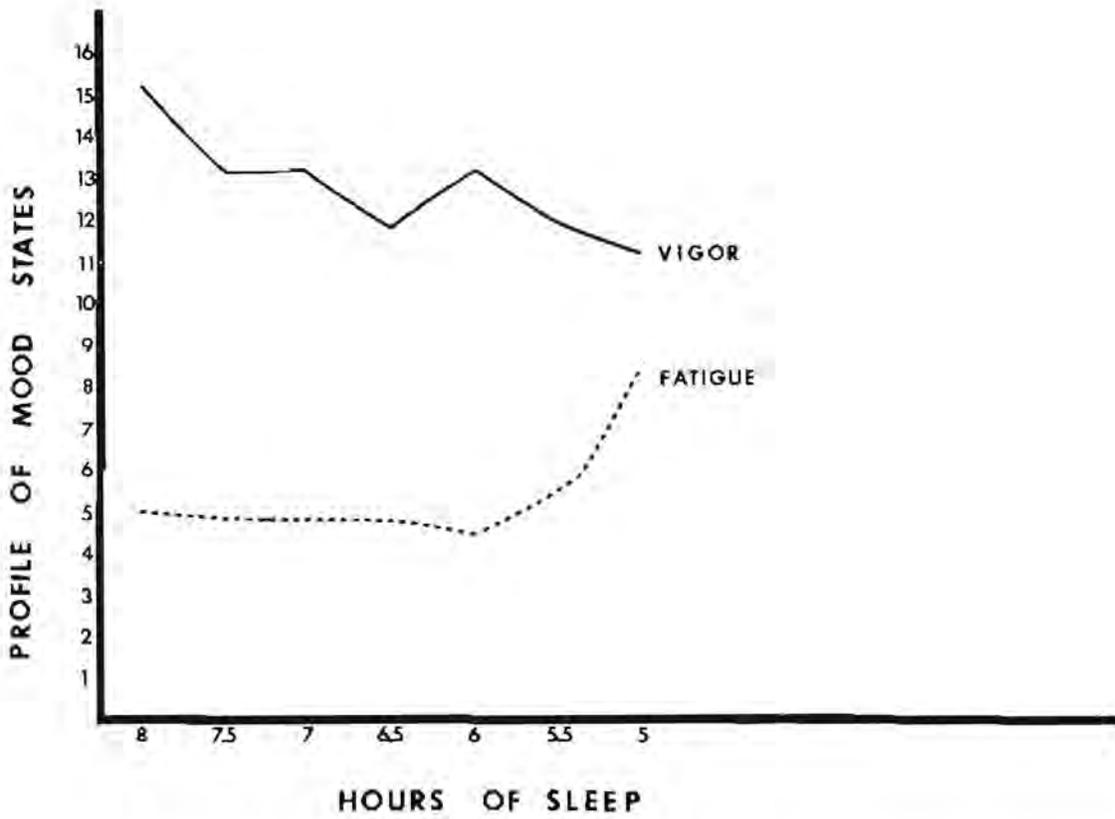


Figure 3. Effect of gradual sleep reduction on feelings of vigor and fatigue.

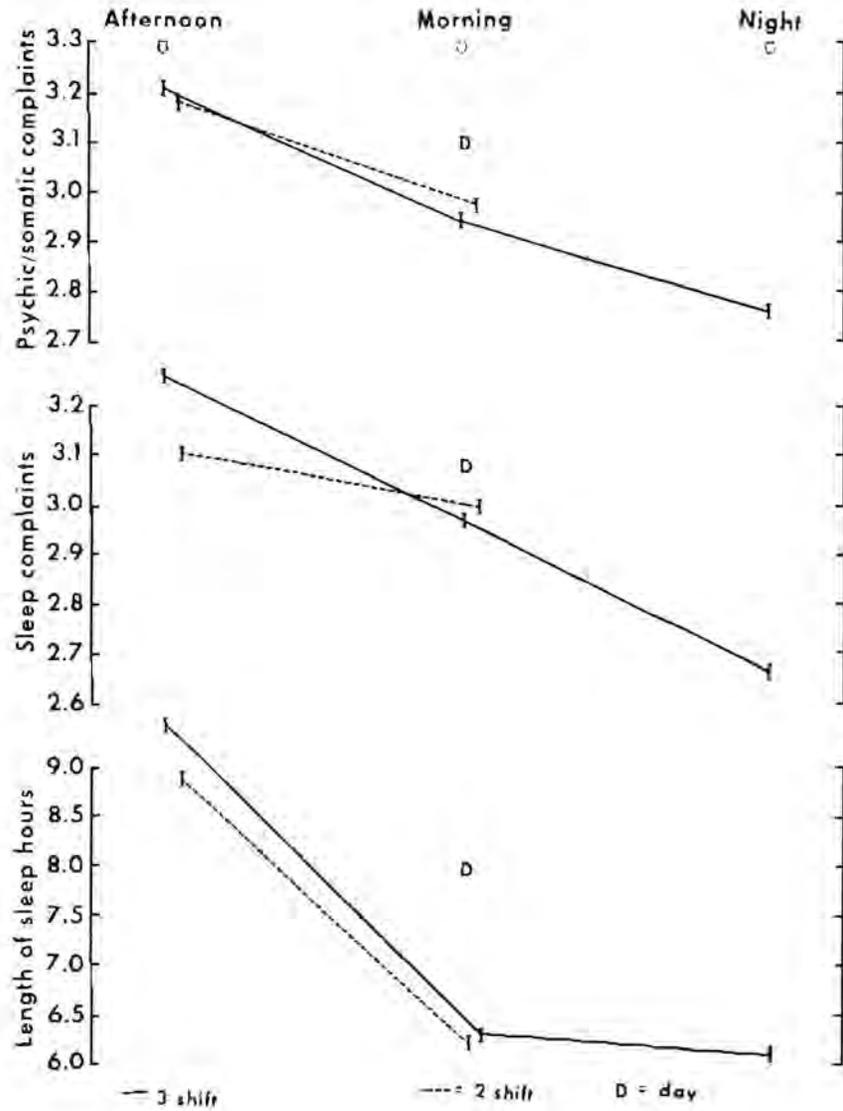


Figure 4. Means and standard errors for complaints and sleep length for each shift of 3-shift workers, 2-shift workers, and day workers. High scores = less complaints [from Åkerstedt (1976), with permission].

One final observation regarding the complaint that noise is a major problem for day sleepers. In 1971, we studied the arousal threshold from sleep of 35 hospital corpsmen who worked nights and slept days, and compared their arousal threshold from sleep with the arousal threshold of night sleepers (Keefe, Johnson, & Hunter, 1971). As shown in Figure 5, the dB level of a 1000 Hz, 5-second tone was significantly higher for the reversed sleepers than for the night sleepers. Our day sleepers were not light sleepers.

We recently further explored the relationship between the arousal threshold and subjective estimates of depth and quality of sleep in good and poor sleepers who slept in our laboratory for at least 7 nights (Bonnet & Johnson, 1978). First, we found no significant relationship between magnitude of arousal threshold and amounts of the various sleep stages. Also, there was no difference in threshold between those subjects who classified themselves as chronic poor sleepers, who reported they were easily awakened by noise, and good sleepers who "slept soundly." Subjective estimate of depth of sleep was not related to the dB arousal threshold.

Examination of individual subject data over nights indicated that, while most subjects had little fluctuation in arousal threshold from night to night, 12 of the 26 showed fluctuations of 10 dB or greater. On low threshold nights, there was significantly more awake time, and subjects reported worse sleep quality and more restlessness. Subjective estimates of depth of sleep also were significantly related to the amount of EEG defined wakefulness and Stage 1. Light sleep was sleep with more awakenings than deep sleep. These awakenings were not noise related.

It was apparent from our results that the relationship of arousal threshold and sleep quality was not determined on the basis of individual knowledge of actual arousal threshold when asleep. They judged their depth of sleep on the basis of how much time they spent awake or drifting in and out of sleep during the night. Remembering that day sleepers had more awake time and increased Stage 1, perhaps their subjective evaluation of their sleep as light sleep and their complaints of noise-disturbed sleep are a reflection of their state of consciousness, i.e., waking or Stage 1. These reversed sleepers may be aware of the noise as they awaken and drift back to sleep and assume the noise is what awakened them.

Conclusions

What are my conclusions--Are the sleep complaints valid? Yes, the sleep complaints should be taken seriously. As with the insomniac who complains of getting little sleep but is found to get 7 to 8 hours of sleep in the laboratory, the sleep complaint of shift workers may reflect problems and discontent. The major cause of this discontent may not be inadequate sleep, however. A decrease in sleep quantity does not appear to be sufficient to cause the extreme feelings of fatigue or the reason for the sleep complaints. The time in the 24-hour cycle that the sleep is obtained appears to be paramount in determining the effectiveness of sleep. There is undoubtedly an interaction between sleep reduction and phase shifts, but how the amount of sleep loss influences the magnitude of the interaction is yet to be determined. We need more studies of the relationship between sleep length at various times over 24 hours and mood and performance. If morning sleep, as it appears, is

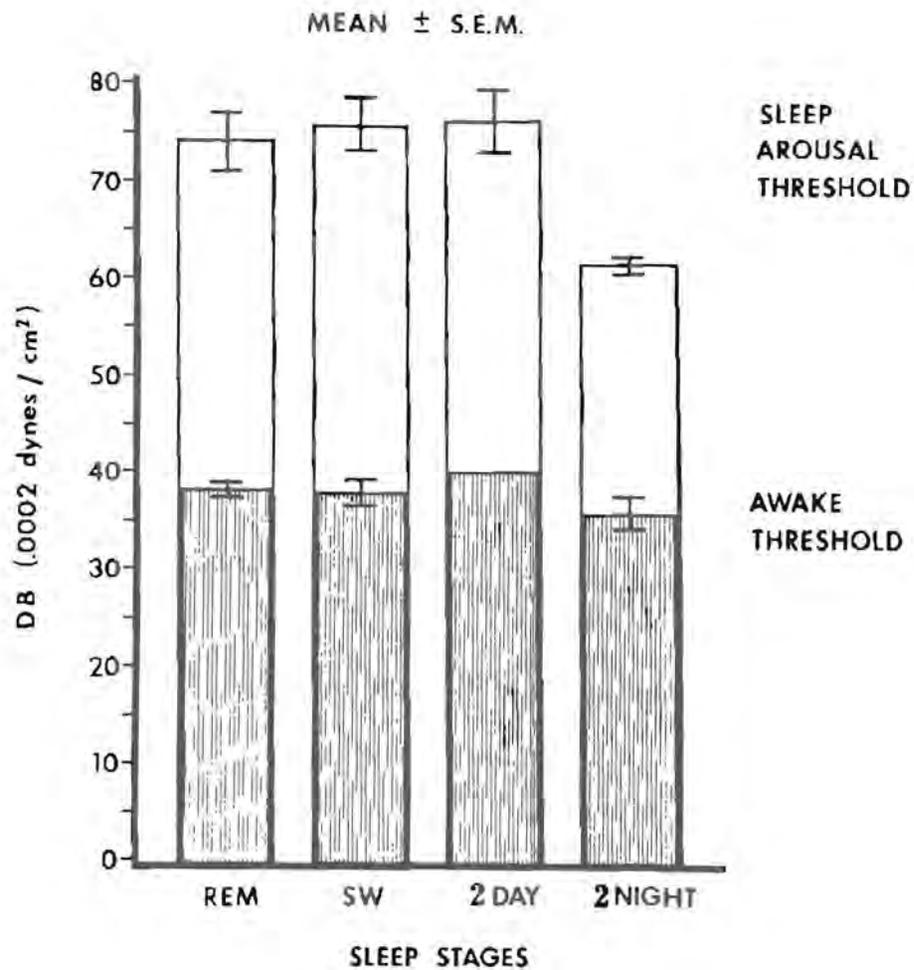


Figure 5. Mean auditory thresholds--awake and arousal from sleep--for the experimental groups. S.E.M. = standard error of the mean [from Keefe et al. (1971), with permission].

less effective than sleep at other times, what would be the consequence if night workers delayed their sleep until after lunch. This schedule would be similar to day workers where leisure follows work, then sleep followed by work; i.e., leisure, sleep, work, instead of the work, sleep, leisure pattern of most night workers.

It is doubtful that this afternoon sleep would be as efficient as night sleep. The importance of sleep at night was further confirmed by the late Dr. Mills and his co-workers, Drs. Minors and Waterhouse (1978), who found that 4 hours of sleep at night were sufficient to stabilize the circadian rhythms regardless of the number of sleep episodes during the day. In the nap studies reported above, some sleep occurred at night, which may be why there was minimal effect on rhythms, mood, and behavior. The suggestion to delay sleep until afternoon or early evening will undoubtedly cause new and perhaps additional social conflicts, but I will leave those problems to Dr. Wedderburn.

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NIOSH

PROCEEDINGS

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EDITORS

Laverne C. Johnson
Donald I. Tepas
W. P. Colquhoun
Michael J. Colligan

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Biomedical and Behavioral Science
Cincinnati, Ohio 45226

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