THE EEG SLEEP OF NIGHT AND ROTATING SHIFT WORKERS

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In the past ten years several studies have examined EEG sleep patterns during sleep-wake variations of the type imposed by short-term exposure to shiftwork. For example, Weitzman, Kripke, Goldmacher, McGregor, and Nogeire (1970), Webb, Agnew, and Williams (1971), and Rutenfranz and Knauth (1970) studied regular nocturnal sleepers during daytime sleep. Kripke, Cook, and Lewis (1971) reported on the day sleep of corpsmen assigned to the night shift for a median duration of 4 weeks. The results of these short-term sleep schedule inversion studies are rather consistent. Rapid eye movement (REM) sleep tended to occur earlier in daytime sleep periods. Total sleep time (TST) is reduced in daytime sleep. Percentages of sleep stages remain constant, or nearly so, with the exception that Stage 1 and waking may be higher for day sleep. Sleep latency does not seem to differ substantially.

Other studies have compared the diurnal and nocturnal sleep of persons on rotating shifts. Bryden and Holdstock (1973) reported on nursing students who changed from night to day sleep every two months. Diurnal sleep was characterized by a higher percentage of Stage 1, a lesser percentage of slow-wave sleep (SWS) and more awakenings in the last third of the sleep period than night sleep. Decreased TST and earlier REM onset were also observed in daytime sleep. Matsumoto (1978) has recently reported similar findings in a study of nurses who rotated on a three shift system although no evidence for reduced SWS percentage was noted. Unfortunately, the latter two studies do not specify how long their subjects had been assigned to rotating shift schedules. Webb and Agnew (1978) placed individuals on a rapidly rotating three-shift schedule for two rotations. Their data indicate no sleep stage percentage differences, but variations in the absolute amounts of REM and Stage 2. REM latency tended to be shorter for diurnal sleep and sleep latencies were shortest for sleep following the night shift.

Foret and colleagues have examined the diurnal and nocturnal sleep of train drivers who work exceptionally irregular rotating shifts. These reports are of special interest because the subjects had worked "months or years in this type of job" (Foret & Lantin, 1972) or, in the case of Foret and Benoit (1974), between 2 and 20 years on this type of shift schedule. The primary findings of these studies are shorter TST, earlier REM onset, and an increase in REM amount early in the sleep period during daytime sleep. Smaller absolute amounts of Stages 1 and 2 during daytime sleep were also reported. Wedderburn (1975) has also reported decreased REM latencies for two long term rotating workers.

With the exception of the reports of Foret's group, one might interpret most of the aforementioned results to suggest that these shift schedule variations result in insomnia-like sleep patterns. That is less TST, more waking and Stage 1 sleep and perhaps less SWS are consistent with a sleep "disturbance" interpretation. The fact that Foret's train drivers are the only group that does not display most of these characteristics and have relatively long exposure to altered shift schedules might suggest that they have partially adapted to their schedule.

From this review one can see that although some consistencies exist, the results of these studies are difficult to integrate and interpret. First, many of the studies consider only short-term effects of shift schedule variations and, therefore, are of indetermined value in the assessment of chronic shiftwork influences upon sleep and any possible adaptation. Second, studies dealing with rotating sleep-wake schedules typically compare diurnal and nocturnal sleeping patterns for the same individuals. It is possible that changes in EEG sleep patterns associated with long term totating schedules may occur for both the day and night sleep periods of individual workers. Therefore, some sleep structure alternations might not be apparent from intra-group comparisons. Finally, most studies have examined the effects of some form of rotating shift schedule. Little attention has been directed toward the effect of steady night work upon sleep. The present study is an attempt to extend our knowledge of shiftwork-sleep interactions by comparing the sleep of day, night and rotating workers who have been on their specific shift schedule for at least one year prior to study.

Method

The general design and methods of this study have been presented elsewhere (Gordon, Tepas, Stock, & Walsh, 1979; Walsh, Gordon, Maltese, McGill, & Tepas, 1979). The data reported here are the result of an analysis from a subsample of the study. Briefly, the participants were recruited through labor unions and selected for laboratory study on the basis of their work schedule. Only workers in good health who reported limited drug use and off-the-job exercise were chosen for laboratory study. All participants were volunteers who were paid $100 upon completion of the laboratory sessions.

The data of ten workers in each of three shift groups will be presented: day shift, night shift, and rotating shifts. All workers slept in the laboratory for four consecutive sleep periods during a typical work week. During this time the workers performed their regular job duties and otherwise led as normal a life as possible. Laboratory sleep times were selected by the individual worker and were usually identical to that individual's normal sleep times. In no case did laboratory sleep times vary by more than 30 minutes from a worker's typical sleep time. Given the individual sleep times of each worker, a general idea of temporal sleep placement can be given. Day workers slept sometime between 21:45 and 6:30. Night workers' sleep periods fell sometime between the hours of 9:00 and 21:30. Rotating workers were studied while working either day or afternoon shift and slept between 21:45 and 11:30. Figure 1 displays the actual sleep times for all 30 participants. The mean ages of the day, night and rotating workers were 37.1 (27-57), 33.5 (19-60), and 36.8 (23-53) years respectively and did not differ significantly. Four night workers were females as were two day and two rotating workers. All participants had worked for at least one year on the shift they maintained during the laboratory sessions.

Standard polysomnographic recordings were performed and scored following the methods and criteria of Rechtschaffen and Kales (1968). All recordings were made while the worker slept in a sound attenuated, electrically shielded chamber.

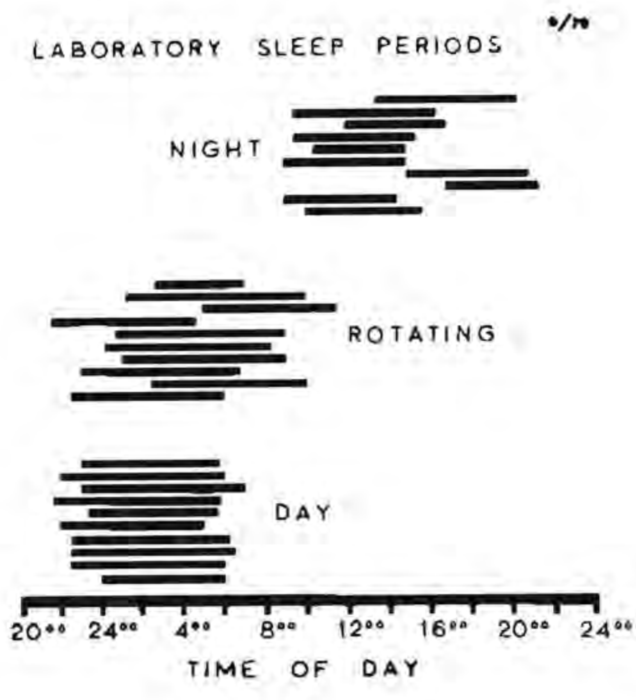

Figure 1. Laboratory sleep periods for the night, rotating, and day shift groups. Each bar represents the sleep period for one worker.

Data Analysis

The first sleep session for each worker was considered an adaptation session and is not included in this analysis. Mean values of 24 standard EEG sleep measures were computed for each subject from the data of the remaining Three sleep sessions. A one way analysis of variance (ANOVA) was performed for each of the 24 measures across shift groups. When the overall F was significant, individual means were compared using the Newman-Keuls technique. Mean hour by hour distributions of each sleep stage were compiled and examined among groups. Statistical comparisons were made as above with ANOVA and Newman-Keuls.

Results

Table 1 displays the mean values for each shift group for each of the 24 EEG sleep measures and the results of the ANOVAs. No differences were obtained between the day shift and rotating shift worker groups. The night shift group differed from both the day shift and rotating shift on several dimensions.

Table 1

Mean Sleep Characteristics for Three Shift Groups

Sleep characteristic	Day	Rotating	Night	F
Minutes of wakefulness	30.69	20.87	34.37	.60
Minutes of movement	7.15	9.61	4.13	2.42
Minutes of Stage 1	47.70	49.69	26.20	5.45*
Minutes of Stage 2	204.08	196.64	152.32	3.16
Mintues of Stage 3	36.09	38.51	35.12	.17
Mintues of Stage 4	12.49	22.15	22.13	1.04
Mintues of REM	94.61	95.89	65.72	5.88**
Mintues of SWS	48.58	60.65	57.25	.92
Movement %	1.66	2.31	1.33	1.76
Stage 1 %	11.92	12.32	8.87	1.52
Stage 2 %	51.00	46.94	49.19	.42
Stage 3 %	9.02	9.65	12.03	1.20
Stage 4 %	2.89	4.99	7.19	2.92
REM %	23.43	23.80	21.40	.41
SWS %	11.91	14.64	19.22	4.38*
Number of awakenings	8.20	7.55	5.45	.88
Number of stage changes	105.55	108.80	74.67	4.21*
Stage 1 latency	12.20	11.29	8.38	.80
Stage 2 latency	18.36	18.35	14.24	.98
Total sleep time	400.81	411.49	305.58	10.62**
Sleep efficiency (TST/TIB)	.93	.95	.91	1.23
REM latency	99.81	91.61	54.32	9.13**
REM cycle duration	89.70	91.99	98.46	1.57
Number of REM periods	4.13	4.25	3.07	7.58*

* $p<.05$; ** $p<.01$

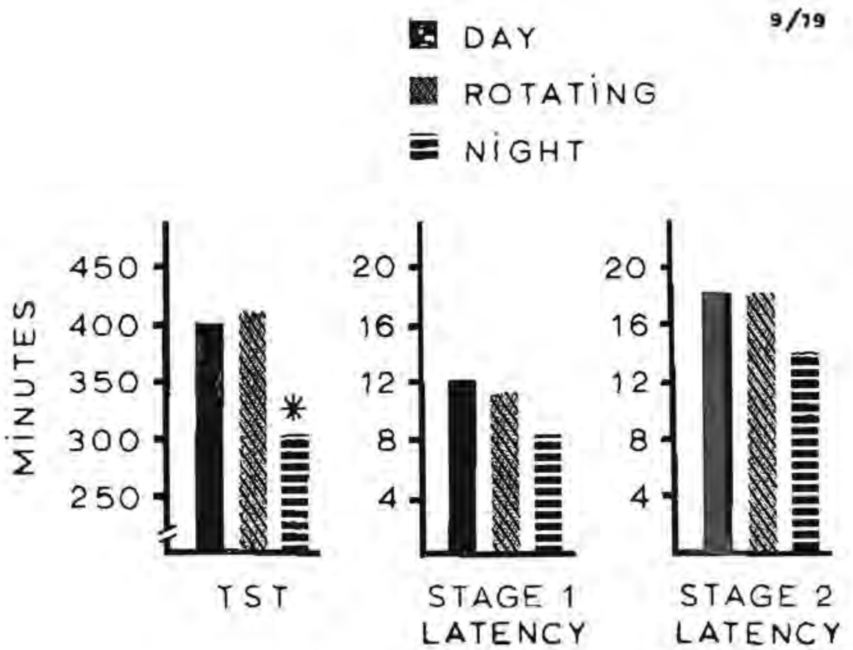

Figure 2. Left graph: Mean total sleep time (TST) for each shift group. Center Graph: Mean Stage 1 latency for each shift group. Right graph: Mean Stage 2 latency for each shift group. Asterisk indicates that TST for the night shift group was statistically different from both other shift groups ($p < .01$).

Figure 2 shows that they had a much lower TST, but latency to Stages 1 or 2 did not differ among shift groups.

Figure 3 displays EEG sleep stages as a percentage of TST. Night workers spent a greater percent of TST in SWS than did day or rotating shift workers. No other comparisons differed significantly. In absolute amounts, the night shift group had less Stage 1 and REM as shown in Figure 4. There was also a trend for night workers to spend fewer minutes in Stage 2.

Figure 5 shows that the night workers differed on two REM related measures. Night workers had a shorter mean REM latency and fewer REM periods during a sleep period. No difference in mean REM cycle duration was found. The average number of sleep stage transitions was also lower for night workers. However, the rate of stage transitions did not differ among groups (.263, .264 and .244 stage transitions per minute for day, rotating, and night shifts, respectively).

The mean hour by hour distribution of sleep stages for each shift group were also examined. Once again no differences were observed between the rotators and the day shift group. The night shift did have a significantly higher mean percentage of REM in the first hour of sleep than the other groups ($F = 6.01$, df-2.27; $p < .01$); the mean values were 13.8%, 0%, and 1.4% for the night, day, and rotating shifts, respectively. The schematic polysomnograms displayed in Figure 6 were derived from the mean hour by hour sleep stage distributions. These polysomnograms illustrate the temporal distribution of the sleep stages for each shift group.

Two phenomena which are atypical of normal nocturnal sleep did appear in the EEG recordings of certain night workers. The first was the occurrence of REM within 10 minutes of sleep onset in the records of two night workers. In the six sessions of these participants,three sleep onset REM periods (SOREMPs) occurred. Neither worker reported or displayed any manifestation of narcolepsy, a disorder characterized by SOREMPs. The second atypical observation was the frequent alternation between REM and Stage 2 in the records of two night workers. At times these alternations were so rapid that scoring became difficult.

Discussion

The EEG sleep characteristics of the day shift group are similar to the norms for adult sleep presented by Williams, Karacan, and Hursch (1974). The lone exception is the somewhat shorter TST of our day shift workers (400.8 min vs. 423.6 min).

The finding that rotating shift workers' sleep does not differ on any dimension from that of day workers could be interpreted as being inconsistent with subjective reports. Rotating workers report having difficulty falling asleep or staying asleep more often than do day workers (Tasto, Colligan, Skjei, & Polly, 1978;Tepas, Walsh, & Armstrong, this volume). It should be noted that the rotators in the present study participated in laboratory sessions while working either day or afternoon shift. Thus, their sleep had approximately the same circadian placement as did the sleep of the day workers. It is possible that the sleep of rotators differs from the normal nocturnal pat-

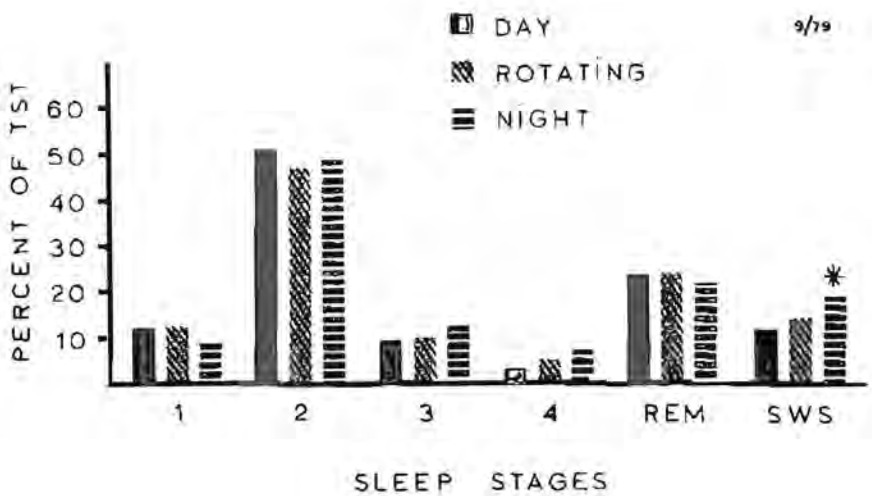

Figure 3. Sleep stages expressed as a percentage of TST for all three shift groups. Asterisk indicates that the night shift group had a significantly greater percentage of slow wave sleep (SWS) than did the day or rotating shift groups ($p < .05$).

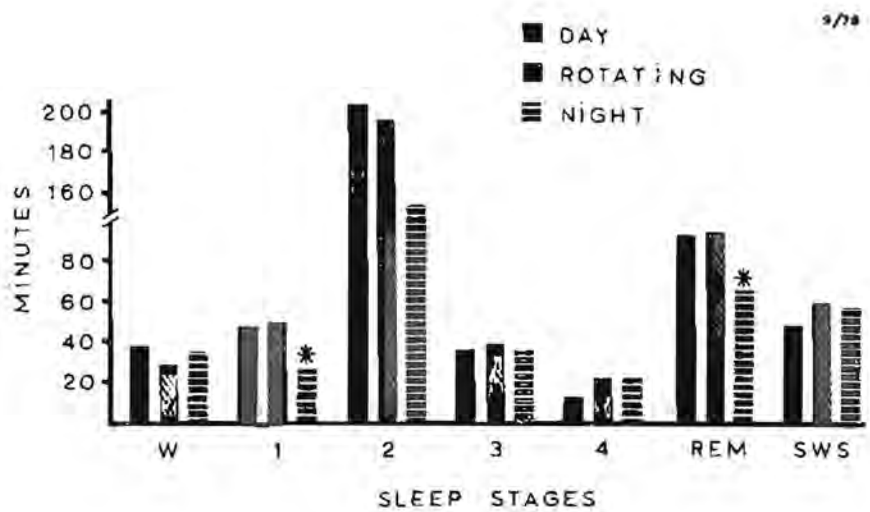

Figure 4. Mean number of minutes of each sleep stage for all three shift groups. Asterisks indicate that night workers had fewer minutes of both Stage 1 ($p < .05$) and REM ($p < .01$) than either the day or rotating shift groups.

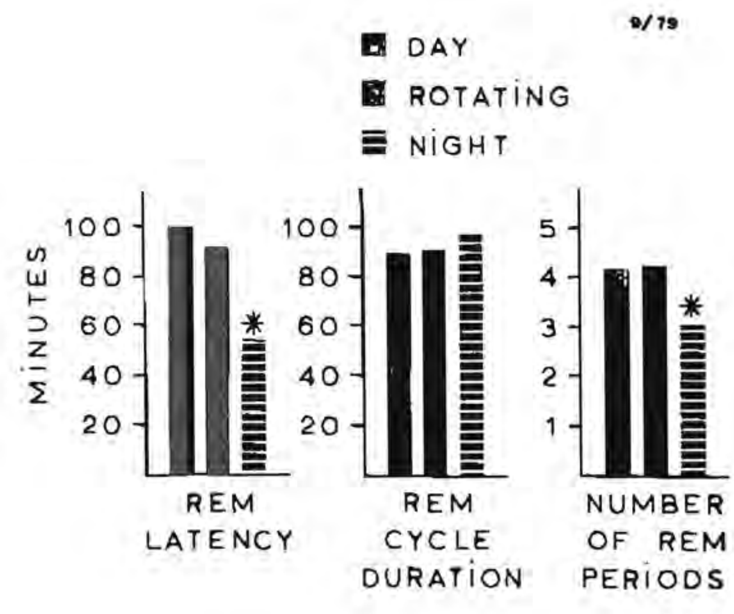

Figure 5. Mean REM characteristics for each of the shift groups. Asterisks indicate that night worker had a shorter REM latency ($p < .01$) and fewer REM periods ($p < .05$) than day or rotating shift workers. REM cycle durations did not differ statistically.

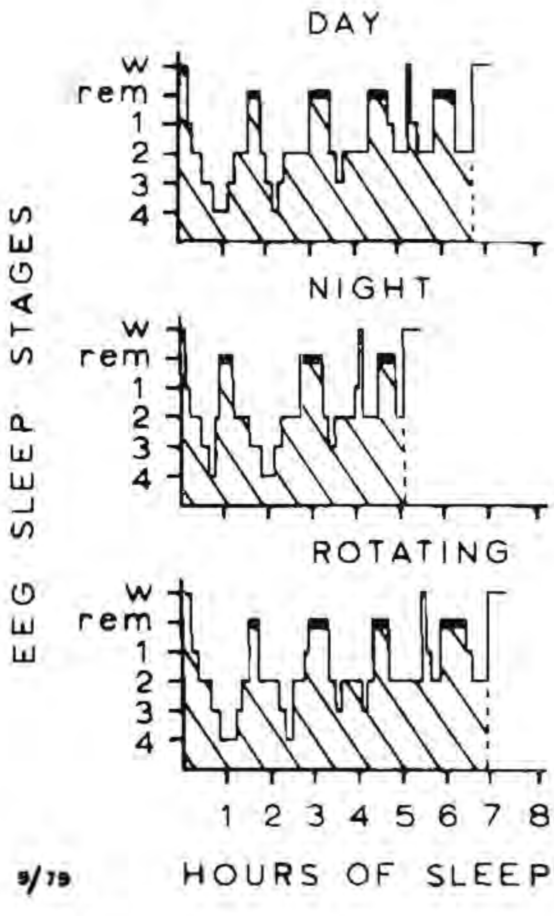

Figure 6. Schematic polysomnograms constructed from mean hour by hour distributions of sleep stages for each shift group.

terns only when they sleep during the day. Differences between the diurnal and nocturnal sleep structure of rotators reported in the literature might be attributable to the propensity for REM to occur in the early morning hours (Webb, 1971), the need or desire to participate in social activities during the daytime or a member of other factors. It is possible that rotators working on the night shift would increase their TST if social pressure to get up was removed (Webb & Agnew, 1975; Webb & Agnew, 1978). If this proposal is accurate, most reported differences between the diurnal and nocturnal sleep of rotators might be explained in a fairly direct manner. Reductions in TST may be a function of the need or choice to participate in social or family activities. REM latency decreases may result from having sleep onset occur in the morning when REM is most likely. Possible reductions in SWS or Stage 2 are the result of being displaced by REM early in the sleep period in conjunction with a shortened TST which prevents their total occurrence later in the sleep period. The subjective report that rotators have more difficulty sleeping may only be relevant to their sleep while on the night shift. Wyatt and Marriot (1953) for example, report that 83% of rotating workers feel most tired while on the night shift, and Östberg (1973) concluded that adjustment to the night shift was the most difficult for workers.

An alternative explanation for the similarity of sleep patterns for day and rotating workers in the present study is that the chronic nature of their shift history has resulted in an adaptation of sleep process while on the night shift, However, given the findings of Foret and Benoit (1974) reported above and the lack of evidence that our chronic night workers' sleep adapted in any major way, the former explanation seems more likely.

The sleep pattern of the night workers differed substantially from both day and rotating workers. The mean TST of just over 5 hours is remarkable especially considering the fact that only four of the ten night workers reported napping often. During the forty days of laboratory study of these night workers only five naps were reported and only one of these was more than one hour in length. Seven of ten night workers did not nap during the laboratory study. This low TST is fairly consistent, however, with reported sleep lengths of night workers (Tepas et al., this volume; Wyatt & Marriot, 1953) and EEG studies of worker's day sleep (Kripke et al., 1971; Rutengranz & Knauth, 1970).

Figure 6 displays schematic representations of average sleep periods for each of the three shift groups. In addition, to the obvious difference in TST, several sleep structure differences exist for night workers. The latency to the first REM period is reduced as is the average number of REM periods. Decreased REM latency may be related to early morning sleep onset, although one night worker in the present study who slept from 17:00 to 21:30 had a rather short average REM latency of 50 minutes. The decreased number of REM periods is probably a direct result of the shortened TST. Therefore, the differences in REM characteristics may be substantially attributable to the circadian placement of the sleep period and shortened TST.

The rapid alternation between Stage 2 and REM found for two of our night workers was reported for all 10 rotators examined by Kripke et al., (1971). Since most of the workers in that study were on night shift for a short period of time, this phenomena may be more prominent in the sleep structure of relatively inexperienced night workers. It should be noted, however, that both workers displaying Stage 2-REM alternations in this study had been on the night shift for between 1 and 2 years.

Previous studies of day sleep agree with the present data that TST and REM latency are reduced (Kripke et al., 1971; Rutenfranz & Knauth, 1970; Webb et al., 1971; Weitzman et al., 1970). However, these studies do not report greater SWS percentages. Furthermore, they suggest that Stage 1 amount may increase, whereas it decreased in the present study. It is difficult to explain these differences, however, they may be related to the difference in shift schedule duration. Certainly, a pattern of insomnia-like sleep is not present for either the night or rotating shift workers in this study.

In many ways, our night workers' sleep resembles that of persons undergoing partial sleep deprivation. Increased SWS percent, decreased REM latency, fewer minutes of REM and occasional SOREMPs have all been reported to be associated with chronic limitations of sleep length (Mullaney, Johnson, Naitoh, Friedman, & Globus, 1977; Webb & Agnew, 1974). Additionally, trends towards less time in Stages 1 and 2 are evident in both types of study. Perhaps chronic assignment to night shift results in a state of sleep deprivation. It is difficult to determine if the sleep structure differences observed in the present study are attributable to sleep deprivation, circadian effects, a combination of the two or some unknown factor(s).

A few methodological issues deserve mention in relation to the results presented. In most instances this study was conducted in a manner which maximized similarity between the participants' typical life and the laboratory schedule. All workers maintained their scheduled work hours and selected their sleep hours just as they would during home sleep. In this way the temporal relation of regular work, sleep, and leisure time activities was simulated quite accurately. Since small shifts in sleep-wake schedules may result in changes in sleep structure (Taub & Berger, 1973a) and performance and mood (Taub & Berger, 1973b) the maintanence of regular schedules is crucial in the assessment of shiftwork affects upon such variables.

The participants in the present study were workers reporting low drug use, infrequent off-the-job exercise and little difficulty sleeping. An examination of workers who do report sleep difficulty, a high level of drug usage or other extreme behaviors may result in different findings. Likewise, the use of sound attenuated sleeping rooms may have influenced our results. Shiftworkers commonly report being disturbed by noise when they sleep (Rutenfranz & Knauth, 1970) and noise levels were minimal during the laboratory sessions. Home sleep periods for our participants might be distrubed by noise although individuals seem to adapt to noise during sleep (Griefahn, 1977).

Concluding Remarks

It should be emphasized that our data do not suggest that rotating shifts are preferred to night shift. The lack of major sleep structure differences, as compared to day workers, may only reflect the fact that the present sample or rotating workers were assigned to day or afternoon shift while the laboratory sessions were conducted. An entirely different conclusion might be reached if chronic rotating workers were studied while working nights. For example, survey data indicate that rotating workers' sleep length varies depending upon the shift being worked (Tepas et al., this volume). To emphasize this point further, consider the actual sleep-wake behavior of our night workers. Most report that they revert to a nocturnal sleeping pattern on non-work days. In fact, most night workers do not have totally or chronically inverted sleep-wake patterns. Their work shift may be steady nights but their "sleep shift" is usually a rotating one--day sleep on workdays and night sleep on non-workdays.

In general, our results concur with the proposal that sleep stage characteristics are, to a large degree, determined by TST (Lubin, Moses, & Naitoh, 1977; Mullaney et al.,1977) and circadian placement of the sleep period (Webb, 1971). Previous research suggests that TST is a more important factor than individual sleep stages in the recovery or maintenance of waking performance (Johnson, Naitoh, Moses, & Lubin, 1974; Lubin, Moses, Johnson, & Naitoh,1974). Therefore, with regard to the differences in sleep structure reported here, it seems most appropriate to emphasize the greatly reduced TST of night workers.

The behavioral, physiological, and psychological consequences of years of limited sleep are unknown. Previous studies of performance and mood during and after weeks of partial sleep deprivation suggest no major decrements (Friedmann, Globus, Huntley, Mullaney, Naitoh, & Johnson, 1977; Webb & Agnew, 1974). Nevertheless, several reports have emphasized the low level of psychosocial and physical well-being of night workers (Åkerstedt & Torsvall, 1978; Koller, Kundi, & Cervinka, 1978), and at least one study implicates short sleep length as a consideration in mortality rate (Kripke, Simons, Garfinkel, & Harmond, 1979). Whether these factors are related to sleep restriction per se or other variables is yet to be determined.

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PROCEEDINGS

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Public Health Service
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THE TWENTY-FOUR HOUR WORKDAY: PROCEEDINGS OF A SYMPOSIUM ON VARIATIONS IN WORK-SLEEP SCHEDULES

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