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The Sleep and Performance of Shift Workers

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The sleep and performance of 12 male shift workers, operating a discontinuous, weekly alternating, three-shift system, were monitored over the course of one complete shift cycle. Compared with nocturnal sleep, day sleep was shorter in duration and was degraded in quality, and its sleep stages were temporally disrupted. Simple unprepared reaction time and four-choice reaction time were impaired at night, and simple reaction time deteriorated as a function of the number of days into the shift and the time on task. Sleep and performance changes can be primarily attributed to circadian factors; however, the deterioration in performance from night to night and with time on task is probably due to an accumulative sleep deficit. As far as sleep and performance are concerned, the best shift system is probably one having a short rotation cycle, with afternoon shifts or rest days preceding and following the night shift.

INTRODUCTION

Sleep disturbances and sleep problems are one of the major consequences of shift work, especially where night work is involved (for reviews and further information see Menzel, 1962; Aanonsen, 1964; Taylor, 1969; Andersen, 1970; Maurice, 1975; Agervold, 1976; Rentos and Shepard, 1976; Carpentier and Cazamian, 1977; Rutenfranz, Colquhoun, Knauth, and Ghata, 1977).

For technical and practical reasons, most studies of the sleep of shift workers have been confined either to questionnaire studies (e.g., Aanonsen, 1964; Tune, 1969; Foret, Bensimon, Benoit, and Vieux, 1981; Akerstedt and Gillberg, 1981; Akerstedt and Torsvall, 1981) or to laboratory-based studies (e.g., Kripke, Cook, and Lewis, 1971; Globus, Phoebus, and Boyd, 1972; Foret and Latin, 1972; Bryden and Holdstock, 1973; Foret and Benoit, 1974; Matsumoto, 1978; Tepas, Walsh, Moss, and Armstrong, 1981; Dalgren, 1981). In the first class of studies, one is obviously limited to general questions concerning the sleep of shift workers, whereas the second class of studies has the drawback of being conducted in the rather artificial and forbidding (for the shift worker) laboratory environment. To date, only two studies have attempted to record the sleep of shift workers in the home (Tilley, Wilkinson, and Drud, 1981; Akerstedt and Gillberg, 1981). The main aim of the present study, therefore, was to monitor and record the sleep of shift workers in their own homes.

The general, composite picture emerging from the aforementioned studies shows that shift work has the following main effects on sleep:

(1) A one- to two-hour reduction in the duration of the main sleep period for the night shift and a reduction of about one hour for a morning or early shift.

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(2) An increase in the total amount of sleep per 24 h, as compared with that of non-shift workers. This increase, however, can be attributed to long naps taken outside the main sleep period and increased sleep time on rest days. Both effects suggest a compensatory response to shorter main sleep periods.

(3) A change in the quality of sleep (i.e., more time awake, increased Stage 1, and sometimes reduced REM) and a disruption of the normal temporal organization of the sleep stages during daytime sleep.

Evidence from laboratory-based studies of sleep inversion (Agnew, Webb, and Williams, 1968; Weitzman, Kripke, Goldmacher, McGregor, and Nogeire, 1970; Webb, Agnew, and Williams, 1971; Berger, Walker, Scott, Magnuson, and Pollack, 1971; Taub and Berger, 1973), which have artificially mimicked the sleep/wake schedules of night-shift workers, and from studies of sleep following real or simulated transmeridian flights (Evans, Christie, Lewis, Daly, and Moore-Robinson, 1972; Klein, 1973; Endo and Sasaki, 1975; Moiseeva, Bogoslovsky, Simonov, and Tonkova, 1976; Ullner, Kugler, Torres, and Halberg, 1976; Klein, Wegmann, Athanassenas, Hohlweck, and Kuklinski, 1976; Endo, Yamamoto, and Sasaki, 1978; Hume, 1980; Athanassenas and Wolters, 1981) has been in general accordance with these findings, although most of these studies do not observe the shortened daytime sleep characteristic of shift workers. The reason for this may be that shift workers are on the whole considerably older than the students or young adults who are normally the subjects in the sleep inversion and time zone studies.

The root cause of the changes associated with daytime sleep stems from trying to sleep at a time of day when physiological arousal is rising and when the body is generally programmed to be awake and active.

A second major problem for shift workers, which again is directly related to their circadian rhythms, is the decline in performance capacity at night. Numerous studies and reviews have addressed this phenomenon (e.g., Browne, 1949; Bjerner, Holm, and Swensson, 1955; Chiles, Alluisi, and Adams, 1968; Colquhoun, 1971, 1972; Fort, Harrison, and Mills, 1973; Ostberg, 1973; Moses, Lubin, Naitoh, and Johnson, 1978; Glenville and Wilkinson, 1979; Illmarinen, Illmarinen, Korhonen, and Nurminen, 1981; Folkard and Monk, 1981). In many cases, the worker's performance capacity or efficiency may have only a marginal effect on safety and production. In certain other cases (e.g., pilots, transport drivers, air-traffic controllers, hospital staff, emergency service workers), however, it could be of great importance. For example, German studies of train drivers (Hildebrandt, Rohmert, and Rutenfranz, 1974, 1975) have shown a dramatic decline in performance capacity at night in the form of an increase in the number of emergency stops. Swedish studies (Akerstedt, Froberg, Levi, Torsvall, and Zamore, 1977) have shown that performance levels of night workers are comparable to those of daytime workers who have had one night of sleep deprivation.

For the most part, these nighttime performance deficits are a direct reflection of an underlying circadian rhythm that happens to reach its lowest levels at night. That is, irrespective of sleep/wake schedules, most aspects of performance will tend to be worse at night. This is not to say, however, that shift work will exert no additional influence on the level of performance. Many factors, such as task demands, the type of shift system, and individual differences will interact to determine "on-shift" performance (see Folkard and Monk, 1979; Folkard, 1981). There is also tentative evidence from a pilot study (Tilley, Wilkinson, and Drud, 1981) that an accumulating sleep debt during the course of the night-shift week exacerbates the circadian performance deficits observed at night.

The second aim of the present study, therefore, was to assess basic performance capacity during each shift by means of two portable performance tests administered at the place of work. The two tests employed for this purpose were a simple unprepared reaction-time test (Wilkinson and Houghton, 1982) and a four-choice serial reaction-time test (Wilkinson and Houghton, 1975), both of which have been shown to be sensitive to the effects of sleep deprivation (Glenville, Broughton, Wing, and Wilkinson, 1978) and lower performance levels at night (Glenville and Wilkinson, 1979).

METHOD

The study was conducted over a two-year period. Two groups of six workers (mean age 43, range 30 to 60 years) from Cadbury-Schweppes Limited, Cambridge, participated in the study. All worked a discontinuous, weekly alternating, three-shift system with shifts at the following times: morning shift (M), 0600-1400 hours; afternoon shift (A), 1400-2200 hours; night shift (N), 2200-0600 hours.

Each worker was studied for a period of three weeks, one complete shift cycle. Two workers served in each of the three-week shifts shown in Table 1.

During each worker's three-week shift cycle, two main factors were examined. First and foremost, 15 sleep recordings (5 per shift) were taken in the worker's home on each working day. One practice night during the weekend began the three-week session. (For details of equipment and technique see Campbell, Weller, and Wilkinson, 1979, and Campbell and Wilkinson, 1981). Briefly, the procedure involved a daily visit to the subject's home before bedtime to attach electrodes and check the equipment. After going to bed, subjects switched on the equipment, slept whenever they wished, got up whenever they wished, then switched off and removed the electrodes. Each worker completed the Stanford Sleep Scale both before and after sleep, and the Cambridge Sleep Questionnaire, which was completed when the subject awoke.

TABLE 1

Shift Schedules

	Week 1	Week 2	Week 3
	morning	afternoon	night
	morning	night	afternoon
Shifts	afternoon	morning	night
	afternoon	night	morning
	night	morning	afternoon
	night	afternoon	morning

The second aspect of the study involved measurements of basic performance capacity, taken at the factory. Two tests were employed for this purpose: a simple unprepared reaction-time test (SRT) and a four-choice serial reaction-time (4CH) test. They were administered approximately one hour before the end of each shift and were run for 10 min each. In order to confirm circadian rhythms, six of the workers also had their oral temperatures taken at this time.

RESULTS

Sleep

The study provided 180 sleep records, recorded on magnetic tape, giving a weekly sleep profile for each shift based on 60 sleep records. The sleep tapes were scored automatically using a hybrid, computer-based system (for details see Campbell, 1981, and Campbell and Wilkinson, 1981) that gives a good approximation of human visual scoring (Campbell, Kumar, and Hofman, 1980). As a further check of the system's validity, a number of randomly selected records were transcribed onto a paper chart and were visually scored according to conventional procedures (Rechtschaffen and Kales, 1968). Agreement was better than 80%. In addition to saving considerable time and effort, the automatic system also has nearly perfect internal consistency, which particularly lends itself to comparing sleep profiles from a within-subject experimental design.

Table 2 summarizes the sleep profiles on a week-to-week shift basis and gives the results of a number of statistical comparisons.

Quantity of sleep. The daytime sleep periods for the night-shift (mean 5.14 h) are more than 1.5 h shorter than the nighttime sleep periods for the afternoon-shift (mean 7 h). This represents a highly significant ($p < 0.001$), 25% reduction in sleep time.

Compared with the afternoon shift, the duration of the nocturnal sleep of the morning shift (mean, 6 h) is also significantly reduced, by about one hour ($p < 0.01$). This is due to the enforced earlier hour of awakening demanded by the early start of the morning shift.

Quality of sleep. In absolute terms (i.e., the number of minutes spent in each sleep stage) there were significant differences among the three shifts with respect to the relative time subjects spent in the various stages of sleep, i.e., waking (Stage W), light sleep (Stage 1), transition (Stage 2), slow-wave sleep, or SWS (Stages 3 and 4), and rapid-eye-movement (REM) sleep. Comparisons (Scheffé's method, see Winer, 1971) between pairs of shifts, shown in Table 2, revealed that these overall differences, particularly the SWS changes, are large attributable to differences between night sleep and day sleep.

In relative terms (i.e., the number of minutes spent in each sleep stage as a percentage of sleep-period time) the only overall statistically significant differences between shifts were with respect to Stage W and SWS. Comparisons between pairs of shifts again re-

TABLE 2

Sleep Measures for Each Week during One Cycle of a Weekly Alternating Three-Shift System

	Shifts			*Statistical Tests*				
	Morning	*Afternoon*	*Night*	*F*		*Sheffé (p)*		
Sleep Measures	(M)	(A)	(N)	(2,22)	*p*	M vs. A	N vs. M	N vs. A
Sleep Period Time (min)	360.0	420.7	314.1	39.3	0.001	0.001	0.001	0.001
Sleep Latency (min)	12.4	14.5	11.5	1.6	n.s.	n.s.	n.s.	n.s.
Stage W (min)	2.7	4.0	9.9	7.6	0.01	n.s.	0.01	0.05
Stage 1	20.4	36.6	31.3	3.4	0.05	0.01	n.s.	n.s.
Stage 2	117.1	209.1	143.9	21.4	0.001	0.001	0.001	0.001
Stage 3	40.5	36.2	23.3	10.4	0.001	n.s.	0.001	0.001
Stage 4	40.1	37.2	26.1	4.0	0.05	n.s.	0.01	0.05
Stage 3 + 4 (SWS)	80.6	73.2	51.5	8.1	0.01	n.s.	0.001	0.01
Stage REM	79.1	98.3	77.3	11.1	0.001	0.001	n.s.	0.001
Sleep Period Time (percentage)								
Stage W	0.7	1.0	3.3	7.8	0.001	n.s.	0.001	0.001
Stage 1	5.7	8.9	10.1	3.0	n.s.	n.s.	0.05	n.s.
Stage 2	49.1	50.5	45.8	2.7	n.s.	n.s.	n.s.	0.05
Stage 3	11.3	8.5	8.1	6.6	0.01	0.01	0.001	n.s.
Stage 4	11.2	8.8	8.1	2.3	n.s.	n.s.	0.05	n.s.
Stage 3 + 4 (SWS)	22.5	17.2	16.2	4.9	0.05	0.01	0.01	n.s.
Stage REM	21.9	23.3	24.5	2.1	n.s.	n.s.	0.05	n.s.

vealed that these differences are mainly differences between night and day sleep.

Referring to Figure 1, the general electrophysiological profile is one of lighter, more fragile sleep during the daytime (increased, faster frequency EEG desynchronization) and deeper sleep at night (intensified slow-wave EEG synchronization).

Temporal organization. In daytime sleep the temporal organization of the sleep stages is severely disrupted. Figures 2 and 3 show the distribution of REM and SWS sleep as a percentage of the total REM and SWS time occurring in each third of the sleep period.

As can be seen in Figure 2, REM sleep is more evenly distributed throughout daytime sleep when workers were on the night shift than when they worked the afternoon or morning shifts. Also, the development of REM tends to be reversed; the level of REM declines as sleep progresses during the day. This is in sharp contrast to the normal course of development exhibited in the nocturnal sleep of the two day shifts, in which the level of REM *increases* with sleep time. This interaction is statistically significant, $F(4,44) = 6.36, p < 0.001$.

When workers were on the afternoon or morning shifts, the distribution of REM sleep during their nocturnal sleep shows some minor differences, with slightly more in the first third of the night and slightly less in the latter two-thirds of the night for the morning shift.

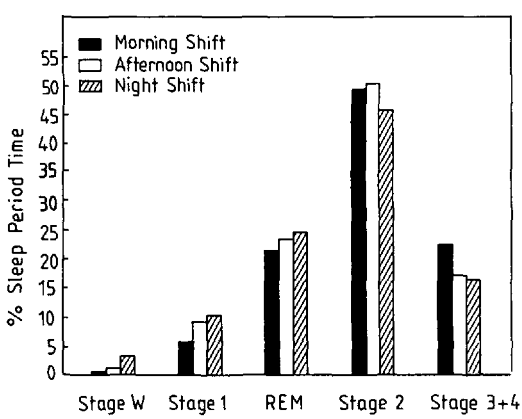

Figure 1. *Sleep quality by stages as a percentage of sleep period time for each of the three shifts.*

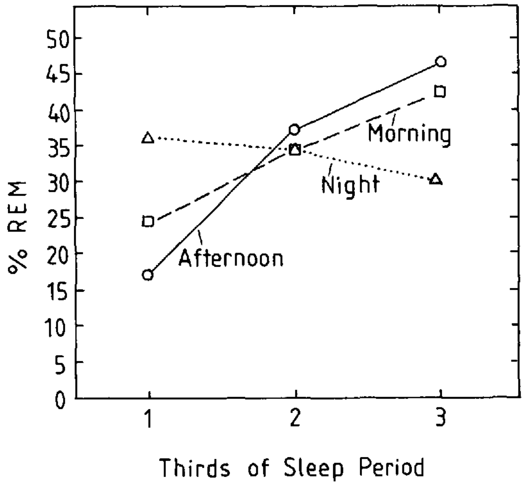

Figure 2. *Percentage of total REM time occurring during each third of the sleep period.*

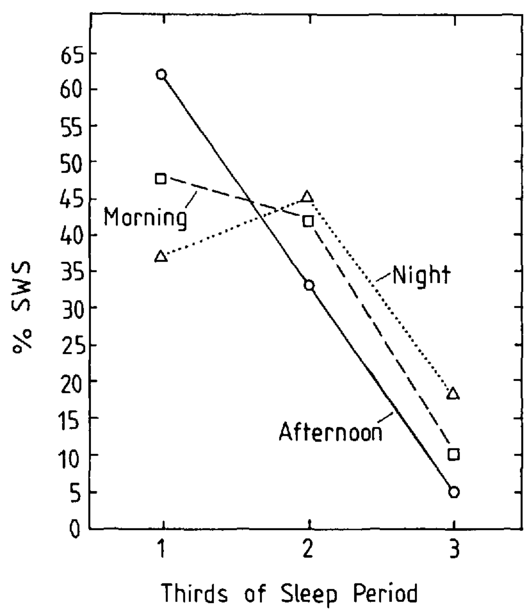

Figure 3. *Percentage of total SWS time occurring during each third of the sleep period.*

The distribution of SWS also shows changes from shift to shift. Under normal conditions, in which sleep occurs at night, SWS is concentrated in the first third of the sleep period and rapidly declines thereafter. This normal pattern is clearly demonstrated by the SWS distribution in the nocturnal sleep of the afternoon shift (see Figure 3). During daytime sleep, however, SWS appears to have been displaced towards the middle of the sleep period, probably by the circadian insurgence of REM.

When on the morning shift, workers appeared to display a subtle adjustment to the pattern of SWS distribution in their nocturnal sleep. Compared with that of the afternoon shift, the level of SWS is slightly less in the first third of the sleep period. This is due to a small increase in the duration of the first REM period, but the pattern recovers in the second and third portions of the night. In fact, the absolute quantity of SWS is actually higher for workers on the morning-shift, despite their shorter sleep period.

Subjective sleep quality. The two sleep questionnaires showed that sleep quality and feelings of well-being before and after sleep were rated significantly worse by night-shift workers (sleep quality: $\chi^2 = 11.2, p < 0.01$; pre-sleep well-being: $\chi^2 = 7.9, p < 0.02$; post-sleep well-being: $\chi^2 = 6.2, p < 0.05$). The shift workers feel more tired before and less refreshed after day sleep than before and after night sleep. There were no discernible differences between subjective assessments of the sleep associated with the afternoon and morning shifts.

Performance

Simple unprepared reaction time. Figure 4 shows the mean reaction time for the whole test on the five days of each shift. Reaction times are significantly slower when workers were on the night shift than on either of the two day shifts, $F(2,22) = 3.55$, $p < 0.05$). In addition, SRT performance tends to deteriorate over the course of the week during the night shift, whereas it remains fairly stable over the course of the week during the afternoon and morning shifts; however, this effect is not statistically significant, $F(8,88) = 1.62$, $p > 0.05$).

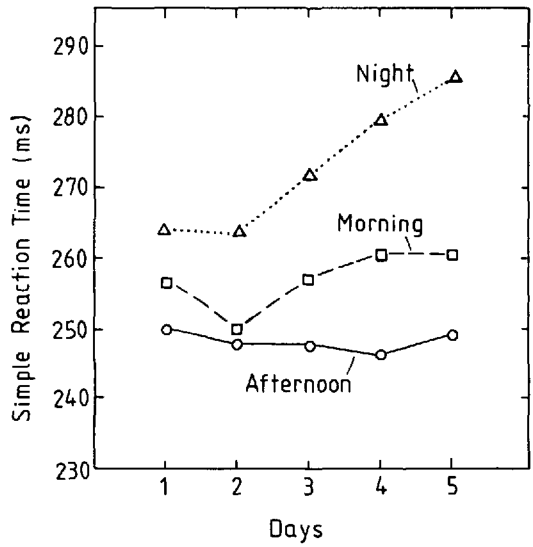

Figure 4. *Simple reaction time on each day of the three shifts: whole test.*

Splitting the test into two halves gives more details of the nature of nighttime performance deficits. During the first half of the test (Figure 5), the deterioration in SRT performance over the course of the week is far less dramatic than during the second half of the test (Figure 6), when the deterioration becomes significantly different from the relatively stable performance levels of the other two shifts, $F(8,88) = 2.64$, $p < 0.05$). This suggests that simple reaction time will become poorer with successive nights on the night shift as the task duration increases. This is especially true after the second night.

Four-choice serial reaction time. On this test, mean RT and error rates were measured. The results are presented in Figures 7 and 8.

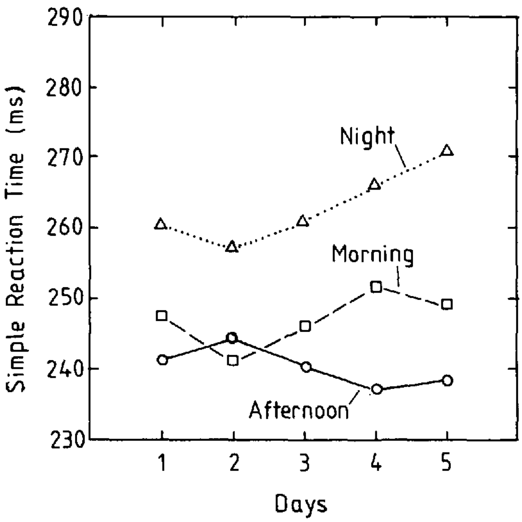

Figure 5. *Simple reaction time on each day of the three shifts: first half of test.*

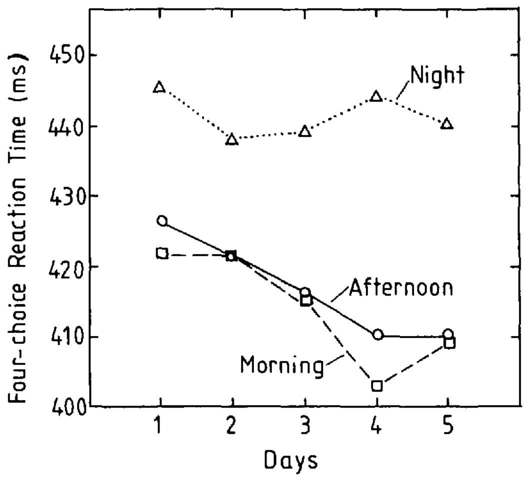

Figure 7. *Four-choice serial reaction time on each day of the three shifts.*

Although the overall reaction time on this task is always slower for the night-shift workers, the effect is not statistically significant, $F(2,22) = 1.75, p > 0.05$). There was also no significant effect with respect to days, $F(4,44) = 1.58, p > 0.05$) or for shifts × days, $F(8,88) > 1$. The lack of statistical significance may be partly due to the unusually large individual differences in performance on this task in this particular study. The task is susceptible to a speed-accuracy trade-off. Although instructed and encouraged to respond as quickly as possible, some subjects opt for a strategy of accuracy at the expense of speed in order to ensure that they make as few errors as possible. This

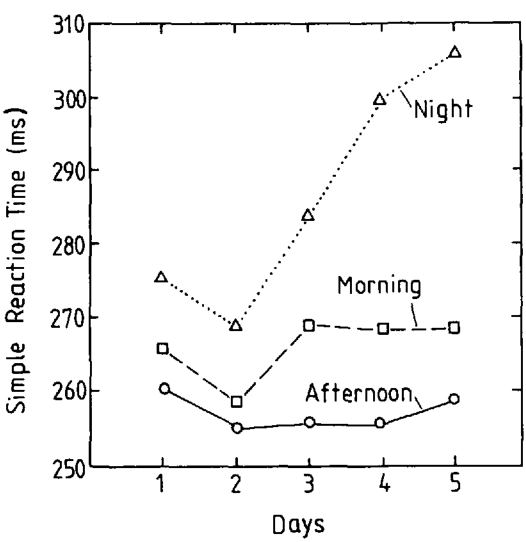

Figure 6. *Simple reaction time on each day of the three shifts: second half of test.*

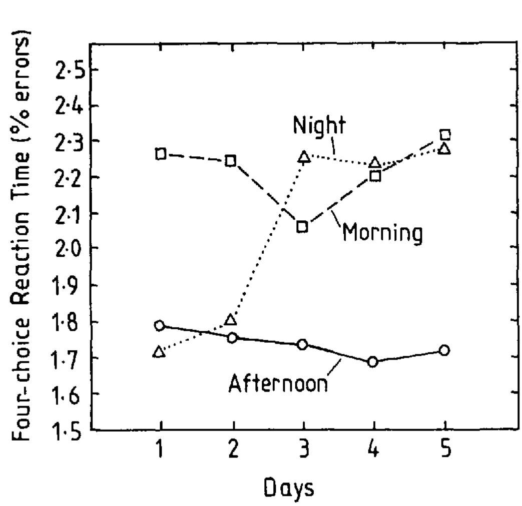

Figure 8. *Four-choice serial reaction time: percentage of errors on each day of the three shifts.*

is particularly true at night, when they are aware of flagging performance efficiency. This strategy tends to increase subject variability; however, a less stringent, nonparametric test (Friedman's two-way ANOVA, Siegal, 1956) does reveal a significant difference in reaction time among shifts, $\chi^2 = 6.2$, $p < 0.05$).

Unfortunately, unlike the SRT test, the 4CH test exhibits substantial and protracted practice effects which, despite the counterbalancing of shift order and practice sessions at the beginning of the three-week study period, probably account for the small day-to-day improvement in performance on this task over the course of the week during the morning and afternoon shifts. No sign of any improvement in performance over the course of the night-shift week is apparent, however, and this may be a net result of the underlying deterioration in performance at night (exhibited by the SRT results) counteracting practice effects.

For error rates, there was no significant main effect of shifts, $F(2,22) = 1.87, p > 0.05$, nor was there an interaction of this factor with days, $F(8,88) < 1$, despite the jump in error rate between Day 2 and Day 3 for the night shift. Once again, relatively wide individual differences are partly responsible for the lack of any statistically significant effects.

Body Temperature

Figure 9 shows the mean body temperature, taken orally immediately after the performance tests, for each day of each shift for six workers. Body temperature was significantly lower at night than during the day, $F(2,10) = 51.2$, $p < 0.001$. More importantly, however, there was no sign of adaptation or change in body temperature during the week of the night shift.

DISCUSSION

This study has shown that there are significant changes in the quantity and quality of sleep as a consequence of shift work and that reaction time is impaired and deteriorates as a function of days into the shift and time on task while working at night.

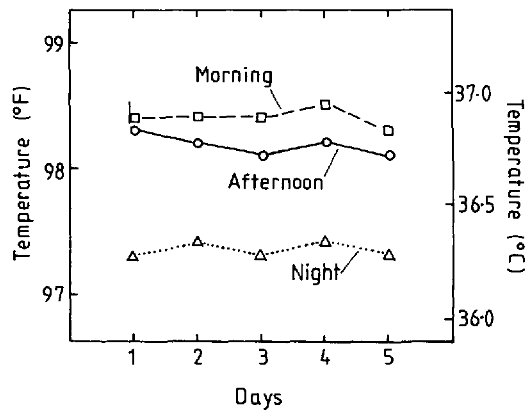

Figure 9. *Body temperature on each day, one hour before the end of each shift.*

Compared with the afternoon shift, during which sleep time is potentially unrestricted, there is a 25% reduction in the amount of sleep for the night shift and 15% for the morning shift. For the latter, the reduction can be entirely attributed to workers' getting up earlier in the morning while maintaining their usual bedtime. The duration of daytime sleep on the night shift, however, appears to be primarily determined by circadian factors. Despite longer hours of prior wakefulness and being initially more tired before going to bed, the shift worker on nights invariably gets up around noon, even though the opportunity exists for staying in bed.

These findings would seem to amount to a net sleep loss for workers while on the night and morning shifts. However, the duration of the main sleep period is probably confounded by shift workers taking afternoon or evening naps and sleeping longer on rest days (Tune, 1969; Dalgren, 1981). Many of the shift workers in our study also claim to take naps in the afternoon or evening during the week of the night and morning shifts, particularly the night shift. This may have reduced the "need" for longer main sleep periods. On the other hand, the very existence of a napping habit strongly implies that this is some form of compensatory response to quantitatively (and for the night shift, qualitatively) inferior main sleep periods. Sleep deprivation, therefore, must still be considered as a potential problem for shift workers, especially if it means that they have to take naps. Moreover, there is the question of just how equivalent periodic napping is to a single, unbroken sleep period. This question is particularly pressing with respect to the quantity and quality of daytime sleep as compared with nighttime sleep. But first, what are the consequences of shortened nighttime sleep for workers on the morning shift?

The reduction in the duration of sleep for the morning shift has certain predictable effects, i.e., an overall increase in SWS and slightly increased REM levels in the first third of the night. These are probably due to a complex interaction of two interrelated factors, longer hours of prior wakefulness and partial REM deprivation, effected by the same cause. To appreciate this interaction, it is first necessary to restate some of the "laws" governing sleep.

First, the natural distribution of the sleep stages is such that SWS is concentrated in the early part of the night and REM in the latter part (see Agnew, Webb, and Williams, 1967). Second, the propensity for REM sleep is primarily circadian in character (Webb and Agnew, 1967; Hume and Mills, 1977), whereas the propensity for SWS is largely determined by the amount of prior wakefulness and will increase following partial or total sleep deprivation (Berger and Oswald, 1962; Webb and Agnew, 1965). Third, selective deprivation of either stage results in an increase in that stage during subsequent "recovery" sleep (Dement, 1960; Agnew, Webb, and Williams, 1964).

Now, compared with working the afternoon shift, working the morning shift typically entails getting up much earlier. Out of habit and for the sake of domestic convenience, however, workers go to bed at roughly the same time for both shifts. The net result is longer hours of prior wakefulness and hence the increase in SWS. This is combined with a limitation on that portion of the night during which REM sleep would normally predominate and hence the small reduction in the amount of REM at this time (see Figure 2). Apparently, the response of the sleep system would be to give overall priority to obtaining a full quota of SWS with some allowance for REM "recovery" at the beginning of the night in the form of a slightly longer first REM period, although the total amount of REM obtained during the night is actually reduced. This reaction offers good testimony to the flexibility of the sleep system to respond and cope with relatively minor intrusions (e.g., a reduction in the sleep period), providing that sleep occurs at night rather than during the day.

The quality of daytime sleep, however, is quite a different matter. Unlike the nocturnal sleep of the morning shift, daytime sleep is apparently unresponsive to sleep loss. In general, day sleep tends to exhibit more desynchronized, fast-frequency EEG activity (Stage W, Stage 1, and REM) and reduced SWS. The increase in Stage W and Stage 1 (light sleep) are symptomatic of the fragile and unstable nature of daytime sleep, offering a sharp contrast to the integrated, smooth progression of the enhanced, synchronous sleep of the morning shift. This illustrates the circadian struggle against sleeping at an inappropriate time.

The most telling disturbance to the quality of daytime sleep, however, is in terms of its temporal organization. In general, REM sleep becomes more evenly distributed throughout the sleep period with a tendency for the level of REM sleep to decline rather than increase as sleep unfolds. (See Figure 2.) The effect on

SWS is to displace it slightly towards the middle of the sleep period. (See Figure 3.) These changes are very similar to those observed in a recent study of newspaper typesetters who sleep during the day while working nights on a weekly rotating, two-shift system (Dalgren, 1981). The effects are due to a combination of the circadian character of REM, which has remained on a normal sleep-wake schedule and shows no signs of adjustment to the inverted regime, and to an inability on the part of the sleep system to respond appropriately to longer hours of prior wakefulness (i.e., by failing to increase SWS, when sleep occurs at the "wrong" time).

Reaction-time performance also suffers as a result of night work, at least as demonstrated by the two simple reaction-time tests employed in the present study. This is not to say that shift workers are *necessarily* worse or less efficient at their particular jobs, but it is more likely that they are, since speed of reaction is a component of many practical tasks. Safety may also be jeopardized by impaired reaction times.

Of course, the observation that performance is impaired at night is not a new finding. It is well known that most aspects of performance are worse at night (see Colquhoun, 1971, 1972). However, the present study has also indicated that the primary circadian performance deficit appears to be exacerbated by a secondary loss-of-sleep effect. The level of performance at night deteriorates as sleep loss accumulates during the week (approximately 1.5 to 2 h per day) and with time on task. In effect, by the end of the night-shift week, the shift worker has lost the equivalent of at least one night's sleep. The deterioration in performance also suggests that even if night-shift workers are taking more or longer naps in an attempt to make up for lost sleep, they are not, in fact, avoiding or repaying the accumulative sleep debt.

These performance deficits are remarkably similar in nature to those observed following sleep deprivation (see Wilkinson, 1965; Johnson, 1973; Naitoh, 1976), and they concur with the findings of a previous study of shift workers that employed the same performance tests (Glenville and Wilkinson, 1979). Furthermore, the effects do not appear to be due to any shift or adjustment of the circadian rhythm, since body temperature, which normally reflects the circadian performance rhythm (but see Wilkinson, in press) shows no sign of any adaptation over the course of the week during the night shift. Again, this is in keeping with previous findings. It is normally only permanent night workers who exhibit any signs of adjustment in the circadian temperature rhythm, and even then the response is only a transient one, in the form of a flattening of the temperature curve (see Colquhoun, 1971, 1972; Dalgren, 1981).

In conclusion, the present study has clearly demonstrated that the quantity and quality of sleep is degraded and performance is impaired and deteriorates as a result of working at night. These changes are primarily caused by the disharmony between the night worker's schedule and the underlying circadian rhythms of the body. The two are completely out of phase. The night-shift worker must sleep and work at times when his or her body is least able to perform either activity efficiently. The body is programmed to be awake and active by day and asleep and inactive by night, and it is extremely difficult to adjust this program in order to accommodate artificial phase shifts in the sleep-wake schedule. It is this resistance to displacement and the slow rate of change by the circadian rhythm that presents the major psychobiological stumbling block to night work. In fact, if night work is discontinuous or nonpermanent, as typifies most shift-work systems, then the capacity for adequate adjustment is extremely limited. From the point of view of sleep and performance, therefore, the best compromise is probably a short-rotation shift cycle with afternoon shifts or rest days preceding and following the night shift. Under this type of system, the loss of sleep experienced during the night shift is only allowed to build up over a relatively short period and will be recovered during the next nocturnal sleep period. This will also circumvent the deterioration in performance levels over successive nights (particularly after the second night), which is probably due to an accumulating loss of sleep.

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