

## CIRCADIAN "PROFILE" OF SHORT AND LONG SLEEPERS

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This study of the biorhythmic characteristics of naturally long and short sleepers was based on the hypothesis that the two types would show different responses to an abrupt change in the wake-activity cycle. We were hoping that, if found, these differences would account for the large discrepancies we had found in individual sleep behavior in studies on shiftwork. But there are many different reasons for being interested in long and short sleepers.

### Description of Sleep Patterns

Definitive data in this area have been published by Webb and Agnew (1970) and Hartmann, Baekeland, Zwillig, and Roy (1971). Other cases of extreme "healthy insomnia" have been reported (Jones & Oswald, 1968; Meddis, Pearson, & Langford, 1973; Stuss & Broughton, 1978; Velok, Passouant, Cadilhac, & Baldy-Mouliner, 1968). One of the clearest results is the constancy of the percentage of paradoxical sleep (PS). Figure 1 shows that if one compares PS amounts of short and long sleepers studied by various authors in various situations, the "need of PS" is almost perfectly linearly correlated with the total sleep time. This constancy seems to contradict the theory that need of PS depends on psychological and behavioral variables (Hartman, 1973).

Of course, the question of sleep need (Hartmann et al., 1971) was implicit in all the above mentioned studies. Studies of spontaneously extremely long and extremely short sleep have, in fact, made it possible to assess the constancy of the sleep requirement. The most striking result was the similarity of SWS amount (Stage 3 + 4) in sleeps of varying duration observed among naturally extremely short sleepers. Surprisingly enough, very few studies have been devoted to naturally short sleepers, perhaps because such people seem to be more difficult to find than naturally long sleepers, as demonstrated by the results of a study concerning the sleep of young students (Merle, 1979) (Figure 2).

Another possible approach is to regard the wake-sleep alternation as a circadian biological rhythm. Although the various and complex relationships between sleep and other biological rhythms (including those in both physiological functions) have been extensively documented, many of the studies were based on artificial modifications of the circadian rhythm (typically, lengthening of activity by sleep deprivation, or phase shifting by time-zone crossing or shiftwork). The purpose of these studies was to determine the ways in which the various biological rhythms respond to an abrupt change of the basic wake-sleep alternation. It seemed to us of considerable interest to study the characteristics of the biological rhythms in cases of spontaneously exceptional wake-sleep ratios.

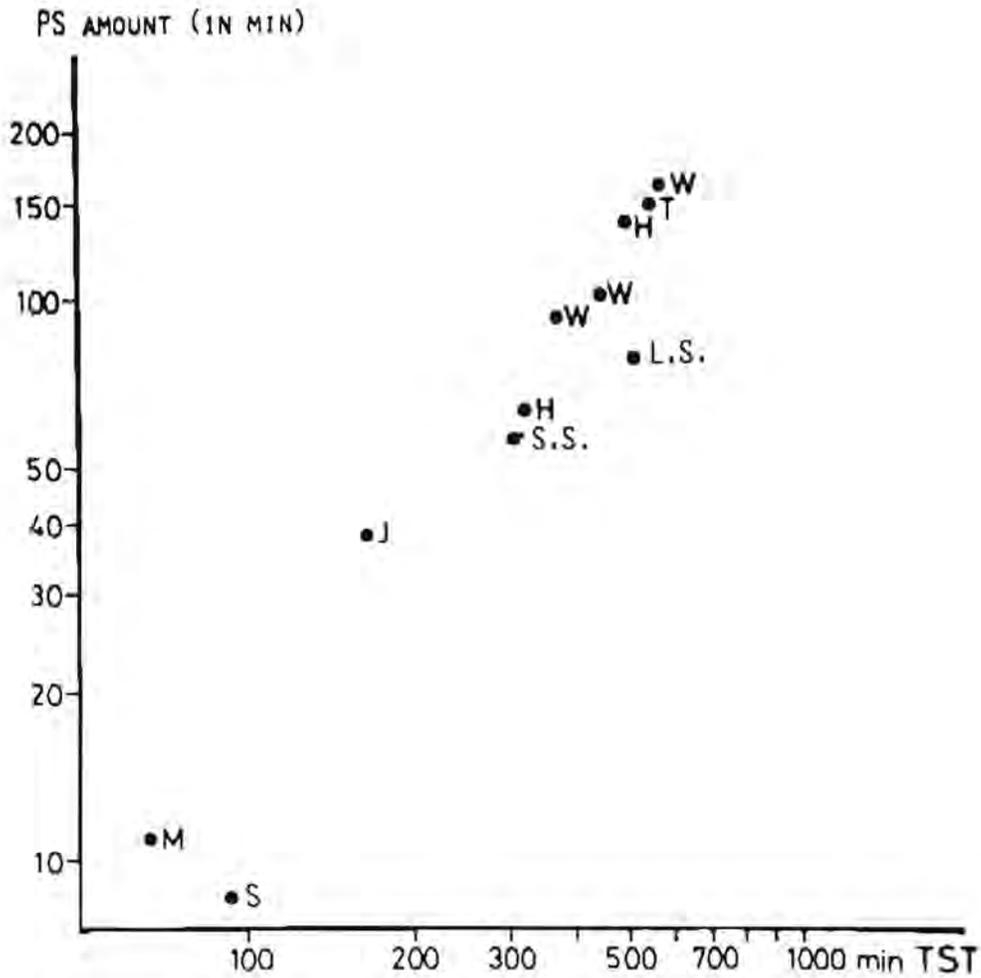


Figure 1. Duration (in minutes) of PS as a function of total sleep time (TST). M: Meddis et al. (1973); S: Stuss and Broughton (1978); J: Jones and Oswald (1968); H: Hartmann et al. (1971); W: Webb and Agnew (1970); T: Taub and Berger (1976b); LS and SS: the present study.

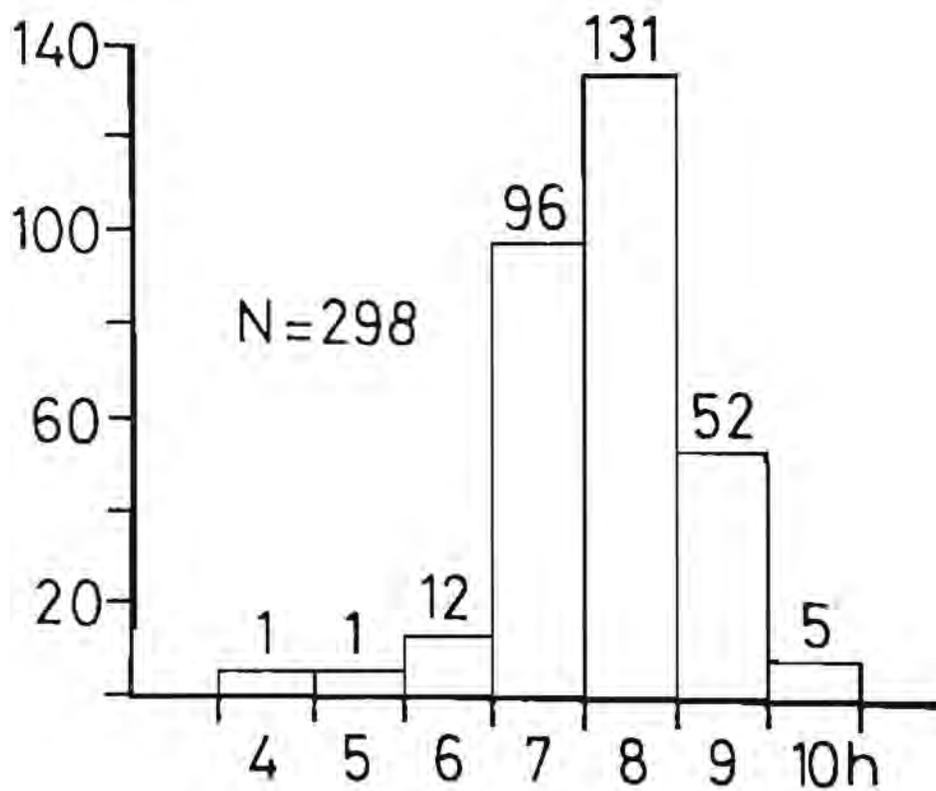


Figure 2. Frequency distribution of sleep durations (self-estimated) in a population of 310 students (age range: 19-24 years) (there were 12 non-responders).

A number of papers have been published on the transitory effects on physiological and performance measures of sudden changes in working schedules, as in shiftwork. They cover changes in sleep structure, body temperature, heart rate, self-rated mood, and many psychological variables (Colquhoun, 1972; Colquhoun, Folkard, Knauth, & Rutenfranz, 1975; Foret & Benoit, 1978a; 1978b; Merle, 1979). Essentially, there are two kinds of change: (a) when subjects go from day shift to night shift (this involves one sleep-deprived night), and (b) when they revert to day shift after a night shift period (in this case, two sleep periods—a morning and a night sleep—typically occur on the same day). In both situations, the variation of physiological and psychological responses (in particular, as regards sleep) is very large, even when environmental and other parameters such as type of task, socio-economic conditions, age, experience of shiftwork, etc., are not dissimilar.

This variation has not, as yet, been satisfactorily explained. It supports the hypothesis that there is a large natural variation in biological rhythms (including sleep). In relation to shiftwork, the important needs are (a) to achieve an appropriate description of this variability, and (b) to determine which parameters influence it most.

Several sleep-related factors have been suggested as partial mediators of the interindividual variability of responses to shiftwork. In particular, the factor "morningness-eveningness" has been emphasized. This factor has been held to correlate with the degree of extraversion-introversion (Blake & Corcoran, 1972; Hartman, Baekeland, & Zwillig, 1972). But the results remain controversial (Webb & Friel, 1971; Horne & Ostberg, 1977). The degree of extraversion-introversion is likely to influence circadian patterns of activity (reflected by the circadian rhythm of body temperature): "evening types" do, in fact, have significantly later peak times than "morning types". However, the degree of morningness is not correlated with sleep length, though Tune (1969) concluded that extraverts sleep less than introverts.

In summary, although some overall trends have been identified, it is very difficult, if not impossible, to draw clear-cut conclusions about the interrelationships between introversion-extraversion, morningness-eveningness, and long sleep-short sleep. On the other hand, the amplitude of certain circadian rhythms has recently been shown to be an important factor in the biorhythmic behavior of individuals subjected to an abrupt change of schedule (Reinberg, Vieux, Ghata, Chaumont, & Laporte, 1978). Indeed, this factor has been proposed as a predictor of the ability to adapt to shiftwork. But it is, as yet, not known to what extent the amplitude of, for instance, the body temperature rhythm is correlated with the other parameters previously mentioned: degree of extraversion, natural sleep length, and "morningness".

In addition to the studies already mentioned, the factor natural sleep length has also been investigated, in connection with the results of sleep deprivation studies (Taub & Berger, 1976a). Thus, one of the interests of the present study is the opportunity it affords to compare the effects on performance and mood of sleep deprivation in exceptionally long or short sleepers with those reported for normal sleepers.

## Methods

The selection of long and short sleepers started with a survey of sleep length (SL) in a large population of students (N=310) with a small age range (20-24 years). Following this, 71 subjects who appeared to be short and long sleepers were selected. This sample consisted of 14 short sleepers (SL<7h) and 57 long sleepers (SL>9h).

We shall not discuss here the controversial question: were we dealing with real short and long sleepers? As Webb (1979) suggested, we simply regarded sleep length as the independent variable. Nevertheless, the asymmetry of the population is to be noted. In other words, it seems much easier to find long sleepers than short ones.

An interview followed, in order to eliminate subjects who:

- clearly had irregular sleep patterns;
- reported having had serious sleep troubles in the past;
- complained about their sleep;
- were under psychotherapeutic treatment;
- were using hypnotics or stimulant drugs (other than coffee or vitamin C in moderate amounts);
- had had accidents, or were suffering from pathological conditions likely to affect EEG or sleep (e.g., diabetes, exceptional weight or stature).

The remaining 40 subjects were asked to complete a sleep log for two weeks. From these logs, we chose the 10 with the shortest and the longest sleep lengths (i.e., about 3% of the original population) for the experiment. There were 5 short sleepers (2 women and 3 men) with a mean SL of 6h 10 min (S.D. 40 min) and 5 long sleepers (2 women and 3 men) with a mean SL of 8h 50 min (S.D. 60 min). The age range was 20-23 years.

Two levels of measurements were made:

- (a) sleep recordings by conventional, well-standardized methods such as EEG, eye movements, muscle tonus, and body movements.
- (b) measurements of circadian rhythms in heart rate (after 15 min rest when awake, and continuously during sleep recordings), axillary temperature, self-estimation of mood (using a 10 cm line, of which the extremities represented best and worst moods), and self-estimation of vigilance on a five-point scale.

The experimental procedure was as follows:

First Session: -(successively)

- two baseline nights (subjects went to bed and got up when they wanted (REF));
- one sleep-deprived night;
- one recovery night (that is, after 36 h wakefulness (RECOV 36)).

Second Session: -(successively)

- one baseline night (REF);
- one sleep-deprived night;
- one morning recovery sleep (that is, after 24 h wake-

fulness (RECOV 24));  
-one recovery night (RECOV).

During the whole experiment, the subjects maintained most of their daily habits, in particular concerning food intake (type and timing) and sleep habits.

## Results

### Sleep

Table 1 summarizes the data obtained from the long sleepers (LS) and short sleepers (SS). In the reference conditions, the differences between LS and SS are accounted for mainly by light sleep (Stage 1 and Stage 2) and by PS. The most striking similarities between the two groups are the relative amount of PS (17.2% in SS, 16.1% in LS) and the absolute amount of SWS (116 min in SS, 110 min in LS).

It has been suggested by Verdone (1968) that SS have a more "efficient" sleep than LS. We computed the same index as Verdone, i.e., the ratio of the sum PS + SWS to the total sleep time (TST) (Figure 3), and confirmed that SS were in fact more "efficient", not only in normal sleep, but also in recovery sleep.

Figure 4 shows the hour-by-hour distribution of "intervening wakefulness", which appeared to be regularly distributed across the sleep period. This measure of "efficiency" was particularly poor during day sleep (RECOV 24). In contrast, the hourly distribution of PS was not significantly different in the different conditions. The average duration of episodes of PS, and its periodicity, were essentially the same for both LS and SS:

Average PS duration (Min)	18.8 (LS) s.d.=10.7	17.3 (SS) s.d.=11.7
Average PS period (Min)	93.3 (LS)	92.6 (SS)

Two features of day sleep (RECOV 24) that clearly distinguish it from other sleep are: (1) the dramatic reduction of TST in both LS and SS; and (2) the trend towards a similarity of the groups in terms of sleep stage amounts. In contrast to other sleeps, there were no significant differences in sleep characteristics between LS and SS in this condition. Thus, it can be assumed that the sleep deficit due to the schedule inversion was larger in LS than in SS.

Those results are in good agreement with other studies on long and short sleepers (Hartmann et al., 1971; Webb & Agnew, 1970). They are to be compared to other results (e.g., Foret & Benoit, 1974) which show that the sleep of the same subjects recorded in different situations (in particular, after schedule inversion) exhibits the same constancies in respect to absolute amount of SWS and percentage of PS. Also, results concerning sleep structure in elderly people (Feinberg, 1969) show that percentage of PS, in spite of the dramatic shortening of SWS, remains approximately the same as in younger adults. In sum, these other data give a picture of PS as a rather passive phenomenon closely linked with the total sleep time.

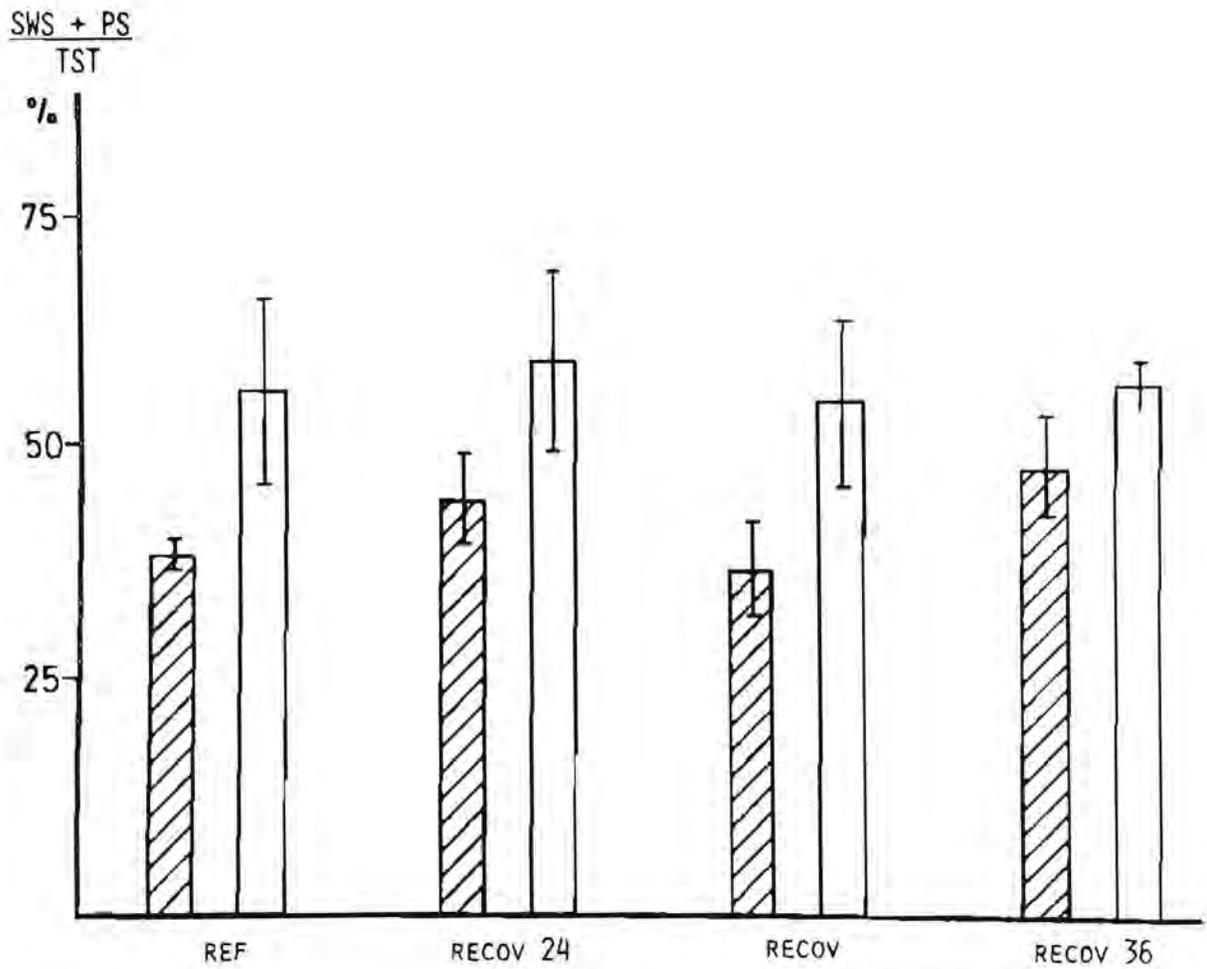


Figure 3. "Efficiency index" of sleep ( $\frac{SWS+PS}{TST}$ )% in the various experimental conditions (Hatched bars: LS; Open bars: SS).

WAKEFULNESS (IN MIN)

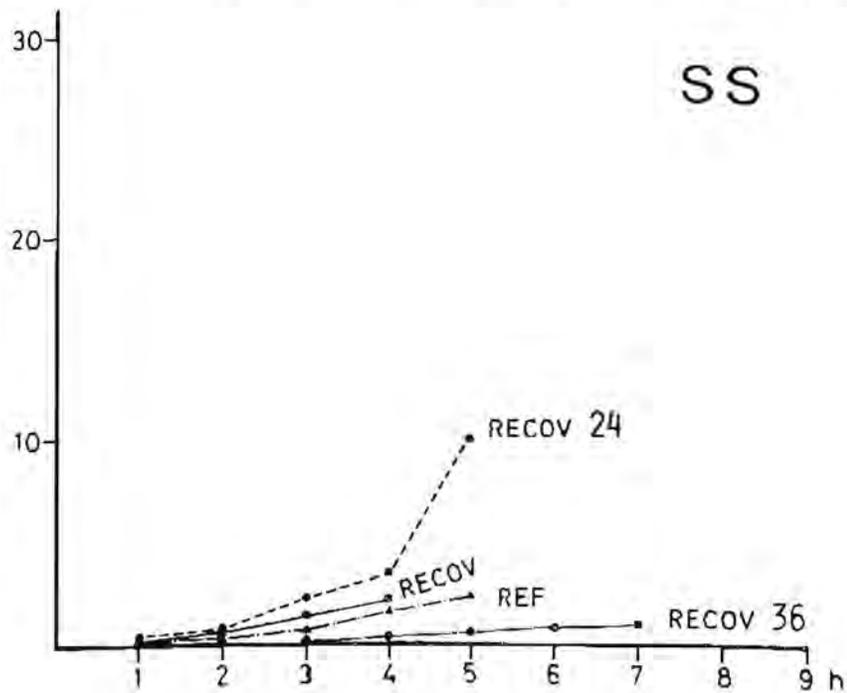
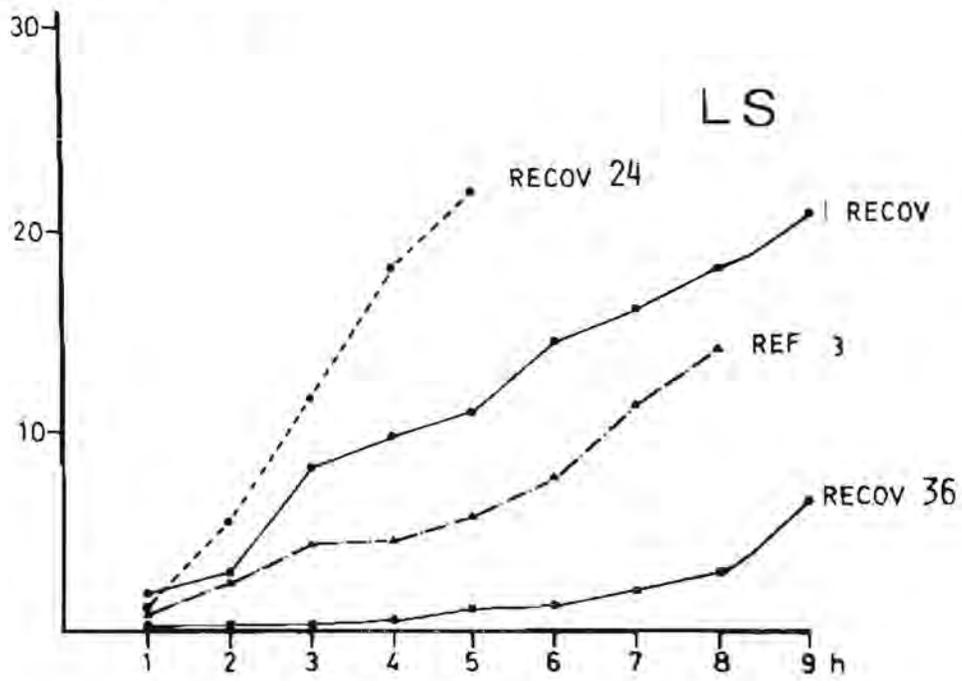


Figure 4. Hourly cumulated amount of intervening wakefulness in the various experimental situations.

Table 1

Sleep Data: Means and SDs (Mins)

	Sleep REF		Sleep RECOV 36		Sleep RECOV		Sleep RECOV 24	
	LS	SS	LS	SS	LS	SS	LS	SS
TST	533.6 ±32.9	*** 303 ±55	560.3 ±17.9	*** 402 ±41.6	554 ±58.4	*** 271 ±68.7	287.8 ±69.7	240 ±73
Wake- fulness	12.3 ±16.1	3.3 ±3.7	5.9 ±6.4	0.4 ±0.5 (p <.1, NS)	13.7 ±5.3	** 3.8 ±4	17.7 ±15.4	4.1 ±4.4 (p <.1, NS)
Stage 1	78.6 ±29.6	** 32.1 ±19.8	46.9 ±12.3	31.7 ±5.9	79.3 ±39	* 24.4 ±13.7	38.9 ±13.8	29 ±20.6
Stage 2	237.6 ±14.9	*** 102.2 ±21.3	235.7 ±23.7	*** 141.4 ±26	259.4 ±44.6	*** 98.9 ±38.6	109.4 ±37.2	68.9 ±25
SWS Stage 3+4	110.2 ±14.9	116.2 ±21.3	171.4 ±26.2	165.7 ±26.3	84.6 ±23	92.1 ±16.9	93.5 ±20.7	105.6 ±31.9
PS REM Sleep	91.8 ±21.4	*** 48.9 ±18.8	95 ±26	62.2 ±30.6	112.9 ±14.8	52.5 ±21.9	27.3 ±23.5	32.4 ±13.8
Stage 2 Latency	18.7 ±7.3	10.7 ±7.3	8.5 ±3.4	8.1 ±2.9	25.9 ±10	** 9.6 ±3.3	10 ±8.2	4.8 ±3.1
Stage 4 Latency	16.5 ±7	15.3 ±4.7	10.7 ±5.6	11 ±6.7	37.7 ±34	25.3 ±9.7	12 ±5.8	12.3 ±2.3
PS Latency	117.9 ±52	105.7 ±65.6	128.5 ±49.9	98.9 ±47.9	68.5 ±49 (p <.1, NS)	69 ±29.1	114.4 ±46.7	79.4 ±57

Reference Conditions: Body Temperature (0°), Heart Rate (HR),  
Mood and Vigilance

For each individual, measurements of 0° collected over ten days were

averaged for each hour (see Figure 5). The temperature rhythm of SS appeared to plateau for a longer time than that of LS. In addition, the amplitude of the rhythm (i.e., the difference between the average level of the diurnal maximum and that of the nocturnal minimum) was significantly smaller in SS than in LS (.42° and .62° respectively,  $p = .07$ , Mann-Whitney U-test).

Peak time. Precise determination of peak time was difficult (a) because of the variability in the data and (b) because (particularly in SS) the maximum was more a plateau than a peak; the cosinor method, by definition, fits the maximum of the sine curve (acrophase) around the middle of the plateau. This is probably the reason why the peak times of SS and LS estimated by this method (Table 2) were not significantly different. But if we take the beginning of the plateau as a definition of peak, the temperature curve of SS is seen to level up earlier than that of LS. There was a positive rank order correlation (Spearman) significant at  $p < .01$  between the time of this peak and sleep length: the longer the sleep length, the later (and thus closer to bedtime) was the peak.

In contrast, Table 2 shows that when the cosinor method was applied to the data on self-estimated mood and vigilance, the acrophases in these variables were significantly later in SS.

Table 2

REF: Times of Acrophases (and Confidence Intervals)

	SS	LS
Temperature	18.3 (17.6--19.0)	17.2 (16.4--18.0)
Heart rate	15.8 (14.7--17.0)	16.8 (16.1--17.7)
Mood	21.1 (19.2--23.0)	15.6 (14.2--16.8)
Vigilance	15.8 (15.3--16.3)	14.5 (14.2--14.8)

It should also be noted that the rhythms of the four variables considered in this study were phase-synchronized much more closely in LS than in SS; the significance of this is not clear at present.

After Sleep Deprivation: Body Temperature, Heart Rate, Mood and Vigilance

Both types of sleep deprivation influenced SS and LS in different ways (see Tables 3 & 4). Because of the very large variability in the LS data, it was not possible to assess the acrophases of the rhythms in some cases in this group. However, it would seem that, on the whole, SS were less affected by sleep deprivation than LS, at least as regards the variables that we studied: thus, in RECOV 36, the shift in the phase of the temperature rhythm was much larger in LS than in SS. In RECOV 24, the time of the temperature peak was less affected in both groups.

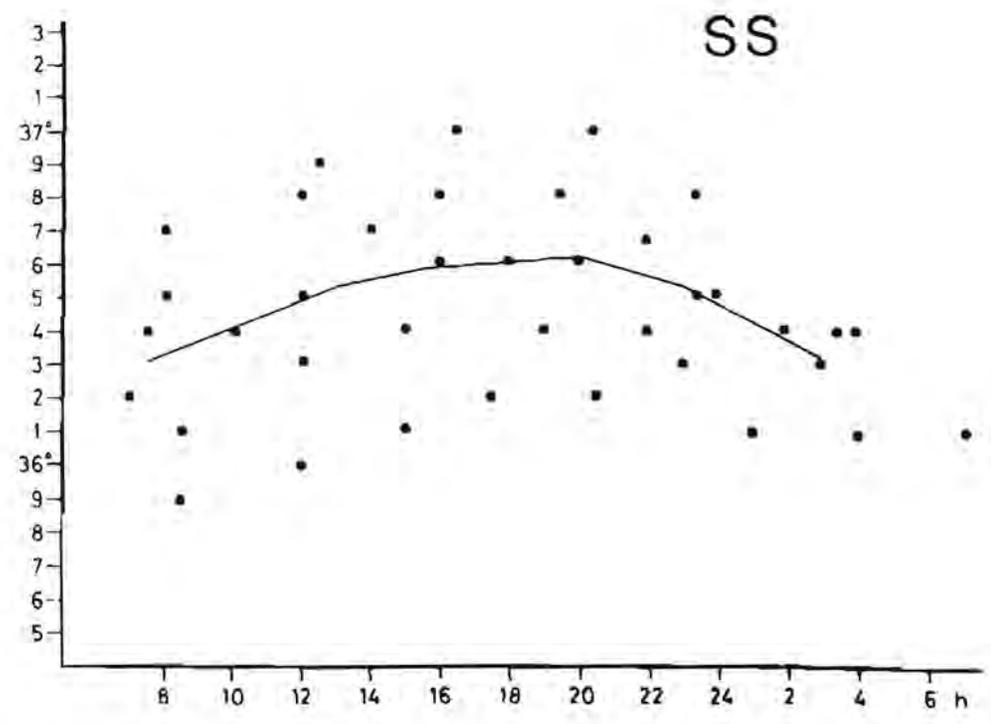
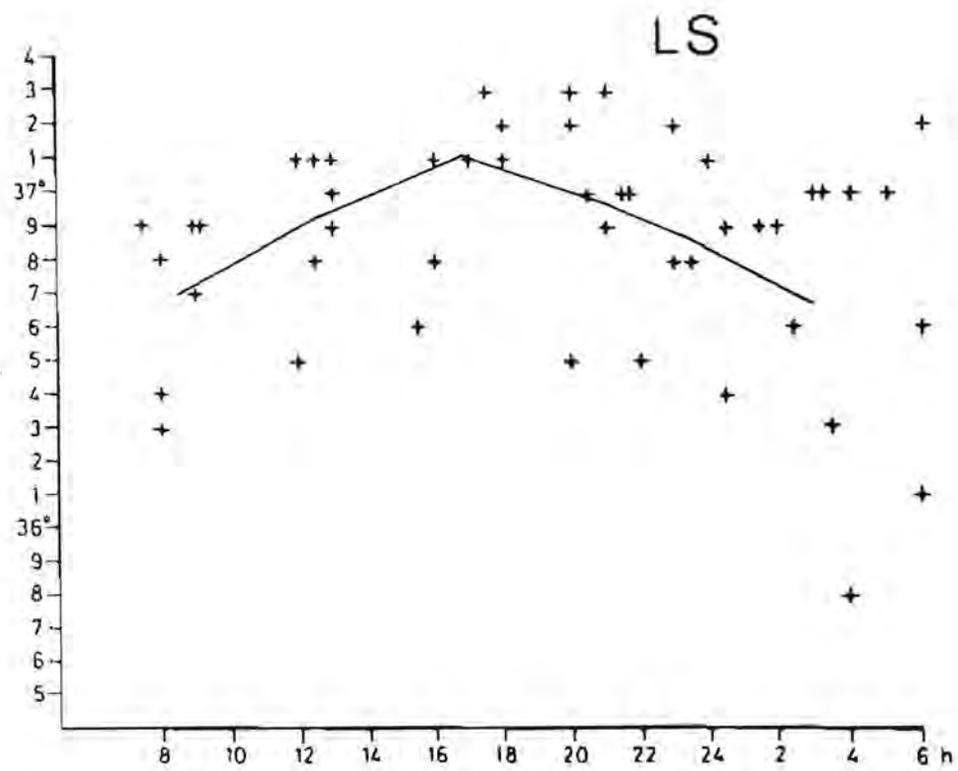


Figure 5. Mean hourly temperatures in SS and in LS. Mean sleep periods for SS were 01.40—07.40; for LS were 23.10—08.15.

Table 3

RECOV 36: Times of Acrophases (and Confidence Intervals)

	SS	LS
Temperature	17.2 (15.6--19.2)	not assessable
Heart Rate	15.5 (13.8--19.4)	19.8 (15.1--24.8)
Mood	20.8 (18.8--22.8)	not assessable
Vigilance	16.5 (15.5--20.6)	not assessable

Table 4

RECOV 24: Time of Acrophase (and Confidence Interval)

	SS	LS
Temperature	18.5 (16.9--20.3)	not assessable
Heart Rate	14.2 ( 8.4--19.4)	not assessable
Mood	22.3 (19.6--24.8)	16.4 (13.8--20.0)
Vigilance	17.9 (16.6--19.2)	17.6 (16.5--19.0)

According to the theory that different oscillators may influence sleep and body temperature (Aschoff & Wever, 1976), our results lead to the conclusion that the degree of coupling between the rhythm of activity and that of temperature is likely to be greater in LS than in SS.

#### After Sleep Deprivation: Correlation with Temperature Amplitude

In some cases, the amplitude of the temperature rhythm in the reference condition was found to be related to the shift in phase of the rhythm after sleep deprivation.

In 24 hours sleep deprivation (RECOV 24), there was a significant rank correlation between the amplitude of the temperature rhythm before deprivation and the shift in its peak the following day: the smaller the amplitude, the larger the shift in the peak (Spearman's rho,  $p < .05$ ). [But it should be remembered that we did not find any clear difference in temperature amplitude between SS and LS.]

This result supports the hypothesis originally advanced by Aschoff (1978) (and confirmed by Reinberg et al., 1978) that people with a naturally small temperature range are more able to "adapt" quickly to schedule inversion. But

the applicability of this finding is still open to question, since it has yet to be demonstrated whether a rapid shift in the phase of the temperature rhythm is actually conducive to an overall adaptation to shiftwork.

In the case of RECOV 36 (a condition that a real shiftworker almost never meets), there was a positive correlation only between sleep length and the extent of the phase-shift in temperature: The longer the spontaneous sleep length, the larger the shift of the temperature peak (Spearman's rho,  $p < .02$ ).

Although there was no correlation between sleep length and temperature rhythm amplitude, LS tended to show a larger temperature amplitude than SS. Thus it seems that the extent to which the temperature peak shifted in this situation was determined by two opposing factors: A large temperature amplitude, which would produce a small shift; and a long sleep length, which would produce a large shift. This perhaps is why the results are not clear in LS.

#### Temporal Relationship Between Sleep and Temperature

(a) The level of the last temperature reading before going to bed (around 2200 for LS, 2400 for SS) was found to be significantly lower in SS ( $p = .07$ ), when this level was expressed as a relative proportion of the total amplitude of the rhythm. However, the time interval between temperature peak and bedtime was found to be much longer in SS (SS = 10 h; LS = 5.1 h). These results show that there is no obvious relationship between thermic level and wake/sleep transition in a normal night of sleep.

(b) In contrast, the level of temperature recorded in the morning after a sleep deprived night seems to affect both the duration and the stage amounts of the subsequent morning sleep. There was a negative correlation between absolute temperature level and TST ( $r = -.51$ ,  $p < .05$ ), and also between absolute temperature level and percent PS ( $r = -.60$ ,  $p < .05$ ).

#### Conclusion

The sensitivity of an individual to a phase displacement appears to depend upon various factors. In the case of a transient displacement, natural sleep length, at least in its extreme values, plays an important part in determining the inter-individual differences observed. Variations in the well-known troubles reported by workers subject to changing working schedules may, in addition, be related to the normal amplitude of the individual's temperature rhythm.

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## **PROCEEDINGS**

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### **THE TWENTY-FOUR HOUR WORKDAY: Proceedings of a Symposium on Variations in Work-Sleep Schedules**

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
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THE TWENTY-FOUR HOUR WORKDAY: PROCEEDINGS OF A SYMPOSIUM  
ON VARIATIONS IN WORK-SLEEP SCHEDULES

EDITORS

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Cincinnati, Ohio 45226

July 1981

DHHS (NIOSH) Publication No. 81-127