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Psychological and psychophysiological effects of shift work

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ÅKERSTEDT T. Psychological and psychophysiological effects of shift work. *Scand J Work Environ Health* 1990;16(suppl 1):67—73. The psychophysiology of shift work is mainly related to circadian rhythmicity and sleep-wake phenomena. Individuals on a rotating three-shift or similar system work the night shift at the low phase of circadian rhythm. On retiring to bed in the morning they fall asleep rapidly but are prematurely awakened by their circadian rhythm and exhibit severe sleepiness and reduced performance capacity. In connection with the morning shift the circadian psychophysiology makes it difficult to fall asleep as early as needed during the preceding night. Around 0400 to 0500, when the individuals should rise, they have difficulties awakening because of the sleep loss and the circadian rhythm, which at that point is at its lowest. Subsequently, day work is characterized by sleepiness and reduced performance. It should be emphasized that it does not seem possible to improve one's ability to adjust over time, even with permanent night work. Older age and "morningness" personality are related to higher than average problems in adjusting.

Key terms: circadian, psychophysiology, sleep, sleepiness.

Shift work is one of the more apparent and dramatic components of the work environment. It has been clearly linked to a series of acute and chronic effects on the organism, most of them related to the circadian rhythmicity of the body. The major effects concern sleep, alertness, and performance, but also long-term health. The purpose of the present paper is to provide a brief review of these effects and to discuss mechanisms and countermeasures.

Before turning to the effects, however, the term "shift work" needs to be defined. The term usually refers to an arrangement of workhours which employs two or more teams (shifts) of workers in order to extend the hours of operation beyond that of conventional office hours. It has, however, become customary to apply the concept also to groups with more unstructured and irregular workhours and to groups with permanent night or evening work. With this usage the proportion of shift workers make up at least one-fourth of the working population in most industrialized nations (1). In the present overview I have restricted the discussion to shift work that, at least occasionally, involves night work, since such schedules are the most interesting from a psychophysiological point of view. Permanent night work, rotating three-shift work, night-oriented roster work, and irregular workhours are included.

Circadian physiology

The psychology and psychophysiology of shift work is intimately related to the rhythmic timing system of humans, particularly that having a 24-h period — the circadian (from *circa dies* = approximately 24 h) system. It has its neural basis in the lower frontal hypothalamus, situated above the optic chiasma (2). These suprachiasmatic nuclei produce a cyclic oscillation with a period of 24 h. Although the rhythm is rather stable, it may be modified by environmental synchronizers such as light, sleep, food, etc. The speed of adjustment to a new time zone is usually about 1 h/d although this speed may differ between variables.

In order to describe the circadian rhythm of an individual, frequent measurements are needed — during work, leisure time, and sleep. This need places a considerable burden on the subjects, and researchers have, for this reason, tended to focus on functions that are easy to measure, such as oral temperature and urinary constituents (2, 3). Figure 1 derives from one of the most extensive studies of oral temperature, with a total of 133 workers in all (4). During the day of the first night shift an increase occurs from the time of rising in the morning to a peak in the evening. Thereafter, the temperature falls during the night shift towards a minimum around 0400, after which a rise is seen towards the end of the shift and the new morning bedtime. The fifth shift shows a similar pattern but with seemingly low temperature during the morning. (No measurements were taken during sleep.) Such a pattern, with low night levels and high day levels, has been demonstrated for many physiological variables, eg, cortisol, potassium, adrenaline, etc (2, 3).

In contrast to the variables just presented, which have a strong endogenous rhythmicity partly unaffected by behavior, other variables mainly reflect di-

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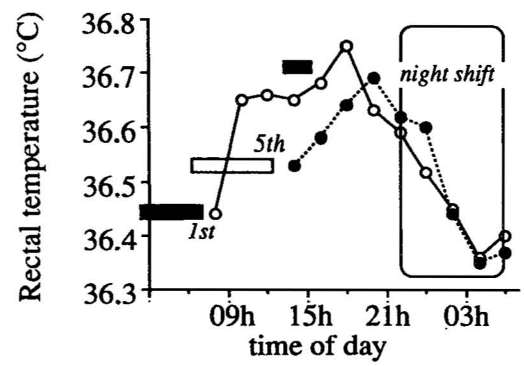

Figure 1. Mean oral temperature of >50 shift workers during the first and fifth night shifts. The 24-h period with the first night shift began as a normal day with awakening around 0700-0800 after a night's sleep (filled bar) but contains an afternoon nap around 1500 (filled bar). [Figure redrawn from reference 4]

rect changes in the rest-activity pattern. This holds true for, among others, noradrenaline excretion, heart rate, and blood pressure. Incidentally, a rather peculiar observation in this context is that the subjective effort associated with a certain heart rate at a given work load is higher during the night shift than during the day shift (5, 6). In some sense this phenomenon could be interpreted as the subjects being "older" on the night shift. Maximum work capacity does not differ though. A somewhat related observation is the occurrence of ventricular ectopic activity in connection with night work (7).

With respect to adjustment over several consecutive shifts figure 1 suggests that a few hours' delay of the nightly fall of oral temperature has occurred by the fifth night shift. Still, the minimum occurs at the same time as during the first night shift. If at all present, the adjustment over the five night shifts must be considered marginal. The same pattern has been observed in many other studies (3). It is likely, however, that part of the apparent adjustment is a direct effect of the environment, unrelated to the biological clock but "masking" its output (8). Lying down will, eg, reduce body temperature, and activity will raise it, both masking the underlying circadian pattern. Actually, it might be argued that the endogenous circadian rhythm never adjusts in shift workers (8). The reason for the marginal or nonexisting adjustment is that the circadian system, as discussed later, is very persistent and needs a longer time for adjustment than night workers ever enjoy since they usually revert to a diurnal life when off duty.

Laboratory studies allow a much better control of environmental influences and make it easier to carry out around-the-clock measurements. In one of the classic studies Colquhoun et al (9) showed that oral temperature across 12 consecutive night shifts flattened but never completely adjusted. Similar results have been published by, eg, Knauth et al (10) and Weitzman & Kripke (11). On the whole, most of the adjustment tends to occur during the first 1 to 3 d and then proceeds at a slower pace. It should be observed that in these studies all environmental synchronizers (light, food, social life) were geared towards a nocturnal life. This is something the night worker has little chance to experience.

It should be emphasized that most of the studies of the physiological circadian rhythms of shift workers are mainly of theoretical interest since a clear relation between rhythm adjustment and health parameters has seldom been demonstrated, except for a few studies suggesting that individuals who have difficulties tolerating shift work may have desynchronized rhythms or small amplitudes of their entrained rhythms (12).

Sleep

Disturbed sleep is perhaps the most dramatic effect of shift work. A number of survey studies have indicated that shift workers have difficulties mainly at maintaining sleep after the night shift and initiating sleep before the morning shift (13). The afternoon shift has usually presented no sleep problems.

The standard psychophysiological approach to sleep usually involves recording an electroencephalogram, an electrooculogram, and an electromyogram on paper and scoring the output visually in sleep stages per 30-s intervals (14). The standard sleep stages include wakefulness (stage 0), superficial to deep sleep (stages 1 to 4), and rapid eye movement sleep (stage REM — dream sleep).

Sleep studies of shift workers have mostly been carried out in the laboratory (13). Recently, however, some studies of shift workers' sleep have been made in the workers' natural sleeping environment (15—17). The results are fairly conclusive in that sleep length on the night and morning shifts of rotating shift workers is reduced by 1 to 4 h. This reduction mainly affects stage 2 and REM. Stages 3 and 4 [which together make up slow wave sleep (SWS) or deep sleep] seem seldom to be affected. Furthermore, sleep latency is increased in connection with the morning shift and is shortened in connection with the night shift. Figure 2b demonstrates a hypnogram (sleep stages plotted against time) for the night shift. Note that the postworkday sleep is short but otherwise exhibits a normal pattern with two sleep cycles.

Rather little is known about the adjustment process across a series of night shifts. The available studies suggest that sleep length does not improve a great deal (18, 19). Permanent night workers seem to sleep longer, however, than rotating shift workers on the night shift (19—23).

The reason for the shortened daytime sleep has in several studies been attributed to higher noise levels at that time (24, 25). This may certainly be one of the causes of disturbed daytime sleep. On the other hand, sleep after the night shift is shortened also under optimal laboratory conditions (26, 27). Thus noise does not seem to be the major cause of disturbed day sleep. A stronger influence is exerted by the circadian rhythm. Postponing sleep to different times of day under conditions of isolation from time-of-day cues (26) shows that the more sleep is postponed from the evening towards noon the next day, the more truncated it becomes, and when noon is reached the trend reverts. Thus sleep during the morning hours is strongly interfered with, despite the sizeable sleep loss that, logically, should enhance the ability to maintain sleep. Similar observations have been made for subjects who can select their own preferred sleep-wake pattern under conditions of long-term isolation from time cues (27, 28). In the latter studies it has been demonstrated that the factor most closely associated with the premature termination of sleep is the rising phase of the temperature cycle.

Sleepiness

Many questionnaire studies have demonstrated that shift workers report more fatigue than do day workers (29). Usually, the fatigue is particularly widespread on the night shift, hardly appears at all on the afternoon shift, and is intermediate on the morning shift. In some studies sleepiness has been reported to be severe enough to have resulted in actual incidents of falling asleep during the night shift.

The upper part of figure 2 illustrates the 24-h pattern of rated sleepiness in a group of 24 three-shift workers at a paper mill (17). In connection with the afternoon shift sleepiness never reached high levels but was low during the day-evening and reached a medium level at bedtime. In connection with the night shift sleepiness increased during the night and reached a pronounced peak during the second half of the night shift. This pattern of early morning sleepiness has been demonstrated in many other studies (19, 30).

Physiological evidence of night shift sleepiness is more scarce. However, in the study illustrated in figure 2, electroencephalography and electrooculography were also carried out. These procedures were done with the aid of small subject-worn tape recorders (Medilog) for a duration of 24 h on three occasions involving morning, afternoon, and night shifts. The lower part of figure 2 shows the hypnogram of one worker during the night shift (17). During work two episodes of sleep can be seen. They are followed by a (short) day sleep of little more than 4 h, and later on by a 45-min nap during leisure time. Similar incidents of sleep occurred for approximately one-fourth of the subjects. Usually they occurred during the second half of the night shift and never in connection with any other shift. Importantly, sleep on the job was not condoned by the company, nor was there any official awareness that sleep would or could occur during workhours. Similar results but with ultrashort intrusions of sleep (as judged by electroencephalography, electrooculography, and electromyography) have been demonstrated for locomotive engineers during work (31) and for other groups (32, 33).

Incidentally, the general impression from most studies of sleepiness during activity is that, although a certain sleepiness is clearly perceived by the individual, there seems to be no "final warning" before dozing off (29). This, very likely, constitutes a major safety problem in many occupations.

As to adjustment over shifts, there is a clear impression that night shift sleepiness will gradually delay its appearance over successive shifts (34—38) in a manner very similar to the behavior of oral temperature discussed earlier. There is no indication, however, that more than a marginal adjustment takes place. This seems to be the case also for permanent night workers.

The cause of night shift sleepiness is apparently the combined influence of circadian and sleep-loss factors. The former was obvious in many of the field studies already cited and is practically always correlated with the body temperature rhythm. The influence of sleep loss is more difficult to isolate in field studies but may be readily observed in laboratory sleep deprivation studies (39). In addition Carskadon & Dement (40) have demonstrated that 3 h of sleep reduction results in increased subjective and physiological sleepiness (using the multiple sleep latency test). Furthermore this sleepiness measure showed accumulation across successive days of restriction.

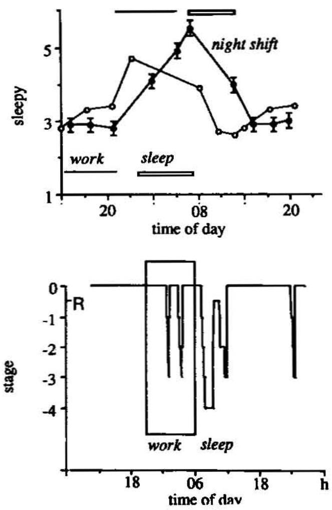

Figure 2. Upper figure: mean and standard errors of self-rated sleepiness during a 24-h period with a night shift and an afternoon shift; lower figure: hypnogram representing a 24-h period with a night shift for one of the subjects in the upper figure. [Figure redrawn from reference 17]

Performance

If sleepiness on the night shift is as widespread and as dramatic as has already been indicated, one would expect to see pronounced effects on performance, and consequently on output and safety. One of the classics in this area is the study by Bjerner et al (41), who showed that errors in meter readings over a period of 20 years in a gas works had a pronounced peak on the night shift. There was also a secondary peak during the afternoon (figure 3). Similarly, Browne (42) demonstrated that telephone operators connected calls at a considerably slower pace at night. Hildebrandt et al (43) found that locomotive engineers failed to operate their alerting safety device more often at night than during the day, with a secondary peak around 1500.

Most other studies of performance have used laboratory types of tests and demonstrated, eg, reduced reaction time or poorer mental arithmetic on the night shift (15). Flight simulation studies have, furthermore, shown that the ability to "fly" a simulator at night may decrease to a level corresponding to that after moderate alcohol consumption (0.05 % blood alcohol) (44). To these results may be added those from numerous laboratory studies which have demonstrated that performance on many tasks deteriorates during the night hours (45).

Adjustment across shifts has very seldom been investigated under practical conditions. Laboratory investigations, however, clearly indicate that adjustment does occur, although it may take up to two weeks. Frequently, the body temperature rhythm adjusts in parallel.

The impression of the night shift deterioration of performance is mainly based on fairly simple psychomotor types of tasks. There is, however, some speculation that high-level cognitive tasks, because of a high memory load, might show a differently phased rhythm (45). The latter would not, however, apply to the situation where sleepiness has come close to actual sleep, since any type of activity would then be interfered with.

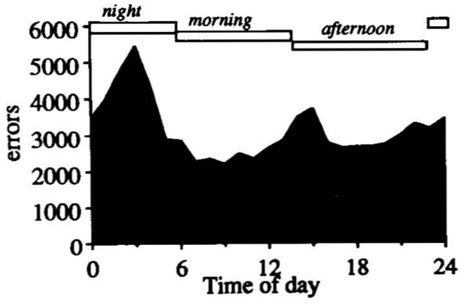

Figure 3. Number of meter reading errors accumulated over 19 years for three three-shift workers. Bars indicate the three shifts. [Figure redrawn from reference 41]

Another important point is that common sense and available data suggest that the output from a production process will not be affected by night work as long the major determinant of the production flow is machines rather than people. Thus, it seems rather unlikely that sleepiness induced by the nightshift would affect output in all occupations.

A more important area of impact may be safety. If sleepiness is severe enough, interaction with the environment will cease, and, if this interaction coincides with a critical need for action, an accident may ensue. Such potential performance lapses due to nightwork sleepiness were seen for several of the locomotive engineers discussed earlier (31). The transport area is, in fact, where most of the available accident data on night shift sleepiness has been obtained. Thus Harris (46) and Hamelin (47, 48) convincingly demonstrated that single vehicle accidents have, by far, the greatest probability of occurring at night (early morning). Most of these accidents are thought to be due to sleepiness. With respect to air transport Ribak et al (49) found military flight accidents to be increased in the early morning, and Price & Holley (50) argued that also many civil air transport accidents may be caused by fatigue due to work scheduling. Finally, a number of spectacular nuclear accidents (including those at Chernobyl and Harrisburg) have been partly attributed to fatigue-inducing work schedules (51).

As with sleepiness, the main reason for night shift deterioration in performance is circadian rhythmicity and sleep loss (45).

Modifying factors

Several factors influence the adjustment to shift work. One such factor is the direction of rotation of the shift schedule. Since the free-running (spontaneous) period of the human sleep-wake cycle averages 25 h and since it can be entrained by environmental time cues only within 1 to 2 h of the free-run period, phase delays are easier to accomplish than phase advances (52). For the rotating shift worker this situation implies that schedules that delay, ie, rotate clockwise (morning-afternoon-night) should be preferred to those that rotate counterclockwise. There has been, however, very few practical tests of this theory. Still, Czeisler et al (53) have demonstrated that a change from counterclockwise to clockwise rotation, together with a change from 7-d to 21-d rotation, improved production and well being for three-shift workers. Orth-Gomér (54) found that a change in the same direction among rapidly (1 d) rotating police officers reduced blood pressure and improved well being.

The length of a work shift is another parameter that one would expect to influence at least sleepiness and performance. In the laboratory it is usually the case that performance falls with time if learning effects are eliminated (55). Still, in one study of policemen, Peacock et al (56) found no effects of a change from 8 h (nine shifts across 8 d) to 12-h shifts (two nights-one free-two days-three free) on overall alertness. However, the distribution of free days changed at the same time. Two other studies of nurses (57) and industrial shift workers (58) have produced similar results. Recently Rosa & Colligan (59) used 2-h ratings in a field experiment and demonstrated that the 12-h night shift, indeed, produced higher ratings of fatigue than 8-h night shifts. In addition, in a study of accidents of truck drivers, Hamelin (48) demonstrated a U-shaped relation between hours driven and accidents, ie, after an initial "warm up" period accident risk was low, with an increase towards 11 h of driving.

As may be expected, also the watch-keeping systems (4 on, 8 off) on ships are associated with low alertness and poor performance during the night (60). Apparently, rotating systems cause greater disturbance to the individual than do stable systems.

Another type of unusual workhours is that of air crews on transmeridian routes. Then, not only are the workhours displaced to "biological" night time, but also the time reference is changed through time-zone shifts. As with other types of shift work, survey studies have demonstrated disturbed sleep and wakefulness (61). The disturbed wakefulness has been evidenced also in flight simulator studies.

In some occupations the personnel may sleep at the worksite until needed. This is the case for, among others, physicians. Since the greater part of such nights are often are spent working, sleepiness-fatigue is often pronounced, and performance tends to be reduced, although the practical implications (for the patients) are still unknown (62, 63). Other forms of "on-call" systems may be found among, for example, engineer officers in the merchant marine (64).

Among individual differences age has been related to sleep disturbances (65, 66). In electroencephalographic studies trends have been found towards more superficial sleep in middle-aged shift workers (16). The studies by Foret et al (65) and Åkerstedt & Torsvall (66) also indicated that experience was negatively related to general well being over a number of years. Koller et al (67) found that reduced health appeared earlier among shift workers than among day workers. Dahlgren (68) found no effects of three years of night work on the rhythm of rated activation across night shifts. Neither did Wynn et al (69), over a temporary 10-week period of weekly alternation between night and day work in a group of nurses. Dumont et al (70) found that the amount of sleep-wake and related disturbances in present day workers was positively related to their previous experience of night work. Guilleminault et al (71) found an overrepresentation of former shift workers with different clinical sleep/wake disturbances appearing at a sleep clinic. Although not directly related to sleepiness, it is still of interest to observe that Angersbach et al (72) have demonstrated an earlier occurrence of gastrointestinal disease among three-shift workers than among day workers. Similarly, Knutsson et al (73) demonstrated that the incidence of myocardial infarction (and cardiovascular disease in general) is related to the amount of exposure to shift work.

Finally, the trait of morningness (having a tendency towards early sleep-wake preferences) has frequently been associated with poor adjustment to shift work (74, 75). This has also been the case for the trait of sleep rigidity (76).

Concluding comments

Taken together, the reviewed literature clearly indicates that shift work that involves night shifts strongly influences the psychology and psychophysiology of the individual.

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