Scand J Work Environ Health 1998;24(3):18-27
Issue date: 1998

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This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/9916813

Print ISSN: 0355-3140 Electronic ISSN: 1795-990X

Scand J Work Environ Health 1998;24 suppl 3:18—27

Is there an optimal sleep-wake pattern in shift work?

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Åkerstedt T. Is there an optimal sleep-wake pattern in shift work?. *Scand J Work Environ Health* 1998;24 suppl 3:18—27.

This paper finds that shift work clearly affects sleep and wakefulness but that there is very little known empirically about optimal sleep-wake patterns — except for the ones commonly used but not evaluated, for example, extension of morning sleep after night work, split sleep (main sleep + nap), nap positioning and duration, delay of main sleep, full commitment to night work (including bright light), phase advance and napping in relation to morning work, and modification of sleep strategies depending on the speed and direction of rotation. Thus computer simulations of the efficacy of alternative strategies must sometimes be used. The paper tries several such approaches and finds some possible ways of optimizing sleep. Still, the need for empirical data is emphasized.

Key terms review, simulation, strategy.

Shift work clearly exerts a negative effect on sleep and wakefulness (1). Since the reason for the problem is the timing of the hours of work and sleep, it would seem possible to establish some sort of "optimum" timing of sleep in order to reduce the negative effects. However, there is very little work available on such optimization, at least in real-life settings. The present paper includes what little solid information there is, but mainly concerns itself with speculation on what approaches might be of interest to gain more information. The term "shift work" is not only used to refer to conventional work in strictly defined "shifts", but also to cover the less rigidly organized "rosters" or "duty schedules" found in transport, nursing, police work, and other areas.

Commonly observed patterns

Before the issue of optimization is addressed, it is necessary to discuss sleep as it is commonly observed in shift work and also how its effects come about. The focus in this section is on traditional forms of shift work with several shifts in a row.

Night work

The night shift characteristically spans the time between 2200 and 0600, although there is considerable variation. The night sleep *before the first night shift* is usually rather long (2— 4), starts rather early, and lasts to around 8 o'clock in the morning or later. It is frequently (30—50% prevalence) associated with napping in the afternoon before the first night shift, especially if the preceding main sleep has been short.

The sleep *after a night shift* is usually initiated 1 hour after the termination of the shift (2, 5—8), with very little variation (30 to 60 minutes standard deviation) between persons. The ensuing sleep is, according to electroencephalographic (EEG) studies, reduced by 2—4 hours (8—12). Most of the loss involves stage 2 and rapid eye movement (REM) sleep, whereas slow wave sleep (SWS) is unaffected. The subjective aspects of sleep seem little affected, apart from premature awakenings and not getting enough sleep (8). Interestingly, about 50% of shift workers experience spontaneous (and effortless) sleep termination (8). Figure 1 illustrates the characteristic pattern of sleep density among a group of shift workers (13).

For about one-third of shift workers, a late afternoon nap is added *between the subsequent night shifts* (2, 4—8). The nap often exceeds 1 hour and the prevalence of napping increases as the length of the prior main sleep decreases. (4, 7).

Night work is also characterized by increased subjective (12, 14—16) and objective sleepiness (12, 16, 17). Several studies indicate that full-blown sleep can occur at work. The effects are particularly severe in the early morning, often involving incidents of involuntary sleep. In addition, during days off, a substantial amount of sleepiness remains.

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Morning work

A morning shift usually spans the time between 0600 and 1400, but, again, variations occur. The sleep pattern appears to be even more rigid in connection with the morning shift than with the night shift. (See figure 1.) As an example, sleep among a group of steel workers (7) with a morning-shift change at 0445 was initiated at 2149 (SD 49), which is almost exactly 70 min earlier than bedtime for days off for the same subjects. In other words, the phase advance of the bedtime was limited (8, 18). The sleep in the example ended at 0349 (SD 50), about 1 hour before the start of the morning shift. Short sleep (6 hours) has also been demonstrated in EEG studies — usually a 2- to 4-hour reduction in sleep length occurs (2, 8, 9, 19). Again, mainly stages 2 and REM are affected.

The main subjective effect is pronounced difficulties awakening, nonspontaneous awakening, and a feeling of not being refreshed by sleep (8). Interestingly, the anticipation of difficulties awakening is associated with reduced SWS (20).

Early times of rising (between 0400 and 0500) are also strongly associated with increased sleepiness during the rest of the day (20—23).

Morning-shift sleep is usually supplemented by an early afternoon nap by about one-third of shift workers (2, 3, 5—8). The nap is taken soon after the worker returns home from the morning shift (7). Again, a short prior sleep seems to be the main precipitating factor for the nap.

Afternoon work

The afternoon shift has been far less investigated than the morning and night shifts. On the whole, one sees a pattern of slightly late bedtimes (2300—0100) with awakenings around 0800 and an absence of napping (2, 5—8). The pattern is less homogeneous, however, than for the other shifts. (See figure 1.) There is more variation in the timing of sleep for the afternoon shift than for the other shifts.

Speed of rotation

Shift schedules frequently differ with respect to the *number of shifts* worked consecutively. While there are no data that indicate that the pattern of attempted sleep would differ depending on such a speed of rotation, there have been discussions on the amount of sleep permitted by certain types of schedules. Thus Foret & Benoit (10) found that neither the total sleep length nor the amount of stages 3 and 4 sleep recovered (changed) significantly across 4 consecutive night shifts (all were strongly reduced in the initial day sleep). Dahlgren (24) found that sleep length was reduced to 4.5 hours (from 6.0 hours) on the first night shift , but it increased again over 6 consecutive night shifts to reach a level of 5.7 hours. The amount of stage 2 sleep and REM also increased as the amount of waking decreased.

Permanent night workers tend to sleep somewhat less than day workers (24—29). For the latter the first day sleep is reduced by 1.1 hours (compared with normal night sleep), and it actually decreases a further 0.8 hours over 6 night shifts. In a review Wilkinson (30) also found that permanent night workers, on the whole, reported longer (6.7 hours) sleep than weekly (6.3 hours) or rapidly rotating (5.8 hours) shift workers. While correct, the results did not consider the effect on the other shifts or days off or free time. Apparently, permanent day workers seem to sleep somewhat less than rotating shift workers when the time is averaged across the entire shift cycle (31, 32).

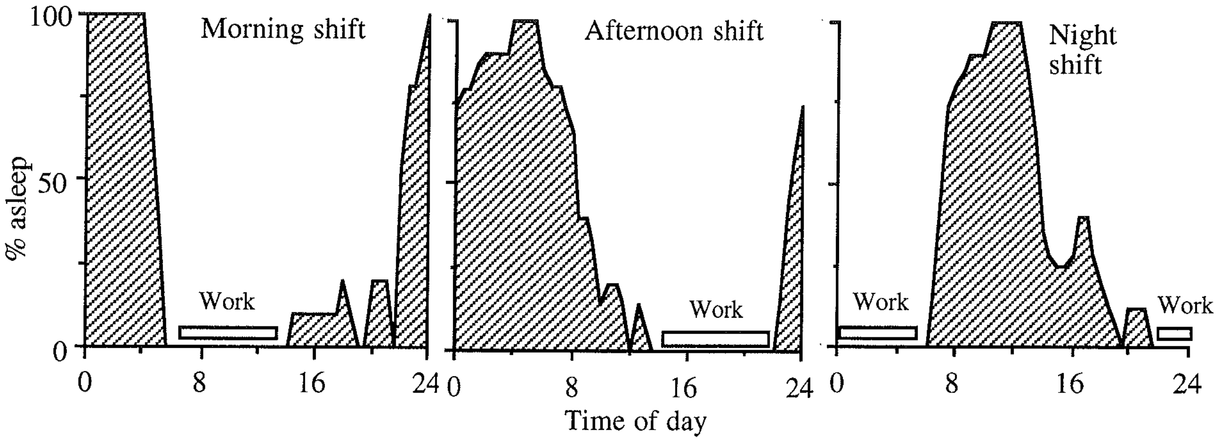

Figure 1. Percentage of 3-shift workers (N=50) asleep at different times of day in connection with the 2nd shift of each type.

Direction of rotation

A third concern is the direction of rotation. It has frequently been claimed that rotation should occur clockwise. While there is some theoretical support for this assumption, there is no solid evidence that sleep should differ depending on the direction of rotation (33), although Barton & Folkard found that a delaying pattern seemed to yield longer sleep (34).

Effects of other aspects of the schedule

Apart from the speed of rotation, one would expect the timing of the shifts to affect sleep. The first concern is the *time of the changeover* between night and morning shifts. Traditionally, this time is around 0600. However, field experiments indicate that sleep before the night shift is sharply curtailed as the phase advance of this time increases, and sleep after the night shift is improved by the same procedure (2, 9). An obvious compromise seems to be to end the shift around 0700 (35).

A second concern is *quick changeovers*, that is, short rest periods (=8 hours) between shifts. The prevalence of this aspect of scheduling is not known, but field work indicates that it is very common because it helps compress the workweek (compared with the conventional 16 hours between shifts) and yields a longer consecutive period of time off from work. This practice invariably curtails sleep (36), and data seem to indicate that the effects start already with 11 hours between shifts (35).

The mechanism

Night shift

One reason for night-shift sleepiness is that the worker is on the job at the nadir (low point) of the well-established circadian pattern, characteristic of most physiological and psychological variables (37—39). Essentially, alertness, performance, and metabolism peak in the late afternoon and reach a nadir in the early morning. The period of maximum alertness also strongly interferes with sleep, whereas the nadir equally strongly promotes sleep (19, 40). Daytime sleep is thus truncated.

The other reason for night-shift sleepiness is that the time awake before a night shift ends is extended to 20—22 hours (since prior sleep termination), in comparison with, for example, the corresponding 9 hours of the day worker. Alertness starts to fall immediately after the termination of sleep and continues for the duration of the time awake (38, 41—43). In addition, reduced prior sleep length increases sleepiness, although alertness seems rather robust against small curtailments of sleep (44—46). Two studies (45—46) show that the effects accumulate over time; a week with 4.5 hours of sleep per day may yield sleepiness close to levels seen in total sleep deprivation.

The homeostatic and circadian systems combine to exert their influence. Thus alertness and performance during sleep deprivation have a circadian pattern superimposed on the gradual fall of alertness and performance (38, 41). Even after several days without sleep one can clearly discern a slight increase in alertness during daytime, even if the mean level is low. The same combination of effects on sleep can be seen. Thus the daytime circadian interference with sleep near the acrophase may be partly counteracted by a high need for sleep (through prior sleep loss), and, of course, a low need may make daytime sleep virtually impossible (19, 47).

On the other hand, one would expect some adjustment of the circadian system across days of night work, which would ameliorate the negative effects of daytime sleep. Under optimal conditions, adjustment to a new circadian phase position occurs at a speed of about 1 hour per day (48, 49), probably through exposure to light at the sensitive portions of the circadian phase (50—52). Exposure before the nadir would lead to a delay and exposure after the nadir to an advance. However, for shift workers, the adjustment is counteracted by a light pattern in opposition to night workhours (53). Thus it appears that only very marginal circadian adjustment occurs in shift workers (54). On the other hand, exposure to artificial light during the hours before the circadian trough may remove most of the sleepiness during night work and improve subsequent sleep (55—58).

Morning shift

Sleep is short before the morning shift mainly because of the need to terminate sleep very early in the morning without being able to advance bedtime to fully compensate. The latter failure may be partly social, but there is also a strong circadian influence on sleep latency. To phase advance bedtime before a morning shift is difficult since it would bring the bedtime close to the circadian acrophase and make sleep difficult to initiate (18, 59, 60). This early evening time of sleep resistance has been called a "forbidden zone" for sleep (61).

The difficult early morning awakening, which seems to be a burden for workers on the morning shift, is also a result of circadian "interference". Thus an early awakening will coincide with the circadian nadir, and this circadian phase seems to be very protective against sleep termination (50) and seems to make forced awakenings very difficult (62). Furthermore the early morning awakening reduces sleep length and thus contributes to morning shift sleepiness. This sleepiness is exacerbated by the fact that the early morning awakening also adds further sleepiness by extending the time spent awake by 2—3 hours. Finally, the difficulties of having to rise at a very difficult time in the early morning seem also to be associated with anticipation stress that suppresses some of the SWS that would normally occur (20).

Optimal sleep-wake patterns

What, then, would constitute an "optimal" sleep-wake pattern? Such an optimal pattern may refer to the ability to sleep as much as possible in relation to a night or morning shift, or it may mean sleep in a way that increases alertness at work as much as possible or sleep in a way that increases alertness during free time as much as possible. The 3 patterns may be in conflict with each other. One also needs to consider the sequential effect of one sleep on the next.

One can conceive of several different ways of trying to achieve optimal sleep: (i) extension of day sleep after night work, (ii) split sleep — main sleep plus a later nap (and the position and duration of the nap), (iii) delayed day bedtime after night work, (iv) phase advance of bedtime before the morning shift.

As indicated, there are too few data available; therefore the discussion will have to focus on potential approaches rather than on established ones. To help the discussion in areas of low data availability, I will also use input from a mathematical model for the regulation of sleep and wakefulness (42, 63—65). The model uses homeostatic and circadian components to predict alertness and sleep length. The former essentially means that alertness starts to fall immediately after rising and starts to rise after sleep onset. The circadian component assumes a maximum value around 1700 and a minimum 12 hours later. The predicted alertness is expressed as the arithmetic sum of the 2 functions . The scale of the model ranges normally from 1 to 16, but in practice "3" corresponds to extreme sleepiness and "14" to high alertness and "7" to a threshold below which EEG/EOG sleep intrusions appear within 5 minutes under conditions of low external stimulation. The latter is also seen as a risk indicator, and time below the threshold constitutes an index of time at risk. Finally, sleep terminates when alertness reaches a predetermined level (14.2), and sleep latency is transformed as an exponential function of alertness.

Extended main sleep

A first and obvious strategy, when faced with several night shifts, is to try to extend the short day sleep after night work. Although this sleep is spontaneously terminated by circadian and homeostatic factors (40, 66), there are probably ways of extending it by improving, insulation from noise and light, and the like. Laboratory studies of shift workers' sleep thus frequently show better sleep than what is expected from reports of home sleep (67). Some of this effect could also be related to lower social pressure to wake up in the laboratory than in the home environment. The needed change in social pressure might, however, be difficult to implement at home.

The effect of extending day sleep at home after a night shift has not been empirically tested in a real-life situation, but several studies of the effects of varying amounts of sleep length in connection with normal night sleep suggest that the alertness-enhancing effects might not be large (44—46), because, normally, the last hours of sleep may not contain large amounts of recuperative value, but the recuperative effect seems to describe a saturating exponential function approaching an asymptote towards the last third of sleep (68). Thus the effect of increased main sleep length is less than what may be obtained later in a nap of the same length. Still, the exponential recovery function also means that the positive effect of an extension will increase in size with decreasing length of the "unextended" sleep. Thus the marginal utility of a 2-hour extension of a 3-hour day sleep will be several times larger than that of a 6-hour day sleep.

Figure 2 shows the simulated effects of a 2-hour extension of a (5.5-hour) day sleep (starting at 0700) on alertness after the first night shift. Alertness is increased, but very little, leaving most of the night trough intact. Still, time in the risk zone (ie, values <7) during an 8-hour night shift starting at 2200 would change from 40% to 23% of the total work shift through the extension.

If instead a 2-hour extension of a 7.5-hour long night sleep (ending at 0730) is considered (one that precedes the first night shift), the time at risk is only reduced to 48%, from 58%, for the 8-hour sleep, mainly because the end of a sleep period contains very little recuperative value. The positive effect is supported by the observation of an increased propensity for afternoon napping among workers with a short prior daytime sleep (7).

It should be emphasized that research on sleep extension among shift workers needs to be experimental. It

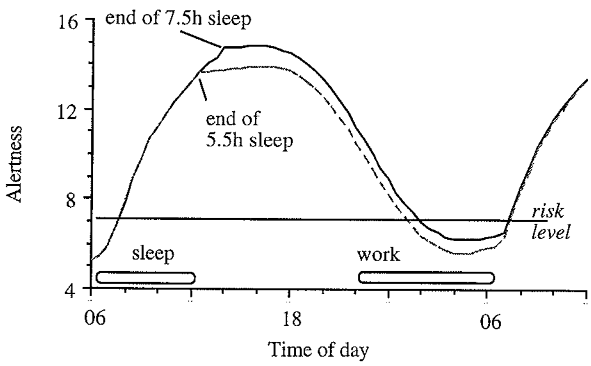

Figure 2. Effect of extension (5.5h to 7.5h) of day sleep between night shifts.

is not sufficient to study alertness in relation to spontaneously occurring differences in sleep length among shift workers. The reason is that strong confounding (sleep loss, caffeine, etc) may cause much of the variation in sleep length. Therefore those who show a long day sleep might have had a large prior sleep debt, while those who show a short day sleep might not have been sleep deprived before. Thus both groups may end up on the same level of postsleep sleepiness instead of showing the expected difference in sleepiness suggested by the length of sleep.

Split sleep — napping

The only shiftwork sleep strategy with any experimental data available is the split-sleep (nap) approach — but most of it still derives from laboratory work, and mainly from naps alone. Essentially, a nap reduces physiological (EEG measures) and subjective sleepiness and also improves performance (69—77). Behavioral measures are frequently the most sensitive ones (75, 78).

Surprisingly, however, there seems to exist no clear results with respect to the importance of the duration of the nap — 20 minutes may be as valuable as 2 hours. In most cases, the alertness-enhancing effects will increase with proximity to the nap (69, 74, 79, 80), up to a point where sleep inertia might interfere (81). The latter may be of importance in occupations which involve on-call work schedules and which require immediate readiness to perform.

Almost no field tests using EEG recordings and performance measures have been carried out. One exception is the National Aeronautics and Space Administration (NASA) study of 30-minute naps of air crew, yielding improved reaction-time performance (82). Many questionnaire studies have compared nappers with non-nappers, but they have yielded inconsistent results — possibly because the nappers are sleep-deprived beforehand — which is why they nap. Therefore causation becomes circular.

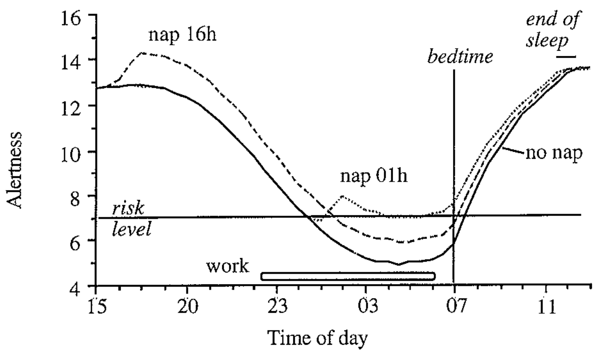

Figure 3. Effect of a nap at 1600 or 0100 on alertness and on subsequent day-sleep length.

Figure 3 illustrates the results of a simulation of a 1-hour nap started at 0100 during a first night shift (prior sleep termination at 0700). Alertness is increased, and the time at risk decreases from 69% to 19%. If the nap instead is taken at 1600, before the first night shift, the time at risk will still be reduced, but only to 54%. The temporal closeness of the nap to the critical work period is obviously of importance (78).

EEG-based field studies are also lacking on how a nightshift nap affects subsequent day sleep or whether a nap after a morning shift will interfere with an early start of the next night sleep and whether that early start implies inferior recuperation and reduced alertness the next day. Again, laboratory studies clearly indicate that the main (night) sleep subsequent to a nap will be reduced with respect to sleep length, SWS, and REM (69, 83—86). Some questionnaire studies seem to support this finding (7, 87).

The simulation in figure 3 also illustrates how the discussed naps reduce sleep length from 5.3 hours for the napless condition to 5.2 hours for the early nap and 4.8 hours for the late night nap. The reason is that, with later napping, recovery starts from a higher alertness level and reaches the sleep termination threshold earlier (64).

One would also need to know whether it would be more advantageous to extend the preceding main (day) sleep period after a night shift, or to reduce it, to make a later nap easier to initiate. One also wonders whether an early night nap would serve as an "anchor", as suggested by Minors et al (88), and thus prevent adjustment to night work. As yet, however, no field studies have been carried out on this topic.

Delays of sleep

Instead of extending day sleep after a night shift, or splitting it, one could try to delay sleep by a few hours, at least if one were willing to commit oneself to a night-oriented life-style. For this purpose bright light during night work, protection against conflicting timing of light, noise reduction, and low room temperature could be used. A laboratory experiment has shown that afternoon sleep is feasible, but it results in a shortening of sleep, as compared with the length of night sleep (89).

Other laboratory studies suggest that the sleep-interfering circadian influence increases with increasing closeness to the circadian acrophase of the rectal temperature rhythm (40, 90, 91), and disturbed afternoon sleep would thus be predicted.

The usefulness of delayed sleep is yet another of the untested sleep-wake tactics, except for 1 study of this type recently carried out on workers on North sea oil rigs. Under conditions of indoor work (no daylight) the workers actually developed a complete reversal of habits. After 2—3 initial days of adjustment a shift that finished at 0700 was followed by sleep delayed to 1030 (92), and the intervening time was used for social activities. Sleep and alertness also reached normal day work levels after this period. The data suggest complete adaptation. However, under these conditions, a return to day work became as difficult as the change to night work.

The simulation shown in figure 4 predicts that moving daytime sleep after a first night shift to bedtime at 1500 (for 5.5 hours of sleep) would reduce the time at risk to 0%, compared with the 58% if the same sleep is taken at 0700, immediately after the end of the night shift. Note that the morning hours before the afternoon sleep would be characterized by severe sleepiness. Probably, however, afternoon sleep would be a difficult strategy to implement for the entrained worker since the circadian rise and social obligations of the evening hours might interfere with sleep.

Delayed sleep would probably also need to include the use of light to phase-delay the circadian system (93), but there have been no real-life tests of this possibility. And, importantly, there has been no evaluation of the long-term effects of frequent phase shifting. Such an evaluation would be important, not only with regard to rotating shift workers, but also with regard to permanent night workers or rotators on very slowly changing shifts. These groups mostly return to day life on their days off, and thus, in effect, behave like rotators. A strategic use of melatonin would also provide a phase shift that may improve night work alertness (94). Practically, however, this approach may not be feasible because of the ethical problems of basing nightwork capacity on the regular use of a hormone.

One delay method that is frequently used by shift workers after the last night shift is to reduce morning sleep and to postpone most of the sleep to the night (2). This has not been subject to polysomnographic field studies, but laboratory experiments suggest that the result is a long and deep sleep (19). Logically, it should be an ideal way of returning to day life after a series of night shifts.

Morning shift — phase advance and napping

Before a morning shift, the shift worker usually tries to phase-advance bedtime. Often this process is difficult, however, since it brings bedtime close to the circadian acrophase and makes sleep difficult to initiate (18, 59, 60). The putative strategy to help shorten sleep latency would be to increase evening sleepiness by curtailing the previous night sleep episode. To the best of my knowledge, such an experiment has not been attempted. However, the simulation in figure 5 suggests that the sleep latency at, for example, 2000 will be 11 minutes for those rising at 0600, rather than the 15 minutes predicted if one were to rise at 0900. Again, this assumption needs empirical verification.

One way of circumventing the difficult phase advance is, again, to use light to phase-advance the circadian system (93), but, again, there has been no real-life test of this possibility. In comparison with light for phase delay on the night shift, the concern for long-term effects is probably less with early morning light, since the phase shift would be limited and within normal ranges of exposure to daylight. Melatonin might provide a similar phase shift (94). Practically, however, administration of a hormone to cope with night work may not be ethically feasible.

Many shift workers use afternoon naps to compensate for the truncated premorning shift sleep (7). However, such sleep makes a subsequent early bedtime difficult. Thus another experiment is needed to decide which strategy would yield the best total sleep and alertness in relation to the morning shift.

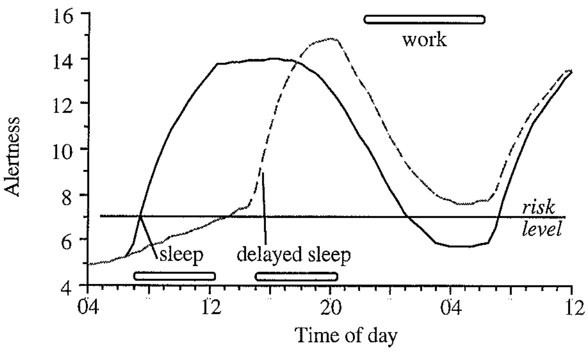

Figure 4. Effect of delaying a 5.5-hour sleep (from bedtime at 0700 to bedtime at 1500) on alertness.

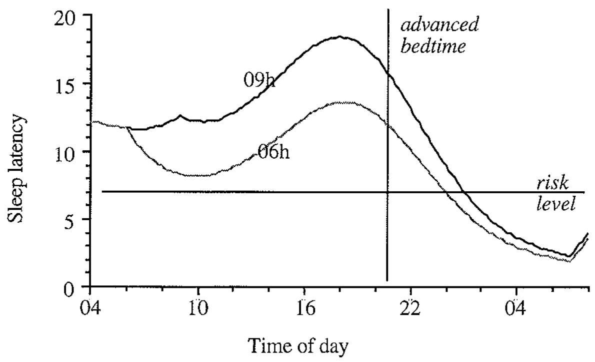

Figure 5. Effect of earlier rising (0600 compared with 0900) on sleep latency.

Modification by the speed of rotation

The preceding discussion was based on a "generic" view of the average type of shift schedule. There are probably calls for modification of one's sleep strategy, however, depending on the pattern of change between shifts, that is, how frequently one switches from one shift to another and in what direction the shift occurs.

Speed of rotation

The speed of rotation of a shift system refers to the number of consecutive shifts of the same type. The number can range from 1 to 10 or even more. Permanent shifts are a special case, but one needs to be aware of the fact that, for example, permanent nights usually mean 4—5 consecutive night shifts, followed by 2—3 days off. The latter are usually day oriented, and, therefore, permanent night work actually involves frequent shifting between night life and day life. As to optimum sleep strategy in relation to the speed of rotation, there is a complete lack of data. However, there is certainly room for speculation based on inference from other types of studies.

First, consider the shift worker who is scheduled to work a *single night shift*, followed by a day-morning shift (24 hours later), that is, a very rapid rotation. Unless there is a strong need for afternoon alertness, it would be possible to postpone sleep after the night shift from conventional bedtime at 0700 to an early night bedtime — around 2100—2300. This postponement would probably be associated with the fastest readjustment back to night work, as already discussed. One would probably recommend "light hygiene" (reduced nighttime light and increased morning light) to prevent a phase delay that might interfere with readjustment to day work. The recommendation would probably be the same even if a day off were interjected before the next workday, although the day off would permit more flexibility in sleep immediately after the night shift. The major research question in relation to sleep strategy on the single night shift would be whether or not to eliminate the day sleep after the shift, or perhaps to find the optimum amount of sleep still permitting proper night sleep later. Incidentally, the single night shift may be rare in traditional shift work, but it is very common in transportation, health care, police work, and the like.

If the schedule requires *2 night shifts in a row*, one would expect conventional post-night-shift sleep behavior with bedtime around 0700 the first day and end-of-night-shift-series behavior after the 2nd night shift, that is, sleep either being postponed entirely to the evening or the morning sleep being sharply truncated.

If there are *many night shifts,* one would be hard pressed not to recommend attempts to adjust through the use of light exposure during night work, avoidance of morning light, and immediate sleep (at 0700) after the end of the night shift (skipped day sleep). Again, end-of-night-work-series behavior would be expected after the last night shift. The effect of the adjustment caused by the sequence of night shifts would, however, require an extra day of recovery before return to day work. The main research question would concern whether full commitment (including treatment with bright light) to night work would, in effect, be preferable to noncommitment. This evaluation would have to include effects on sleep, alertness, and performance during the nightshift sequence, as well as during other shifts and during days off. Alertness during days off may, indeed, be the most important from the point of view of the shift worker.

The *single morning shift* would, as was the case with the single night shift, best be handled by the avoidance of adjustment — most shift workers are diurnal evening types and would probably have difficulties adjusting, and an afternoon nap should be implemented to supplement night sleep. In a slowly rotating shift system (>4 days in a sequence), on the other hand, one would recommend the morning-shift strategy already described. It should probably be supported by light treatment in the morning. Even if the shift workers are evening types, one might still expect some alertness or sleep problems the first days on a subsequent night shift. For extremely slow rotation patterns, light treatment may be a necessity.

Direction of rotation

The direction of rotation may also be of importance. No proper experiments on optimal sleep strategies have been carried out, but one may assume that a clockwise direction of rotation (morning - afternoon - night shift) would yield the standard sleep behavior already discussed. A counter-clockwise rotation (night - afternoon - morning) would probably yield a very late and long lie-in after the last night shift leading to the first afternoon shift. One could also perhaps expect a skipped day sleep, or pronounced difficulties getting to bed in the evening before the first morning shift. One would probably need to use the recommendations of truncating sleep after the last evening shift to increase evening sleep propensity, perhaps in combination with morning bright light. It should be emphasized that the counter-clockwise direction is often rather popular with shift workers since it ends with a morning shift, which starts the time-off period early in the day. It also gives workers a possibility to start their free days without too much readjustment from night work remaining — the readjustment being taken care of on company time, by the last morning shift(s). Counter-clockwise rotation also invites quick changes, that is, only 8 hours between shifts, which is a particular problem for strategic sleeping. The sequence night-afternoon -morning could, thus, become work 2200—0600, 8 hours off, work 1400—2200, 8 hours off, and work

0600—1400 — a very demanding schedule. Another variation may be morning - night - afternoon, that is, work 0600—1400, 8 hours off, work 2200—0600, 8 hours off, and work 1400—2200.

Individual differences

In discussions of optimal sleep strategies, one needs also to consider individual differences. One traditional such factor is morningness-eveningness, as well as "sleep flexibility" (95). There are indications that morning types have more disturbances of daytime sleep (96), which probably necessitates a sleep strategy with more supplementary napping.

However, more important factors may be gender, marriage status, and number of children in the family. Clearly, having small children might prevent sleep, particularly for women (97, 98), and the sleep pattern would have to be adapted to times when the children can be looked after by others. Clearly, being married or cohabiting is of major importance with respect to child care.

Concluding remarks

Shift work clearly affects sleep and wakefulness in a very predictable way and the answer to the question "Is there an optimal sleep-wake pattern in shift work? must be "yes" On the other hand, very little is empirically known about the finer points of shift work, and it can be expected that there is not only one, but numerous optimal sleep strategies, depending on the characteristics of the schedule, and perhaps on the make-up of the person. Obviously, there is a great need for experimentation, and some of the issues to study concern the extension of morning sleep after night work, split sleep (main sleep + a nap), nap positioning and duration, delay of main sleep, full commitment to night work (including treatment with bright light), phase advance and napping in relation to morning work, and modification of sleep strategies depending on the speed and direction of rotation.

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