Mini Review

What Can the Chronobiologist Do to Help the Shift Worker?

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Abstract This article is composed of a review of how the increasing numbers of people working abnormal hours (referred to as "shift workers") can best be helped by the science of chronobiology. While recognizing that chronobiologists can give much general advice regarding such things as diet, sleep hygiene, cardiovascular health, and the need to address social and domestic tensions, this article will focus specifically on the advice that can be given to employers and employees, which is directly rooted in our knowledge of chronobiology.

Key words circadian rhythms, human, shiftwork, night shift work, sleep

Without doubt, shift workers need help. Approximately one-fifth of all employees are engaged in some form of work that requires their presence outside of the "standard" 8-to-5 working day, and the figure is increasing as second jobbing and mandatory overtime increase (U.S. Congress, Office of Technology Assessment, 1991). The fastest growing sector of most Western economies is the service sector, and increasingly, people are demanding and receiving around-the-clock availability of such services. Even in the production sector, plant machinery has become so expensive and so quickly obsolete that it has to be run 24 h per day, 7 days per week, for it to be profitable. Also, many nations have adopted taxation and business evaluation strategies (e.g., in assessing profitability) that encourage employers to squeeze as many work hours per year as possible from their existing employees, rather than hiring new ones, as the volume of business increases. This leads to extended work weeks and fewer different work teams covering each 24-h day. In Europe and North America, the problem is, moreover, compounded by two major social and demographic trends (Presser, 1987). First, there is the social trend away from the "standard family" of one breadwinner and one housewife. In most households, there is now no longer a full-time homemaker to run the household and raise children. This inevitably places extra stresses on working parents, particularly mothers, who often bear a disproportionate share of child rearing and housekeeping responsibilities in addition to their career commitments (Gadbois, 1981). Second, with regard to demographics, the postwar baby-boom generation is reaching their early 50s—precisely the age at which significant shift work coping problems start to develop, even in those who had hitherto coped comparatively well (Foret et al., 1981). Arguably, in the Western industrialized nations, at least, we are headed for a crisis.

On the face of it, we are fortunate that these trends have coincided with an unprecedented increase in our understanding of the biological clock and its relationship to sleep and daytime functioning. Chronobiology should definitely be able to help. Without doubt, there is plenty of commonsense advice chronobiologists can give concerning the need for an appropriate attitude toward shift work. Thus, wearing our "expert consult-

JOURNAL OF BIOLOGICAL RHYTHMS, Vol. 15 No. 2, April 2000 86-94

ant" caps we can suggest strategies that make sense and are likely to help the employee to cope. Thus, for example, we can highlight the social and domestic problems that are likely to arise and can suggest counseling and educational strategies to improve them. We can highlight the health risks of shift work (particularly the cardiovascular ones) and suggest dietary and behavioral changes and the provision of an exercise program. We can educate people into good sleep hygiene practices and tell them of the dangers of excessive alcohol and caffeine use. In one nuclear power plant where regulators caught everyone in the control room asleep one night, one major recommendation of the "chronobiology expert" was that hard chairs be installed! These actions derive, however, from using our "bully pulpit" to make points that are empirically valid, but which do not flow directly from our knowledge of chronobiology. The powerful question remains as to whether there is anything useful we can say from a *directly chronobiological* point of view. Put another way, is there much we can say from our research of the behavior and characteristics of the human endogenous circadian pacemaker (ECP) that is of direct benefit to real shift workers? This review article seeks to answer that question. Thus, it will largely confine itself to chronobiological interventions and will limit discussion of issues such as health, sleep hygiene, and social and domestic issues, despite the present author's published belief in their paramount importance to the shift work question (Monk, 1988).

What Are Most Shift Workers Trying to Do?

From a series of sleep diary and time budget studies from several different countries, it is clear that most night workers seek to acquire a 9- or 10-h phase delay of their daily rhythms rather than a complete 12-h inversion (Kogi, 1985). Most night workers take their recreation *before* work rather than after work, and thus adopt an 8 or 9 AM bedtime, depending on when their shift ends. This leaves them able to interact with day-oriented friends and family members during the evening hours. Thus, for the ECP of a night worker to be perfectly appropriate for an 8 or 9 AM bedtime, its phase (timing) has to be changed to be 9 or 10 h *later* than the phase appropriate for an 11 PM bedtime. In terms of the body temperature rhythm, this change may, for example, be reflected in a minimum occurring at 1 PM, rather than at 4 AM.

Married night workers with family commitments typically do *not* retain a day sleeping regimen during their off duty ("weekend-type") break, as they want to interact with their day-oriented family, rather than be awake when everyone else is asleep. In doing so, they experience powerful zeitgebers (such as morning daylight) pulling them away from a nocturnal circadian orientation. Thus, even permanent night workers typically show a day-oriented ECP (as indicated, for example, by the body temperature rhythm) on their return to duty after a "weekend-type" break (Knauth and Rutenfranz, 1976; Monk, 1986). Thus, to a certain extent, even permanent night workers are often actually rotating between nocturnal and diurnal circadian orientations.

Evening shift workers usually adopt a schedule that requires a 2-h or 3-h phase delay in their bedtime. From a biological point of view, this is seldom a problem, and sleep diary studies indicate that, on average, evening shift workers get *more* sleep than their day working counterparts (Tepas, 1982). However, from a domestic and social point of view, evening work is often problematical in that it eliminates the ability of a parent to interact with his or her school-aged children for a week at a time. This again highlights the difference between what might work quite well from a strictly chronobiological point of view and what may or may not actually be feasible for people living in society with domestic and social commitments.

Rotating shift workers (who experience day, evening, and night shifts on a schedule that changes weekly or every 2 or 3 weeks) face a particular challenge. Studies have shown that such workers are particularly vulnerable to alcohol and substance abuse (Gordon et al., 1985). Because of the social and domestic issues mentioned above, and because of the taboos provided by society to protect nocturnal sleep, rotating shift workers tend to sleep at night whenever they possibly can. Thus, although the most chronobiologically sensible phase-adjustment strategy for rotating shift workers might be to schedule their sleeping so that they ride the wave of a gradually phase-adjusting ECP (as nicely shown by Eastman, 1990, in her "nudging" experiments), this very seldom occurs in real life. Thus, after evening shifts, most workers will sleep as soon as possible after work, and after everything but night shifts they will seek a normal late evening bedtime (Knauth et al., 1983). The implication of this is that after a transition between different shift timings, even nocturnal sleeps can be significantly disrupted by an inappropriately phased ECP. This partially accounts for the popularity of very rapid shift rotation, under which the ECP remains diurnal through-out and nocturnal sleep is never impaired by phase adjustment issues (see below).

Does It Help to Phase Adjust the ECP?

At first glance, the answer to this question might be obviously in the affirmative. Simple laboratory simulations of a single acute phase shift invariably show that as the ECP becomes re-entrained, so sleep and waking functioning return to baseline levels (Aschoff et al., 1975). In jet-lag situations, which have a similar etiology to shift work, the re-entrainment of the ECP several days after the flight heralds the normalization of sleep and the disappearance of daytime symptoms (Klein et al., 1972). When shift work is simulated in the laboratory using young volunteers, several authors have shown that ECP phase adjustment reaps benefits in terms of improved sleep and work functioning. In particular, bright light interventions that enhanced ECP phase adjustment also enhanced alertness, sleep duration, and sleep quality (Czeisler et al., 1990; Dawson and Campbell, 1991; Eastman et al., 1994). In terms of the two circadian markers most often used, the issue for night workers is to phase delay the ECP such that their (demasked) rectal temperature minimum (Tmin) moves into their morning day sleep episode, and their dim light melatonin onset (DLMO) moves to a few hours before that day sleep.

When one moves from the laboratory to the field, the desirability of complete phase adjustment becomes less obvious. Many shift workers are *not* in their late teens or early 20s, but are in their middle years of life (Mellor, 1986). Middle-aged subjects not only show more sleep impairment in response to a single phase shift (Moline et al., 1991) but also appear to have lighter and more disrupted sleep under baseline conditions (Carrier et al., 1997). Most important, when Campbell (1995) performed a landmark (laboratory) phase shift study on middle-aged subjects, he showed that a bright light manipulation that had been of benefit to young subjects conspicuously *failed* to reap any statistically reliable benefits in terms of daytime sleep or night time alertness *despite* having accomplished an increased phase shift of the ECP. Thus, it appears that middle-aged people show an increased sensitivity to any residual mismatch between ECP phase and imposed routine. There is also the complication of reversion to a diurnal circadian orientation during off-duty (weekend type) breaks. Unless circadian phase adjustment is quite rapid, it will only be complete by the end of the work week, after which most of the advantage would then be lost. Using subjects working on a socially isolated oil rig, Barnes et al. (1998) recently showed that the rate of phase adjustment of the ECP to night work (as measured by melatonin sulphate) was exactly as predicted by Aschoff et al.'s (1975) rule of thumb, namely, 90 min of phase delay per day. Thus, 5 or 6 days were needed before the melatonin onset achieved its desired timing, just prior to the (day) sleep episode. In most work situations, however, this would bring the individual to an off-duty break when a reversion to a diurnal pattern would likely ensue. Sack et al. (1992) studied actual shift workers who worked an unusual schedule of seven consecutive 10-h night shifts. Even in that schedule, in 7 of the 9 night workers, the timing of melatonin onset, while different to that of day workers, was *not* occurring between 6 AM and noon, that is, prior to or within the day sleep. This is similar to Weibel et al.'s (1997) conclusion that night work led to disparate timing of melatonin onsets and to an uncoupling of melatonin and temperature rhythms. In general, there seems to be an absence of published studies of actual shift workers in which a more rapidly obtained nocturnal orientation was associated with an improvement in symptoms. In an exhaustive series of studies on the sleep of shift workers, Tepas et al. (1981) concluded that major factors truncating sleep were often decisions by the shift worker to accommodate the needs and responsibilities of their everyday life, rather than strictly biological effects springing from an inappropriately phase adjusted ECP. Thus, it may well be the case that for most real shift workers, rapid phase adjustment is largely an unrealistic goal, which, even if achieved, may reap only limited benefits.

Can Bright Artificial Light Help?

Ever since the seminal work of Lewy and colleagues in 1980, which showed that only daylight levels of illumination were sufficient to suppress the production of melatonin by the human pineal, the dominant view has been that the human ECP can best be reset by extremely bright levels of artificial light (see Volume 10, Issue 2 of this journal for a comprehensive review). This was in contrast to the views, held in the 1960s and 1970s, that the human ECP (then called the "Group I" or "X" oscillator) could be changed only through its coupling to the oscillator(s) controlling the sleep-wake cycle (then called the "Group II" or "Y" oscillator(s)). The discovery of the strong zeitgeber effects of bright lights led to a series of studies using light to assist in changing the phase of the ECP. Typically, the bright light exposure regimens (e.g., of Czeisler or of Campbell) required at least 3 hours of >3000 Lux exposure from a bank of florescent tubes in a "light box." Eastman and Martin (1999) conducted a careful series of experiments using student volunteers to assess the utility of bright artificial light in helping shift workers to cope. As with other investigations, however (e.g., Czeisler et al., 1990), these studies indicated that darkness during the sleep period was almost as important as the light. Thus, complete bedroom light proofing was required, and (more problematically) Eastman et al. (1994) showed convincingly that dark welder's goggles usually needed to be worn during the morning commute home from night work for the required ECP phase delay to be accomplished, a procedure that might compromise traffic safety.

The case can still be made quite strongly, however, for workplace lighting to be increased in brightness. Several studies have shown that bright light on the night shift definitely increases alertness even when the light is of insufficient intensity to induce a strong resetting of the ECP. It appears plausible that this increase in alertness is, at least partially, associated with suppression of melatonin. When Badia et al. (1991) pulsed bright lights during the night shift, equivalent pulses were seen both in subjective alertness and in melatonin suppression. This was developed further by Wright et al. (1997) who showed that the combination of caffeine and bright light (2 K Lux) suppressed nocturnal melatonin to a greater extent than bright light alone. Also, Martin and Eastman (1998) showed that even moderate levels of night shift illumination can phase shift the ECP. Thus, when comparing 5700 Lux with 1230 Lux (3 h / night for each), they found that while all of the 5700 Lux group had sufficient phase delays to put Tmin into their day sleep episode during the third through the fifth night shifts, a surprisingly large 85% of the 1230 Lux subjects achieved the same goal. This is important because a 1230 Lux workplace is several orders of magnitude less expensive to achieve than is a 5700 Lux workplace. Thus, from a pragmatic point of view, it makes sense to advise brightly lit night shift workplaces, with the level of illumination determined by "what the market will bear." Paradoxically, this runs counter to common practice, which is often to dim workplace illumination levels during the night shift. In some situations, the extra cost of obtaining a Type 0 (strong) resetting of the ECP can be justified. For example, Czeisler and colleagues (1991) showed in the NASA astronaut crew quarters in Houston, when extreme measures are taken to get true daylight illumination at night, phase shifts may indeed be accomplished quite rapidly.

Can Melatonin Pills Help?

This is a difficult issue, not the least of which is because many U.S. shift workers are making use of the easy commercial availability of the hormone in America and are using melatonin pills on a regular basis. Because melatonin pill manufacture in the United States is largely unregulated, the issue is both one of efficacy and one of safety. In terms of efficacy, one must separate the possible roles of melatonin pills as hypnotics (assisting in initiating and / or maintaining sleep) and chronobiotics (changing the phase of the ECP). Regarding its role as a hypnotic, several studies have shown that melatonin pills assist in acquiring daytime sleep (Zhdanova et al., 1997; Hughes and Badia, 1997). However, there have recently been several double-blind placebo controlled trials of melatonin pill efficacy prior to a daytime sleep in actual shift workers, and not all have had positive findings. While Sack et al. (1997) did show some beneficial effects of melatonin pills, other studies (mostly from the field of emergency medicine) have been less successful. Jorgensen and Witting (1998) showed that while 10 mg melatonin before bed improved night shift alertness and daytime sleep, the effect was not statistically reliable (n = 22, cross-over design). James et al. (1998) showed that 6 mg melatonin derived no significant benefits in terms of diary measured day sleeps (n = 22, cross-over design).

Sack and Lewy (1997) discuss the role of exogenous melatonin as a pharmacological chronobiotic, that is, a drug that acts as an effective zeitgeber, and have constructed a phase response curve (PRC) for its circadian resetting properties. However, for the shift worker, the problem with using melatonin as a zeitgeber is that its PRC has less power than that of the bright light PRC, with an excursion of only 1 or 2 h. This means that if bright light (e.g., daylight) is in competition with melatonin as a zeitgeber, then the former is likely to win out. Thus, as distinct from its hypnotic properties, the chronobiotic properties of exogenous melatonin are likely to be insufficiently strong to be of much help. This is supported somewhat by a Dawson et al. (1995) study showing that bright lights at night helped more than did melatonin pills taken before and during the day sleep, although the timing of melatonin administration was not optimal.

With regard to safety, there are two issues of concern. First, in the United States at least, no federal or state agency is regulating the manufacture and sale of melatonin pills, and one thus must therefore be wary of contaminants such as those that caused the Tryptophan tragedy. Second, no studies have been done as to the effects of chronic flooding of the brain with pharmacological doses of a hormone that is usually only present in rather minute quantities. In conclusion, while using melatonin to enhance day sleeps makes good empirical sense, there remain many concerns before melatonin pharmacotherapy can be unequivocally recommended.

Can Naps Help?

In certain situations, it would appear that naps can be of significant benefit. Most notably, since Dinges and Kribbs (1991) have shown a long-lived prophylactic effect of naps on subsequent alertness and performance during sleep loss, and since we know that a "gate to sleep" opens during the afternoon hours (Lavie, 1991), an afternoon nap prior to the first night or a run of night duty is clearly advisable. Similarly, at the end of a run of night duty, a nap after work might allow the individual to remain awake until a nocturnal bedtime (assuming that he or she is then reverting to a diurnal orientation). More contentious is the issue of napping at work. In an ideal world, this would not be necessary as a nocturnal orientation would eliminate the need for it. However, many Japanese companies and some Canadian companies have provided the opportunity for controlled napping at work and shown it to be beneficial. The NASA-Ames group (Rosekind et al., 1994) have clearly shown that controlled cockpit napping can be enormously effective in long-haul airline operations and have developed an appropriate protocol that can be followed to avoid sleep inertia effects. Unofficially, many shift workers do nap during their meal break (or at work) and companies are starting to realize that it may be better to have controlled official napping than uncontrolled unofficial napping. Since it appears that sleep per se does not act as a zeitgeber, it would appear that such naps are unlikely to impede phase adjustment of the ECP.

Can New Shift Rotation Schedules Be Recommended?

Many chronobiologists are familiar with the phone call from a plant manager who wants to discover in a 5-min telephone conversation what might be the "best" shift rotation schedule for his or her plant. Usually, the manager is disappointed to learn that there is no simple "off the shelf" schedule that will eliminate all of his or her shift work woes, and is further disheartened to learn that the one conclusion that *can* be drawn is that the manager's current backward weekly rotating schedule (often referred to in the United States as the "Southern Swing") is probably one of the worst possible choices (Knauth, 1993).

Even over the phone, however, there are some chronobiological principles that can be suggested. First is the question of shift start times. As Folkard and Barton (1993) have shown, very early start times for a morning shift (earlier than 7 AM) can lead to almost as much sleep disruption as a night shift. One reason for this is the early evening circadian "forbidden zone," which makes sleep onsets at around 9 PM extremely difficult to accomplish (another, of course, is prime-time TV scheduling). Thus, one piece of advice concerning scheduling is that morning shift start times earlier than 7 AM should be avoided. In a study of a three-shift steel rolling mill, Rosa et al. (1996) showed that delaying the start time by 1 h reaped significant benefits for morning shift alertness, which outnumbered the slight reductions that appeared in evening and night shift alertness. Second is the question of recovery time. Because, from chronobiological principles, we know that sleep is difficult to take during the "wrong" circadian phase, any schedule having a daytime "quick return" (i.e., having 8 h or less between the end of a night shift and the beginning of an evening shift the same day) is unlikely to allow the individual sufficient sleep (Barton and Folkard, 1993). Thus, schedules having quick returns should be avoided (although workers often like them because they compress the work week allowing longer stretches of time off).

Third, there is the question of shift rotation direction. Since circadian adjustment to a phase delay is about 50% quicker than to a phase advance (Aschoff et al., 1975), forward (clockwise) shift rotation would seem to be preferable to backward rotation, and many authors (including the present one) are in print as suggesting that forward shift rotation should be adopted. However, there is surprisingly little hard evidence from field studies of actual shift workers to support this assertion. In Czeisler et al.'s (1982) "Potash Mine" study, not only the *direction* but also the *speed* of rotation was changed, making the positive results ambiguous with regard to directional asymmetry. The issue has been addressed directly in studies by Barton and Folkard (1993) and Barton et al. (1994). Surprisingly, these careful studies have shown that when a direct comparison is made between a weekly forward and a weekly backward rotating system, there is no evidence for any reliable superiority in the former, unless it leads to the absence of a quick return. Thus, in comparing discontinuous systems (i.e., weekly rotating with weekend breaks), Barton et al. (1994) conclude that "there seems to be little evidence from our study to support the view that advancing as opposed to delaying systems are the most detrimental" (p. 754). A possible reason for this is given in an earlier article by Turek (1986) who suggested that although the timing of work might rotate in a particular direction, the timing of sleep need not.

Also contentious is the issue of speed of shift rotation. While almost all experts agree that weekly shift rotation is inadvisable, there is disagreement about what the alternative should be (U.S. Congress, Office of Technology Assessment, 1991). Unlike North America, Europe has many operations working a rapidly rotating shift system, which involves all three shift timings covered within a single week. Most notable of these is the 2-2-2 rota (two morning shifts, two evening shifts, two night shifts, two days off). This type of system is seldom seen in North America except in the 2-2-1 schedule (two evening shifts, two morning shifts, one night shift, and two days off) worked by most U.S. air traffic controllers. To understand the appeal of rapidly rotating systems, one must remember that their aim is to keep the ECP resolutely diurnal, so that no symptoms of internal desynchrony appear. All but one or two sleeps of the week can be taken at night, and the off-duty recovery break immediately follows the night shift(s), allowing time for sleep deficit recovery. The disadvantage, of course, is that all night work is undertaken during the "wrong" circadian phase. This is important because there is a well-documented circadian rhythmicity in human performance and alertness that usually shows a trough in the early morning hours (Folkard and Monk, 1979; Johnson et al., 1992).

In contrast to rapid rotation of shifts is a slow rotation schedule (or fixed shift schedule) in which phase adjustment is encouraged by having 3 weeks or more on the given shift timing before moving to a different timing. As mentioned earlier, though, one can argue that such a system is flawed in that a nocturnal orientation is usually lost during weekend type breaks, from workers wanting to spend time with their day-working friends and family, and that de facto the rotation remains weekly. However, it is still true that most night shifts will be spent in at least a partially adjusted state, and many shift worker surveys have indicated that to the worker, both alertness at night and sleep during the day improve after the first couple of nights at work. A further advantage is that, where feasible, countermeasures such as melatonin pills, bright lights in the workplace, and bedroom darkening can be of benefit (but see the caveats noted above). The only definitive way to answer the controversy from a chronobiological point of view is to determine which is the more harmful: (a) working through one or two nights per week without changing ECP phase (i.e., occasionally being in a state of *external desynchronosis*) or (b) changing ECP phase on a regular basis and thus, during the process of phase adjustment, suffering from *internal desynchronosis*. Unfortunately, we currently do not know whether external desynchronosis or internal desynchronosis is the more harmful. Sorely needed is an animal model to tease out which of the two most adversely affects longevity. Until that model is available, decisions must rest upon the appropriateness of the task being performed (monotonous repetitive tasks are unlikely to fare well under rapid rotation) and the personal preferences of the workers involved.

Can Educational Strategies Be Developed for the Worker?

The answer to this is an unequivocal yes. However, as Popkin has shown, if the workers are to actually implement the information given to them, the intervention must have a continuous presence and relevance, rather than be a single 2-h training session. Thus, the chronobiological education strategy should be similar to the semicontinuous campaigns for safe work practices that are conducted by company safety departments and / or the year-long exercise and smoking cessation campaigns that are conducted by company medical officers. All too often the organization tries to get by with just a single training session or take-home video. The aim should be to keep shift workers as continuously aware of the physiological and behavioral aspects of the problem as professional deep-sea divers are of theirs. Just as divers are working in an unnatural *physical* environment, shift workers are working in an unnatural *temporal* environment.

In deciding what might go into an educational strategy, it is worth emphasizing the multifaceted nature of the problem, and thus the need for multifaceted solutions. From a circadian viewpoint, workers need to know the endogenous nature of the ECP, its slow adjustment to a change in routine, and its profound influence on sleep and waking functions. Also needed to be acquired are the concepts of phase adjustment and zeitgebers, so that the worker can understand what he or she needs to do with regard to the timing of his or her ECP and the zeitgeber pattern that is most likely to accomplish it. From a sleep viewpoint, the worker needs to understand the concept of sleep hygiene, as well as the benefits and pitfalls of agents such as sleeping pills, melatonin, alcohol, and caffeine. From a social and domestic viewpoint, the worker needs to understand the ubiquity of family strains in shift worker households, recognizing that he or she is not alone in experiencing them. Coping strategies (possibly including self-help groups and counseling) should be also suggested. From a health viewpoint, the worker needs to be informed of the cardiovascular and gastrointestinal risks of shift work so that behaviors that further increase the risk can be avoided. Also, the issue of aging should be addressed. Many middle-aged shift workers are puzzled by their sudden difficulty with shift work rotas that they had coped well with at a younger age and erroneously think that they are now suffering from a new disease, rather than from a natural effect of aging, in conjunction with an unnatural work / rest schedule.

CONCLUSIONS

Many shift workers are experiencing significant problems in coping. Often, these problems result from inadequate training regarding the human circadian system and its relation to sleep, alertness, and performance. Educational strategies by the chronobiologist can thus reap significant benefits, particularly if presented in a sustained campaign. From a chronobiological viewpoint, useful strategies might include the judicious use of bright lights at the workplace, napping strategies at home, and (possibly) the use of melatonin pills to facilitate daytime sleep. Unduly difficult shift work rotation strategies might also be avoided. However, further research needs to be done (particularly in regard to appropriate animal models) before any truly definitive advice can be given concerning more specific chronobiological countermeasures.

ACKNOWLEDGMENTS

This work was supported by NAG 9-1036, NAS 9-19407, MH 01235, AG 15136, and AG 13396. Research and clerical assistance were provided by Kathy Kennedy and J'aime A. Hall.

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