Chapter 5

Biological Rhythms and Work Schedules

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Chapter 5

Biological Rhythms and Work Schedules

As discussed in chapter 3, disruption of biological rhythms can result in physiological changes that adversely affect both health and performance. In the workplace, certain types of work schedules can require persons to work at inappropriate points in the circadian cycle and cause disruptions of biological rhythms, notably circadian rhythms. However, in these situations, the physiological changes caused by disruption of circadian rhythms often interact with other stressors associated with work schedules (fatigue, sleep deprivation, and social or domestic stress) to compound the effects. This chapter discusses these interactions, their consequences, and possible interventions to prevent them.

WORK SCHEDULES

The characteristics of work schedules that can be varied include the length of the work period, the placement of the work period in the 24-hour day, the regularity of that placement, the speed at which the placement changes, and the ratio of work time to rest time. Any schedule that requires workers to work when they would normally be sleeping (and sleeping when they would normally be awake) can disrupt circadian rhythms (31). This includes schedules that require workers to constantly change the hours that they work or to work for extended periods of time.

Shift work is not new (103,144). Historically, bakers have worked through the night to ensure fresh bread in the morning, and in ancient Rome deliveries were restricted to the night hours in order to relieve traffic congestion. With the initiation of the Industrial Revolution, more and more work processes required fill-time operation. Since then, there has been an increase in the prevalence of shift work as industrial needs for 24-hour operations combined with more and more service industries providing evening or around-the-clock coverage.

As described in chapter 4, a variety of shift schedules are used in work settings, including schedules of fixed or rotating shifts. In a rotating shift schedule, the individual works one shift for a period of time before rotating to the next shift. Thus, the person will frequently be changing the scheduled hours he or she works. In a fixed shift schedule, the worker always has the same work hours.

Work that continues for long periods of time (i.e., usually beyond 12 hours) and causes workers to decrease or miss their normal sleep is considered extended duty hours. Often there is not a clear distinction, or there is overlap, between shift work and extended duty hours. For example, workers on a rotating shift schedule may work overtime, exposing them to both extended duty hours as well as the rotating shift. Extended duty hours can lead to disruptions in circadian rhythms that interact with other factors, especially loss of sleep and fatigue, to affect health and performance. (Sleepiness is the inclination to sleep, whereas fatigue is weariness due to physical and mental exertion.) It is possible to experience one without the other, but both, either alone or in concert, can have deleterious effects. This is especially true if such work schedules are consistently marked by extended work periods interspersed with relatively short rest periods and are irregularly scheduled. Examples of occupations that involve extended duty hours are medical and surgical residencies at hospitals, military operations, long-haul trucking runs, and any setting in which there is frequent overtime work.

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METHODOLOGY

Because the effects of work schedules are sometimes subtle and involve a number of factors, they can be difficult to study. Frequently, the most important variables are those that occur outside the workplace (e.g., quality of sleeping during the day, social effects), thus research relies to a large extent on self-report and anecdotal information. Three basic classes of studies have been used to examine effects of work schedules: 1) field studies, 2) survey studies, and 3) laboratory studies.

Field studies, in which the researcher studies subjects in their actual work environment, are comparatively rare in the world literature and largely absent from the U.S. literature because of the high cost and difficulty of getting substantive physiological, production, or subjective measures from a group of workers for a reasonable period of time (e.g., one complete cycle of a rotating shift schedule). Field studies often have a small sample size and require a dedicated group of volunteer subjects if circadian rhythm or sleep variables are to be measured properly. Such studies can provide an invaluable picture of what is happening to the sleep, circadian rhythms, and performance of shift workers under various conditions. An example of field studies that have been carried out in the United States are those conducted by the National Aeronautics and Space Administration (NASA) on fatigue, sleep, and circadian rhythms in flight crews. Field studies in other occupations have been carried out in Sweden (5), West Germany (84), the United Kingdom (158), and France (129).

Physiological measures taken in field studies are typically in the domains of circadian rhythms and sleep. Body temperature is the preferred variable in measures of circadian rhythms because it is easily measured and reliable in indicating the status of the circadian system. Ideally, sleep is measured by directly monitoring physiological functions (e.g., brain activity, eye movements, muscle activity) during sleep, but this is often impractical, so subjective measures, such as sleep diaries or sleep questionnaires, are used. Another method, which has been used more recently, is wrist activity monitors worn by workers to collect information on activity levels, from which amounts of sleep are inferred (128). Mood, social and family factors, and performance can be measured by self-report tests, sometimes augmented by measures of on-the-job performance.

Survey studies are considerably easier to conduct and usually involve questioning the worker in one or two interviews or classroom-type sessions. These data are augmented by data from personnel, health service, and absenteeism files and a review of production figures. Neither circadian rhythm nor sleep diary measures can be obtained directly in survey studies. Data on these variables are gleaned from questions about perceived levels of alertness while on duty and average timing and quality of sleep after various shifts. Survey studies are often carried out before and after an intervention in order to assess its impact (36). Contamination by placebo effects,[1] which can endanger the validity of outcomes, is a problem that needs to be carefully controlled for in survey studies (116).

Laboratory studies attempt to simulate the workplace in a controlled situation. In some cases, workers are used as subjects, but since that is often impractical, studies usually use other individuals as subjects (86,175). The major advantage of laboratory studies is that they are the best way to get accurate, clear, and complete recordings of sleep and circadian rhythms (and mood and performance measures) without all of the interference and missing of readings that are so characteristic of field studies. The disadvantage is that some factors that play a role in the real work situation (e.g., social and domestic strains, the length of exposure to the schedule being studied) and the types of stress experienced may not be replicated exactly. Another important consideration in laboratory studies is the nature of the task the subject is to perform. In some cases, when general information about the effects of a work schedule on variables such as performance, alertness, and vigilance is desired, standardized tasks and tests can be used. However, in studies of the effects of a schedule on a specific type of job, simulators are used to recreate the work environment. For example, simulators that replicate an aircraft cockpit, a nuclear powerplant control room, or an air traffic control tower are effective aids in the study of the effects of work schedules on worker performance during specific job-related tasks.

[1]The placebo effect is when an intervention that has no real, direct action results in an effect, e.g., when a subject reports feeling better after having been given a sugar pill. The effect is due not to the intervention but to the subject's anticipating an effect from the intervention.

STRESSORS CAUSED BY WORK SCHEDULES

Human beings are essentially diurnal creatures, whose internal clocks are naturally geared toward sleep and inactivity at night and activity and wakefulness during the day. Because of this, the vast majority of human society is structured with the expectation that work will be done during the day, recreation in the evening, and sleep during the night. Morning and evening rush hours are catered to by mass transit; prime-time television, sports events, and social gatherings occur in the evening; and a quiet environment is enforced at night. Social taboos, for example, protect a day worker's sleep from nonemergency telephone calls at 2 a.m., but none protects a night worker's sleep from 2 p.m. calls. Thus, the shift worker is very often fighting both the natural diurnal trend and sociocultural attitudes.

Consequently, there are three sources of stress, or stressors, for the shift worker:

- disruption of circadian rhythms,
- disruption of sleep and fatigue, and
- social and domestic disturbances.

These stressors act alone and in combination to produce adverse effects on the worker. The first two are physiological effects associated with the hours of work and the length of the work period. The third can result from the worker's interactions at home and with the rest of society as a result of the work schedule. How much stress these three sources place on the worker varies with the nature of the work situation and the work schedule. For the person working extended duty hours, sleep loss and fatigue may be the most salient factor, while for the rotating shift worker, circadian disruptions may be as important.

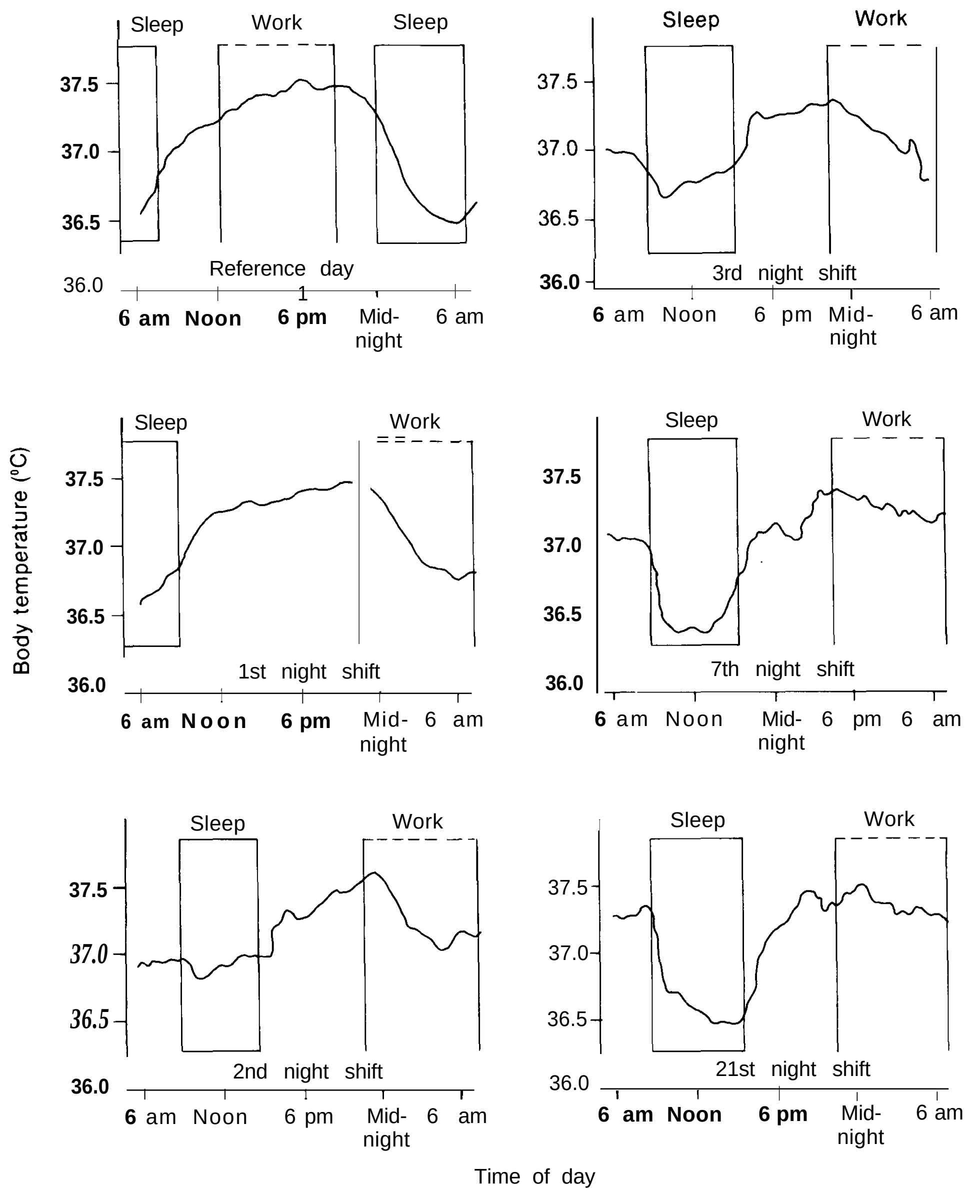
The impact of these stressors and their resultant consequences may, in some individuals and some situations, lead to difficulties in coping with the work schedule. There is great variability among people in their ability to adjust to shift work, with some individuals suffering few, if any, problems and others finding certain work schedules intolerable. It should be kept in mind, however, that even those individuals who appear to adjust well to shift work may experience negative effects on factors such as performance or safety. Also, for some individuals, some of the nonphysiological characteristics of shift work (e.g., improved access to daytime services, more time with young children, a sometimes lighter workload, higher pay) may be positive attributes. For others, the negative factors associated with shift work make adaptation difficult. In a study of 9,000 shift workers, it was found that 20 percent had difficulty adapting to shift work (140). This percentage rises as one moves to older age groups. In a study of an Austrian oil refinery, it was found that more than 80 percent of the sample expected to be unable to continue shift work until retirement (88).

Disruption of Circadian Rhythms

As previously mentioned, work schedules can have two consequences related to circadian rhythms. First, a schedule may require that an individual be awake and active at an inappropriate time during the circadian cycle. Second, work schedules can result in a state in which the individual's circadian rhythms are out of synchrony. As described in chapter 3, the circadian system is kept on track by an entrainment mechanism that uses time cues in the environment (light-dark) and the behavior of the individual (social interaction, meal times, sleep-wake schedule, and so on). This entrainment mechanism keeps an individual's circadian cycles aligned and in tune with the 24-hour rotation of the Earth. The process of adjustment to the abrupt, large changes in routine caused by shift work is slow, typically taking a week or more (82,108,175) (figure 5-1). Not only does the inherent inertia of the circadian system slow adaptation to a work schedule, the presence of competing time cues (e.g., light-dark. social cues) further slows the adjustment process.

Irregular work schedules (e.g., those routinely experienced by locomotive engineers) and schedules that involve frequent crossing of time zones (transmeridian airline crews) result in chronic circadian desynchronization. In rotating shift work, although the rotation schedule is freed and regular, the length of time spent on a given shift may not be sufficient to allow for complete resynchronization of the circadian system. In weekly rotations, complete re-entrainment may never occur, and the worker may be in a perpetual state of circadian desynchronization (150). In a rapidly rotating schedule (1 to 3 days) shift changes occur so quickly that the circadian system does not have enough time to begin resynchronizing before the next rotation change; as a result, the worker's cycles remain diurnal (figure 5-2). However, the individual will be out of synchrony when he or she is working on the night shift. Some researchers (56,82) maintain that, regardless of rotation length, complete realignment of circadian cycles never actually takes place in shift work due to the competing influences of cues in the society telling workers that they are on an abnormal schedule. Even in permanent night shift work, if the worker does not maintain the same schedule on days

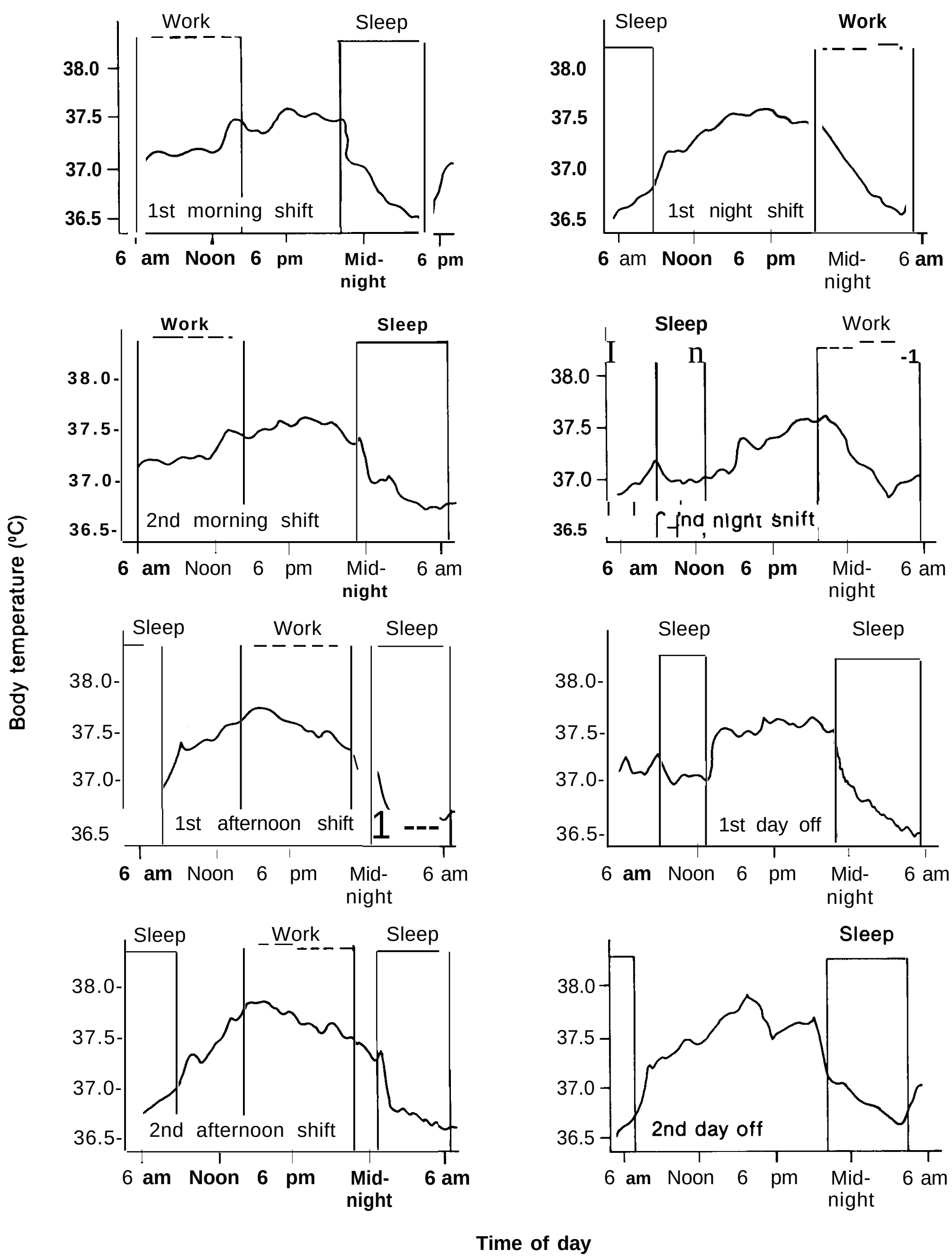
Figure 5-l—Relationship of Body Temperature, Work, and Sleep on a Permanent Night Shift



Graphs showing average body temperature of workers on the day preceding the start of night work and on days on the night shift. By the seventh night, body temperature has synchronized to the night schedule.

SOURCE: Adapted from S. Folkard, D.S. Minors, and J.M. Waterhouse, "Chronobiology and Shift Work: Current Issues and Trends," *Chronobiologia* 12:31-54, 1985.

Figure 5-2—Relationship of Body Temperature, Work, and Sleep in a Rapidly Rotating Schedule



Graphs showing average body temperature of four workers on a 2-2-2 rotating shift system. On the night shift, the low point of body temperature coincides with the work period.

SOURCE: S. Folkard, D.S. Minors, and J.M. Waterhouse, "Chronobiology and Shift Work: Current Issues and Trends," *Chronobiologia* 12:31-54, *1985*.

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off as on workdays, he or she will rapidly revert to the natural diurnal orientation (105,165). In such circumstances, the circadian system never fully synchronizes to the night schedule.

A desynchronized circadian system produces a number of effects on the individual. First, since the circadian system sets the time for sleep and wakefulness, a disrupted circadian system will interfere with both sleep and daytime functioning. Daytime sleep will be disrupted by daytime mechanisms, and the ability to stay awake at night will be impaired by circadian functions that are normally associated with sleeping (5,7,56). In some tasks, particularly monotonous ones such as driving, vigilance, monitoring, and quality control, this may lead to decrements in performance that compromise productivity and safety (42,57,108). Second, as discussed in chapter 3, the ability to perform certain types of tasks is also on a circadian cycle. A desynchronized circadian system results in the person's attempting to perform certain tasks at a time in the circadian cycle when his or her ability to perform those tasks is not optimal (56). Finally, an inappropriately synchronized circadian system is in a state of disharmony akin to that of a symphony orchestra without a conductor. The disharmony itself may result in feelings of malaise and fatigue, as well as certain gastrointestinal symptoms (37,140).

The degree to which individuals are affected by circadian disruption varies (132). There is often an interaction between aging and circadian rhythms, which would indicate a greater susceptibility to rhythm disturbances with age (see ch. 3) (80). These factors suggest that some people may be better able to tolerate the circadian desynchronization associated with shift work than others.

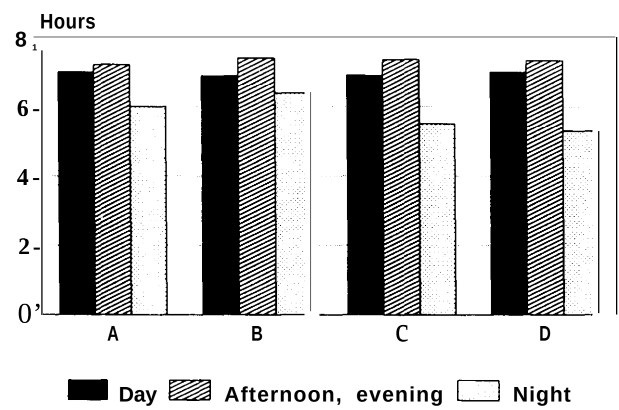
Sleep Disruption and Fatigue

Schedules that require work during nighttime hours are associated with sleepiness and fatigue. About 60 to 70 percent of workers on rotating shifts complain of sleep disruption (141), and general fatigue is reported more frequently by shift workers than by day workers (5). In a study of diverse occupational settings that included steel workers, meteorologists, and police, 80 to 90 percent of the subjects reported that they experienced fatigue during night work (6). Sleepiness is generally associated more with the night shift than the morning and afternoon shifts. The most common complaint is the inability to sleep as long as necessary during the day (2). Permanent night workers also have shortened sleep, although to a lesser extent than rotating shift workers (38,172) (figure 5-3). Sleep disturbances and fatigue can occur as a result of the irregular hours typically worked by railroad engineers (154,159), the work schedules and jet lag experienced by commercial airline pilots (64,67), the watch schedules aboard merchant ships (142), and the extended on-call schedules of resident physicians in hospitals. Any job involving long work periods, whether as a result of overtime or as part of the regular schedule, can result in sleep loss and fatigue (box 5-A).

A worker's sleep can be disrupted by both endogenous and exogenous factors. As mentioned earlier, the endogenous factors stem from the desynchronized circadian system, which has failed to prepare the body and mind for sleep and wakes the system up before 7 or 8 hours of restful sleep have been obtained (5,56). Often, workers will complain of being wakened by exogenous factors (e.g., traffic noise, children playing), whereas in reality it is their desynchronized circadian system that is the culprit (4,59). Workers will also experience fatigue and sleep loss from any work schedule that requires them to stay up for long hours.

Exogenous factors can be just as big a problem. The daytime environment is much less conducive to sleep than the nighttime. Daylight can intrude on

Figure 5-3-Length of Sleep of Permanent and Rotating Shift Workers



Average sleep lengths on different shifts for two samples of permanent (A,B) and rotating (C,D) shift workers. Rotating shift workers on the night shift had the shortest average sleep lengths.

SOURCE: M. Colligan and D. Tepas, "The Stress of Hours of Work," *American Industrial Hygiene Association Journal* 47:686-695, 19s6.

Box 5-A—*Nigbt Shift Paralysis*

One consequence of sleep deprivation is the occurrence of a ram phenomenon known as night shift paralysis. This condition is marked by a momentary paralysis, usually lasting about 2 minutes, during which individuals are aware of their surroundings but are unable to make voluntary movements. Night shift paralysis has been observed in studies of nurses, naval officers, printers, and air traffic controllers and is associated with high levels of sleepiness.

In a study that looked at night shift paralysis in 435 air traffic controllers from 17 countries, 26 claimed tohave experienced night shift paralysis at some time during their careers. A total of 75 incidents was reported by these 26 controllers. The researchers conducting the study calculated that the potential for an accident resulting from an occurrence of this paralysis is 0.5 time in each individual's working life. No accidents or near misses were associated with any of the episodes of night shift paralysis reported in this study.

Factors identified as contributing to the occurrence of night shift paralysis include time of night, the number of consecutive night shifts the person had worked, and having worked both a morning and a night shift on the same day. Of the 75 reported incidents, 56 took place during the night shift, 12 during the day shift, and 7 during the morning shift. Interestingly, it was observed that individuals who were more rigid in their sleeping habits were more likely to experience night shift paralysis than persons who were able to fall asleep at unusual times. This seemingly paradoxical finding maybe due to the fact that flexible sleepers may suffer less sleep deprivation when working shifts (see text),

The researchers concluded that the incidence of night shift paralysis maybe a useful reflection of the extent of sleep deprivation. They also suggested that its occurrence maybe reduced by limiting the number of successive night shifts to one and by not allowing an individual to work both a morning and a night shift on the same day, Thus, while night shift paralysis is an extremely uncommon event, it does illustrate how work schedules can cause sleep deprivation, with potentially far-reaching effects.

SOURCE: S. Folkard and R. Condon, "Night Shift Paralysis in Air Traffic Control Officers," Ergonomics 30:1353-1363, 1987.

sleep if the sleeping quarters are not sufficiently darkened. Households are noisier, and there is a much greater chance of interruption from telephones ringing, televisions playing, and general activity both inside and outside the home. In addition, the worker may feel compelled to interrupt sleep voluntarily in order to meet family and social demands that occur during the day (101,153). Consequently, day sleep is much more susceptible to disruption by domestic commitments (shopping, child care, and so on) than is night sleep. Very often, social and domestic disharmonies (see later discussion) tend to develop because family members get blamed for sleep disruptions that may not be entirely their fault. In addition, if a shift worker takes on another job, the likelihood that he or she will set aside adequate time for sleep diminishes further.

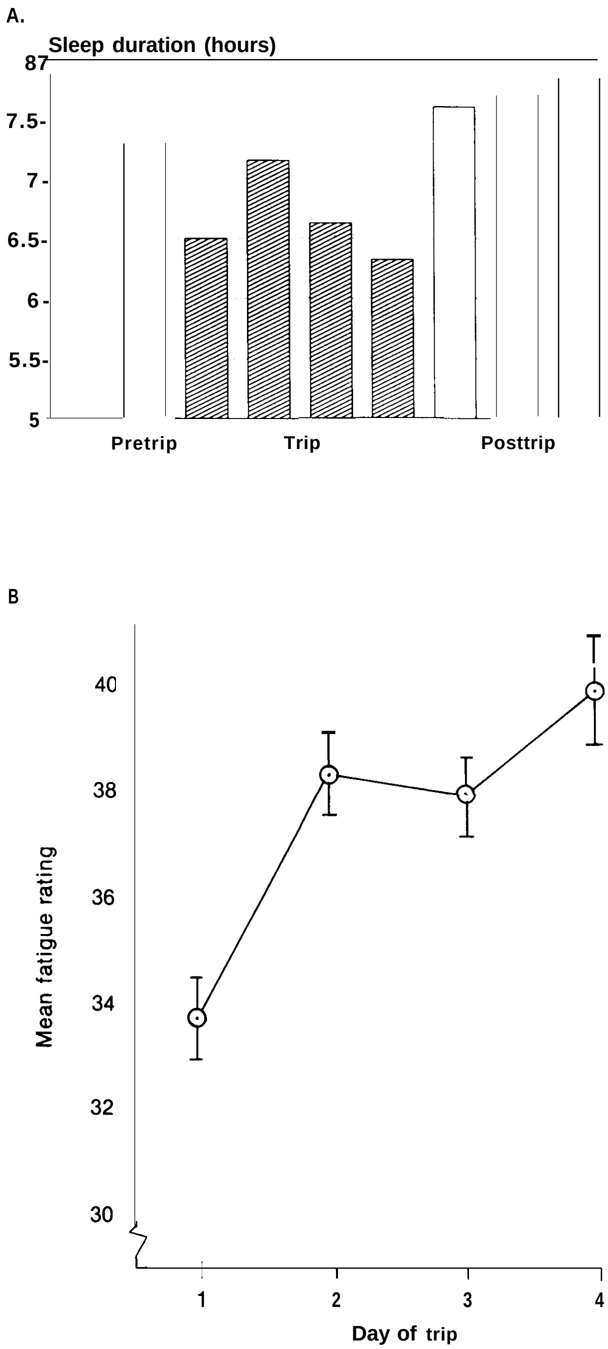
The net effect of these sleep disruptions is lack of sufficient sleep, which often results in a state of chronic fatigue and sleepiness referred to as sleep debt (5). This is especially true for rotating shift workers while they are on the night shift, permanent night workers, and individuals who are routinely subjected to long and irregular hours of work that extend into the night. For rotating shift workers, there may be some respite while they are on the morning or afternoon shifts, but depending on the design of the schedule, the degree to which they recoup the sleep lost during the night shift will vary. Sleep debt has important implications for worker performance, safety, and health (figure 5-4).

Individuals vary in their ability to sleep. Some people are more rigid in their sleep habits and have trouble sleeping at unusual times, while others seem to be more flexible in their ability to sleep at odd times. Some evidence suggests that people who find it easier to sleep at odd times may have an easier adjustment to the disruptions in sleep that can occur from work schedules (33,57).

Social and Domestic Disturbances

Work schedules may induce stress by preventing the worker from fulfilling important family roles (167). Social companionship, parenting, and sexual partner roles can all be compromised by work schedules. These effects may be major and can severely affect mood, motivation, and sleep, therefore having indirect effects on performance and safety. Marital problems, excessive domestic load, and community alienation have all been documented as a result of the strain placed on workers by work

Figure 5-4-Sleep Duration and Fatigue in Aircrews During a 4-Day Trip



A) Self-reported sleep duration of aircrews on a 4-day trip and the days preceding and following the trip. B) Subjective ratings of fatigue during the trip.

SOURCE: Adapted from R.C. Graeber, "Aircrew Fatigue and Circadian Rhythms," *Human Factors in Aviation,* El. Weiner and D.C. Nagel (eds.) (San Diego, CA: Academic Press, 1988).

schedules. A survey of 1,028 married couples in the United States found that shift work is associated with lower-quality family time and more frequent family conflicts (148). Another study found that shift work increased the probability of divorce from 7 to 11 percent over the 3-year period of the study (178). A more dramatic effect was reported in a study of 1,490 workers (152) in which an almost 50 percent increase in divorce and separations was found among those on freed night shifts compared to morning and evening shifts. When asked whether they were satisfied with the amount of time they had available to spend with family and friends, workers on night or evening shifts were about half as likely to respond "yes" as their morning shift colleagues. Similar findings come from Europe and Scandinavia. In a 15-year study of 504 Swedish paper mill workers (87), the divorce rate among shift workers was double that of day workers.

Excessive domestic workload represents a major source of stress from shift work for women workers. Married women are often expected by their husbands to continue to run the household, raise the children, and do domestic chores; shift work can compound this burden (63). For these women there is usually insufficient free time available for household duties, and time is therefore borrowed from sleep. It has been observed that female night workers with two children slept about 9 hours less per week than their unmarried female colleagues (63).

With the increase in dual-income families, a more common mode of arranging child care is for spouses to work different shifts (113,125). This splitting of child-care responsibilities between two working individuals also extends to nonspouse care givers. A study showed that one-third of grandmothers who provide child care for their grandchildren, and who are employed, work a different shift than the children's mothers (126).

Finally, social problems are encountered by shift workers. Society is geared toward a Monday to Friday, daytime work schedule. Several researchers (167) have found that shift workers may feel alienated from the community because they are unable to attend evening educational, sports, or religious meetings or weekend recreational events. Team or club membership becomes difficult because of irregular attendance, and few shift workers hold office in clubs and. societies. The shift worker can feel left out of community benefits and opportuni-

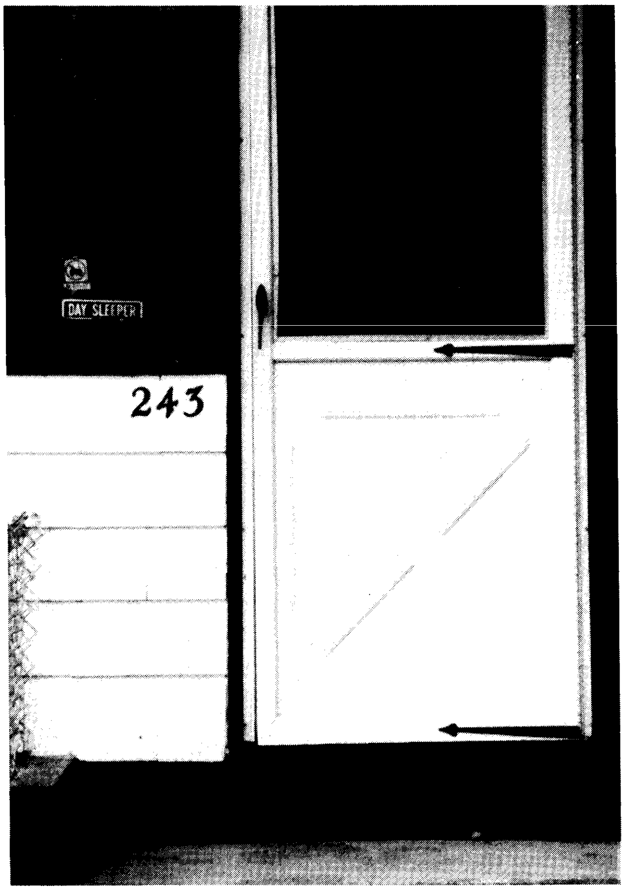


Photo credit: David Liskowsky

Obtaining adequate sleep during the day is often difficult for the shift worker.

ties. Such effects are much less frequent in company towns, where shift work is the rule rather than the exception, and as a consequence nonstandard work schedules are considerably better tolerated (174).

CONSEQUENCES OF WORK-RELATED STRESSORS

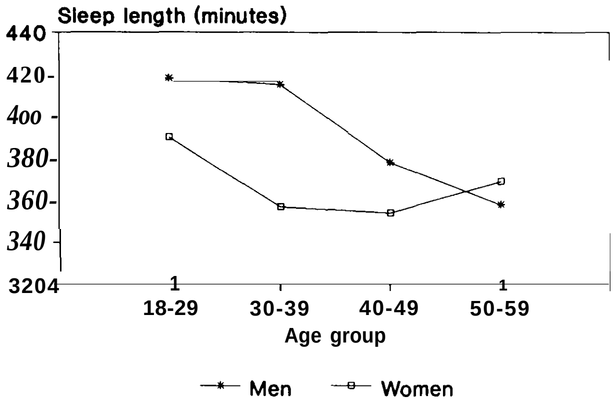
The three stressors previously described (circadian rhythm disruption, sleep disruption, social and domestic disturbances) can combine to cause a variety of problems for the worker. The degree to which a person suffers from the consequences of work-related stressors varies greatly among individuals. At the present time, not enough is known to make a definite statement about who will or will not be able to cope with shift work. As was mentioned earlier, the ability of a person to adjust to circadian disruption and sleep disturbances may affect his or her ability to tolerate the demands caused by work schedules. For example, circadian rhythm patterns are not the same in all people. Some people have consistently longer free-running periods and a wider amplitude between their maximum and minimum daily body temperatures. Evidence suggests that these individuals are better able to tolerate shift work than persons with naturally shorter free-ruming periods and a narrower body temperature range (20,129,130,131). However, it is not clear if these characteristics are a benefit in all shift work schedules.

Other characteristics related to sleep habits and personality have been combined to divide people into two categories. It has been hypothesized that these categories may have some validity in predicting success in coping with work schedules. A morning person is someone who gets up easily and is active in the morning, has a hard time sleeping late, and falls asleep quickly in the evening. In contrast, an evening person is more alert at night, able to sleep late in the morning, and takes a long time to fall asleep at night. It is thought that the evening person is more adaptable to varying work schedules (106,1 10,120). Additional information is needed to test the validity of this hypothesis and to identify more clearly variables that might make some individuals better able to cope with changing work schedules than others.

Another important factor in determiningg who will cope best with shift work is age. As one ages, the internal clock and sleep patterns change (figure 5-5). The internal clock may become harder to reset with age, and sleep becomes more fragile and easily disrupted. These effects usually begin to occur after the age of 45. For example, a survey of rotating shift workers found that older workers (45 to 60 years old) had more difficulty adjusting to night and afternoon shifts than did younger workers (79). It is not uncommon for a person who has been working shifts all of his or her career without undue strain to start having trouble coping as he or she gets older. A variety of health problems can appear with age and can add to the difficulty of coping with shift work (109).

While these factors suggest who might be best suited for shift work, the combined effects of these and other factors (e.g., physical ailments, family and social status) increase the variability of individuals' ability to cope with shift work (90). As a result, for some people, shift work is only an

Figure 5-5-Length of Sleep of Permanent Night Shift Workers



Graphs showing the average sleep length for male and female permanent night shift workers, according to age.

SOURCE: D. Tepas, Department of Psychology, University of Connecticut, 1990.

inconvenience, while for others it can have major consequences. It has been estimated that about 20 to 30 percent of shift workers actively dislike their schedule (56). Often, workers who find they cannot adjust to the demands of shift work change to day jobs. Thus, there is a strong self-selection process in operation that has important implications for studies of the effects of work schedules. The populations being studied may represent individuals who are indifferent to or who can tolerate the negative consequences of shift work, and thus the studies may underestimate the true effects of nonstandard schedules (11 1).

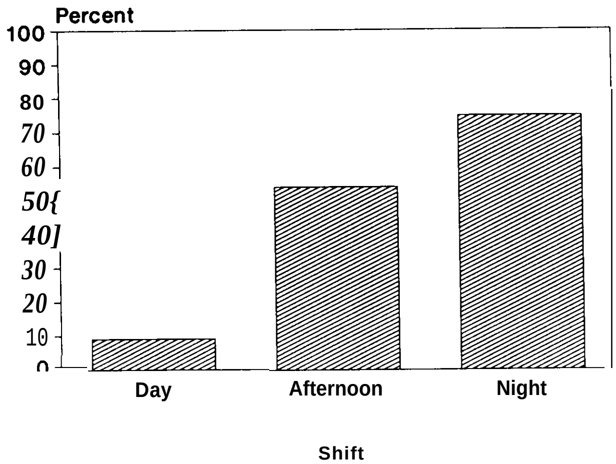
Health

The stressors described in the previous section may interact to have negative effects on the health of a worker. In general, these effects result from chronic, repeated exposure to stressors, for example, the continuing circadian desynchronization that rotating shift workers experience or the constant stress placed on night workers to meet family and social obligations during the day. Surveys have shown that shift workers, particularly those on rotating shifts, have a higher incidence of sick leave, a higher rate of visits to clinics at the work site, and poorer scores on a variety of indexes of health (11 1,112). Thus it appears that a greater proportion of shift workers than day workers suffer general health complaints. For example, a study of policemen found that those working rotating shifts reported a higher incidence of complaints of muscle aches, respiratory infections, and gastric complaints than did officers working days (123). In addition to general health complaints, there is some relationship between shift work schedules and the occurrence of specific disorders, primarily gastrointestinal problems.

Shift workers, particularly those on night shifts, commonly complain of gastrointestinal disorders (94,111), including general gastric discomfort and peptic ulcer disease (15,37,111,140). One study comparing the incidence of peptic disease in night workers and in day workers showed that the two groups begin to differ only after 5 years of exposure to their respective work schedules (10). There are probably several reasons for the higher incidence of gastrointestinal complaints among night workers. Intestinal enzymes are secreted in a circadian cycle that is disrupted by night or shift work schedules, contributing to digestive distress. Also, the link between meal patterns and the circadian system, which has to suspend appetite and voiding in order to allow 7 or 8 hours of uninterrupted sleep, may play a role. For example, the eating habits of shift workers tend to be irregular, with workers not adjusting their meal schedules to match their work schedules (47,56,72,120). It is also often difficult to obtain high-quality meals at odd hours (56) (figure 5-6). The link between eating habits and gastrointestinal complaints in shift workers indicates an area in which employee education might play a useful role. Risk factors associated with gastrointestinal disorders, such as increased alcohol and tobacco consumption, have also been shown to be higher in shift workers than in day workers (10,149). Finally, the psychological stress associated with family disharmony or social disruption could contribute to gastrointestinal problems.

Another major medical concern is cardiovascular disease; however, the link between it and shift work is not as strong as that for gastrointestinal problems. While some earlier reviews of the field did not find compelling evidence of a link (72,140), more recent research from Sweden (87) has demonstrated that shift work is associated both with increased risk of cardiovascular disease and with its associated risk factors (122). A study of Akron police officers showed that rotating shift work may be associated with high levels of norepinephrine (a body chemical that causes an increase in heart rate and blood

Figure 5-6-Shifts Interfering With Eating Habits



The percentage of coal miners reporting that a given shift interfered with their eating habits.

SOURCE: J.C. Duchon and C.M. Keran, "Relationship Among Shiftworker Eating Habits, Eating Satisfaction, and Self-Reported Health in a Population of Miners," *Journal of Work and Stress* 4:1 11-120, 1990.

pressure), which could place workers at higher risk of cardiovascular problems (54). A recent review of the literature related to cardiovascular disease and the work environment concluded that "... the better studies in the field consistently find a modestly higher incidence of cardiovascular disease among shift workers" (89).

Finally, a few studies present data suggesting a slightly increased risk of miscarriage, preterm birth, and lower birth weight among women who work rotating shifts or irregular hours (12,14). A study of complications during pregnancy and adverse outcomes of pregnancy found no link to shift work, but it did note an association between shift work and a tendency for babies to be smaller for their gestational age (1 19).

Beyond these specific disorders, the adverse effects of shift work on workers' health seem to be diffuse, affecting some workers' general sense of well-being. These workers frequently report sleep disturbances and fatigue, menstrual problems, increased feelings of irritation and strain, increased use of alcohol and other drugs (tranquilizers, caffeine), and a general feeling of malaise that maybe exacerbated by psychological stress related to being less satisfied in the domestic and social areas of their lives (65,112). It has also been proposed that the stresses associated with shift work might exacerbate preexisting health conditions, increasing their severity without increasing their incidence (29).

A related health problem maybe the inability of the shift worker to comply with health and medication regimens. As discussed in chapter 3, the body's metabolism and response to drugs are generally circadian. Also, symptoms of some disorders, such as diabetes, depression, and asthma, evidence significant circadian fluctuations. A shift worker could be in the position of taking medication at inappropriate or constantly changing times. Also, variable work schedules could make it difficult to coordinate taking medication with the work-rest cycle and mealtimes, thus interfering with the worker's ability to take medication at all (29).

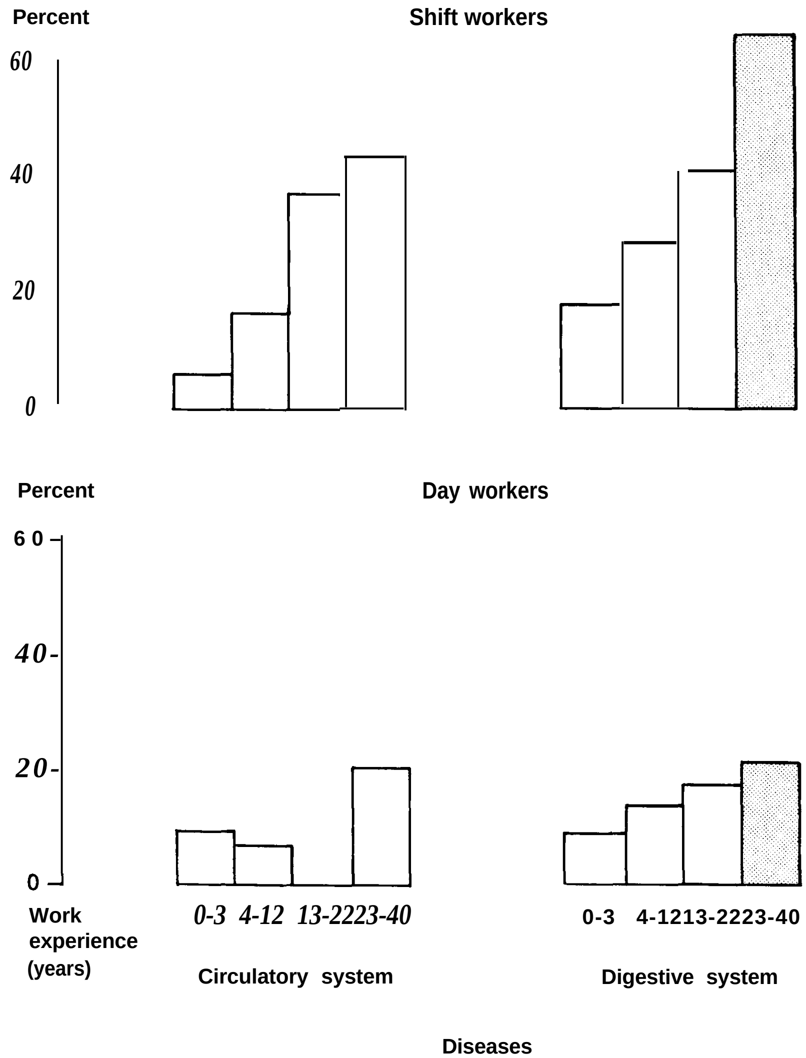
In summary) shift work schedules are associated with increased gastrointestinal complaints among workers and may be a risk factor in cardiovascular disease and such pregnancy outcomes as low birth weight and preterm births (figure 5-7). Beyond these specific ailments, the health effects of such work schedules generally manifest themselves as complaints of decreased well-being, chronic malaise, and poor sleep. Shift maladaptation syndrome is the term used to describe the effects of long-term shift work on the health of workers who have never been able to adjust to it.

Performance

***The* effects** of work schedules on performance are part of a complex set of factors that shape a person's performance in a given situation. These factors include the circadian, sleep and fatigue, and social and domestic stressors already described. They also include the type of task to be performed (e.g., vigilance, physical, cognitive), motivational effects (which are significantly influenced by social and family concerns), the work schedule being employed, and individual differences among workers (e.g., personality, age, health, sleep needs, behavior patterns) and how they adjust to changes in routine. Unlike health effects, performance decrements may occur soon after exposure to a work schedule.

As discussed in chapter 3, performance on a number of different types of tasks displays a circadian rhythm, and different types of performance differ in their normal phase and the degree to which they are affected by outside influences. For example, tasks involving signal detection, reaction time, and handling of simple arithmetic correlate with cir-

Figure 5-7—Prevalence of Disease in Shift Workers and Day Workers



Percent of shift workers and day workers at an oil refinery, subdivided into groups according to work experience, suffering from circulatory and digestive diseases. Shaded bar indicates that there was a statistically significant difference between the shift workers and day workers.

SOURCE: Adapted from M. Keller, "Health Risks Related to Shift Work: An Example of Time Contingent Effects of Long-Term Stress," *International Archives of Occupational and Environmental Health* 53:59-75, 1983.

cadian changes in body temperature, peaking during the afternoon, while performance of cognitive tasks involving memory may peak in the morning (28,56). Performance can be directly affected by circadian desynchronization and inappropriately timed activity, as well as by the loss of sleep they can cause. There is a large body of literature regarding the effects of fatigue and sleep deprivation on performance; these factors clearly have a negative effect on the performance of most tasks (28,91).

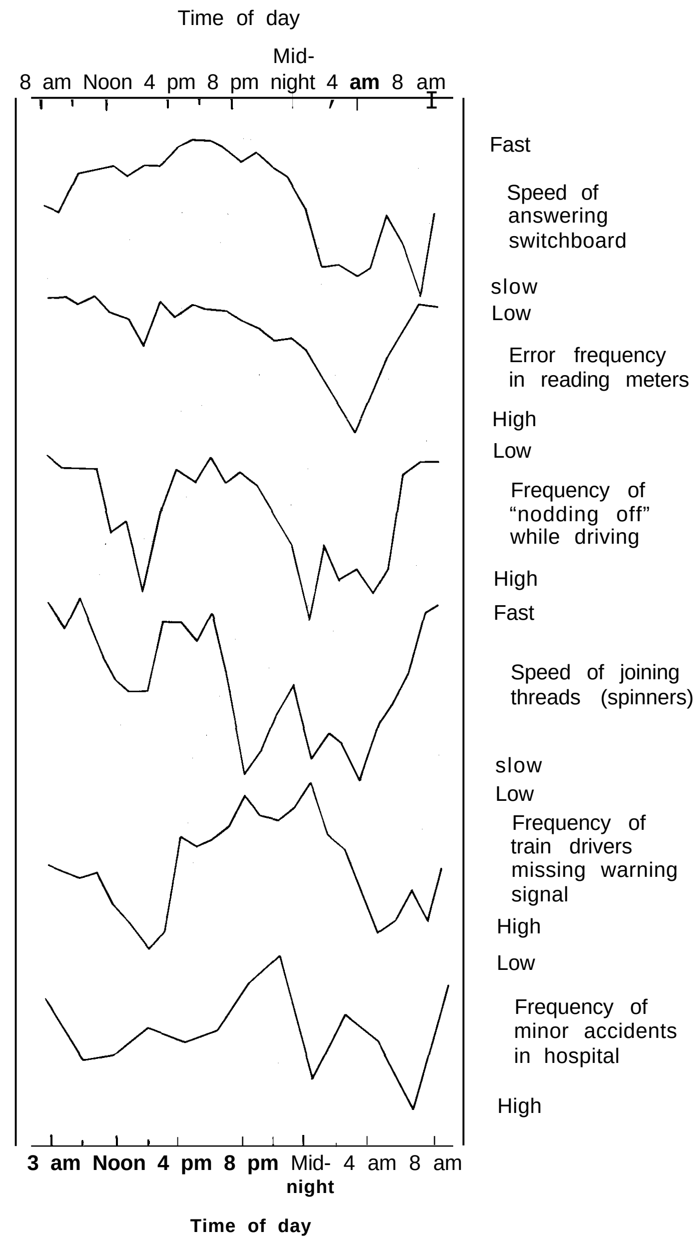
In contrast to the fairly extensive research on the circadian component of performance and the effects of sleep deprivation on performance, much less research has been done on the complex interaction of variables that occurs in a work setting that can also affect worker performance. To determine the effects of work schedules on performance, studies can examine the performance of a worker either on a standardized test battery after being exposed to a certain work schedule or on the

actual task the job involves. A factor that can complicate the study of intershift differences in task performance and perhaps mask the effects of shift work is the difference in working environments. Not only environmental conditions, such as lighting levels, but also supervision levels, group morale, and distractions can all vary between night shifts and day shifts. Also, poorer performance can occur on the night shift simply because no one is available to repair broken machines (102). The work itself may be quite different on the night shift. Very often, certain parts of the job are saved for the night shift, either because the process demands it (preparing things for shipment in the morning) or because it places less demand on the night workers. In continuous-process operations, complicated development work may intrude during the day but not at night **(40).**

The relatively few studies that have recorded 24-hour real-task data in the field demonstrate decreased performance at night. They have shown that the speed at which a task can be performed decreases at night (21,182) and the probability of making an error, missing a warning signal, or nodding off while driving is highest at night (17,58,75,127) (figure 5-8). In addition, some evidence shows a pronounced postlunch dip in these measures. More recent studies have found the risk of accidents involving truck drivers between midnight and 2 a.m. to be more than double the average during the day (69). Job performance of nurses, as measured by a questionnaire filled out by supervisors, was found to be lower in those on a rotating shift than in those on freed day, afternoon, or night shifts (27).

Studies using other measures of performance have also found effects related to work schedules. For example, results of a study that measured manual dexterity and search performance of 10 factory workers on a rotating shift showed the workers performed worst on the tests when working the night shift (181). The tests were administered just before the start of a shift and after 4 and 8 hours of work. Another study brought shift workers into the laboratory during nonwork hours for performance testing and measures of brain activity during sleep. These workers continued to work at their normal workplace, but they commuted to and from the laboratory rather than home (155,156). Their performance on a vigilance task was examined just before bedtime, at bedtime, and on awakening. The study involved 10 night workers, 10 day workers,

Figure 5-8-Work Performance in Various Job Settings



Variations in measures of on-the-job performance, by time of day, from a variety of studies.

SOURCE: Adapted from T.H. Monk, "Shiftworker Performan-," *Shift-work, Occupational Medicine State-of-the-Art Reviews*, A.J. Scott (ed.)(Philadelphia, PA: Hanley & Belfus, 1990).

and 10 (slowly) rotating shift workers who were working day or evening shifts at the time they were tested. Night shift workers performed worst on all three performance tests, but there were no reliable differences between the other two groups. The differences in performance were not accompanied by equivalent differences in body temperature, but they were correlated with brain activity during sleep in a way that is typical of subjects undergoing chronic partial sleep deprivation.

Similar results were obtained when 12 shift workers were studied for one complete cycle of their weekly rotating shift in the field rather than in the laboratory (158). Reaction speeds on both a simple and a complex reaction-time test were slower among workers on the night shift. There was also strong evidence of an increasing deterioration in performance, which the authors interpreted as a buildup of partial sleep deprivation. The effects on a number of different measures of performance of the 4-hours-on, 8-hours-off schedule typically used on merchant ships for standing watch has also been examined (32). There was only a partial adaptation of circadian rhythms to this schedule, and most performance measures showed lower values during the night hours. The decrements in performance were exacerbated by disturbances in sleep that occurred as a result of the split hours of sleep time necessitated by this schedule. These studies demonstrate some of the effects that disrupted circadian rhythms can have on performance and their interaction with other factors involved in shift work, notably sleep deprivation.

The studies described above examine the effects on performance of work schedules involving rotating shifts or night shifts. Jobs that require sustained or extended duty hours can also affect performance. For example, jobs such as cross-country truck driving require long hours of constant attention, often in a boring or repetitive environment, while jobs such as those of residents in hospitals involve continuous work, interrupted by periods of reduced activity or rest breaks. While circadian disruption plays a role in the performance decrements observed under these conditions, sleep loss is probably an equally salient factor (91).

A laboratory study that required subjects to perform 54 hours of continuous work found that reaction time, logical reasoning, vigilance, and encoding and decoding messages all declined in a stepwise fashion; that is, declines in performance were interspersed with plateaus in performance (11). The declines in performance were paralleled by subjective ratings of fatigue and sleepiness; the greatest declines occurred in conjunction with the lowest point in the circadian cycle of body temperature. Similar results have been described when a computerized test battery was used to measure performance (115). While these studies show that decrements in performance can occur as a result of extended duty hours, a number of other studies found that certain kinds of performance are more sensitive to sustained operations than others (91). In general, these studies found that psychological tasks, such as cognitive, vigilance, long-term memory, decisionmaking, and perceptual-motor tasks, were more likely to be adversely affected by sustained operations than were physical tasks involving gross motor activity and strength.

Thus it is reasonable to assert that, in general, shift work decreases performance and that a number of factors besides circadian desynchronization contribute to this decrease, notably sleep deprivation and fatigue. A great deal more information still needs to be derived, however. As with health effects, there is a complex interaction of factors that under actual working conditions could contribute to or counteract decrements in performance (namely, nature of the task, speed at which the task is performed, work schedule employed, worker age, family and social factors, motivation). More information is needed to delineate the effects of these interacting factors in a given work situation. A better understanding of how performance on different types of tasks can be affected will make it possible to devise interventions and countermeasures.

Safety

The factors described earlier also have an impact on worker safety. Performance decrements resulting from sleepiness, circadian disruption, or distraction by family problems can cause situations that might compromise the safety of the individual and, depending on the nature of the job, public safety as well.

In the United States, the major mechanism for collecting data related to workplace injuries and mishaps is the Bureau of Labor Statistics (BLS) in the Department of Labor. Currently, BLS forms for reportable injuries and illnesses include no questions regarding the time of day an incident occurred, the type of schedule an employee involved in an incident was working, the number of hours since the employee began work, or the total number of hours or shifts the employee had worked over the preceding days. Thus, data currently being gathered by the BLS provide no information that could facilitate an assessment of the impact of shift work on employee safety and health. The Occupational Safety and Health Administration, within the Department of Labor, may record information on time of day and hours of work when investigating workplace fatalities and catastrophic incidents in which five or more persons are injured or substantial property damage is caused.

Data on injuries can be put to three possible uses. First, they can be used to investigate whether the work environment or supervisory practices were different on a particular shift and to see if schedule changes had any effect on injury rate. Second, they can be used for research examining features of the work environment and schedules that are related to injury rates. Finally, the data can be used in providing surveillance of the workplace.

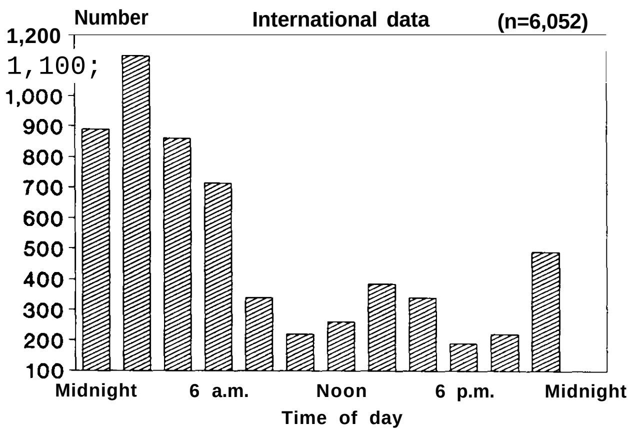
Another source of data is the National Transportation Safety Board (NTSB), which investigates transportation-related mishaps. In its investigations the NTSB routinely collects information regarding the role work hours might play in such incidents. Other Federal agencies and departments (e.g., the Nuclear Regulatory Commission or the Department of Transportation) may examine the role of work hours when investigating incidents that occur within their domain. For example, the U.S. Army, as part of its Army Safety Management Information System, maintains a database regarding Army aircraft accidents involving a death or loss of an aircraft (55). This database includes information related to sleep and work periods. To date, no analysis of these data has been performed to determine the role of duty hours in these incidents.

Other sources of information related to work schedules and their implications for worker safety include surveys of specific industries or work sites and data from other countries. As described earlier, studies of the effects of work hours are often confounded by the fact that in some settings the conditions surrounding night work are quite different from those surrounding day work. This is particularly true of industrial or manufacturing settings.

While it is possible that the performance decrements that occur in shift work will translate into an increased rate of mishaps and injuries in the workplace, the published data in this area are meager. Some studies in industrial settings have not found an increase in injuries related to night shifts or shift work [injuries at a chemical plant (118), U.S. coal miners (173), survey of industrial accidents in New Zealand (49)], while others found that, although injury rates were higher during the day, the severity of the injuries suffered at night was greater [iron and steel mill workers in Singapore (121), U.S. iron miners (166)]. On the other hand, a survey of occupational mishaps in a glass factory and a steel factory and data on occupational mishaps occurring in Ontario over a 5-year period found that the number of occurrences peaked just before and after lunch, as well as between 2 a.m. and 4 a.m. (180). A survey of a paint factory in the United States found that the injury rate was 25 percent higher for night shift workers than for day shift workers (95). It was also noted that this effect was most pronounced in the last 3 hours of the night shift. Thus, there is some indication that shift work can result in decreased safety in an industrial setting; however, there is no complete characterization of the types of settings most likely to be affected. Until there are more data on the relationship between work hours and workplace mishaps, the extent to which mishaps are caused by shift work will remain uncertain and the development of interventions to counteract them will be hindered.

In contrast, examination of factors contributing to transportation mishaps shows the role of circadian disruption, sleep loss, and fatigue (figure 5-9). These three factors have been noted in specific incidents involving every mode of transportation, including airline, railroad, maritime, and highway driving (93). Studies have shown that the risk of a truck driver's being involved in a traffic collision is higher for trips occurring at night. One study identified the period between midnight and 4 a.m. as the most dangerous, with the peak being between midnight and 2 a.m. (69), while another identified the period between 4 a.m. and 6 a.m. as the most crucial (100). The chances of an accident were increased further if the driver had been on the road or working for an extended period of time (69), and the effects of sleepiness and fatigue were compounded if the

Figure 5-9--Fatigue-Related Vehicular Accidents



The distribution, by time of day, of 6,052 vehicular accidents that were judged by investigators to be fatigue-related.

SOURCE: M.M. Mittler, M.A. Carskadon, C.A. Czeisler, et al., "Catastrophes, Sleep, and Public Policy: Consensus Report," Sleep 11:100-109, 1988.

driver was on an irregular schedule (100). A recent study by the NTSB highlighted the role of combined sleep loss and fatigue and its interaction with drug use in a study of fatal-to-the-driver heavy truck crashes in the United States (117). The report found that sleep loss and fatigue was the most frequently cited single cause or factor in the fatal crashes examined and that many of the drivers involved in these incidents were also impaired by alcohol or other drugs. Another study of crashes involving large trucks in the United States found that the "relative risk of crash involvement for drivers whose reported driving time exceeded 8 hours was almost twice that for drivers who had driven fewer hours' (76). Similar results were found in a study of naval pilots who were involved in serious mishaps (destroyed aircraft, fatalities) during a 5-year period (19). Pilots who had worked at least 10 hours before a mishap were more likely to have been at fault than pilots who had worked less than 10 hours. Also, the mishap rate was significantly related to time of day, with pilots having a lower rate of incidents during daytime hours.

Safety consequences of shift work can affect not only the worker, but also the public. They have been listed as contributing to such highly publicized incidents as the Three Mile Island nuclear powerplant accident and the grounding of the Exxon *Valdez (box 5-B). In these* incidents, the strain of extended duty hours and the time of day may have led to errors in attention, decisionmaking, and response to pertinent information. Events such as these can threaten thousands of lives and seriously affect the well-being of surrounding communities. At the other end of the spectrum are less publicized but more common examples of threats to public safety, such as accidents involving interstate truckers. Any occupation involved with public safety and welfare can be influenced by the effects of work schedules and their attendant problems. Decrements in performance among police, free, and health care personnel could result in negative outcomes for the public. Additional data on the occurrence of incidents threatening the public safety are needed to derive a clearer understanding of their frequency, nature, and magnitude. Such information can serve as the basis for preventive measures.

INTERVENTIONS

The previous sections have described the consequences and impact shift work can have in a variety of realms. This section describes some interventions that may be used to lessen those effects. While a number of different interventions are being examined as possible means to counteract circadian desynchronization, sleep disturbances, and social disruption associated with work schedules, definitive statements regarding their effectiveness cannot be made yet. Additional research is needed on the mechanisms at work in specific situations and on the effectiveness of these interventions.

Work Schedules

***Since* a** number of possible negative consequences are associated with shift work, an obvious approach to prevention is to avoid the use of such schedules. However, around-the-clock operations are a fact of life in many occupations, so the best intervention regarding scheduling is to identify those schedules that will have the least unfavorable impact on the individual. Making such a determination is difficult, because a schedule that may be the most beneficial from a circadian perspective may not be optimal in terms of sleep and fatigue, or a schedule that tries to avoid sleep loss may create hardships for the worker in the social or domestic arena. Also, the nature of the job and the type of performance it requires may make a schedule suitable for one type of task but not suitable for another. As stated by one researcher," . . . the effects

Box 5-B—The Grounding of the Exxon Valdez

At about midnight on the morning of March 24,1989, the tanker ***Exxon Valdez,*** loaded with almost 1.3 million barrels of crude oil, ran aground on Bligh Reef in Prince William Sound, Alaska, Approximately 258,000 barrels of oil spilled, resulting in severe damage to the environment. Damage to the vessel was put at $25 million, and the cost of the cleanup during 1989 was $1.85 billion. In the opinion of the National Transportation Safety Board (NTSB), which investigated this incident, the probable causes for the grounding of the tanker were:

- the failure of the third mate to properly maneuver the vessel because of fatigue and excessive workload;
- the failure of the master to provide a proper navigation watch because of impairment from alcohol;
- the failure of the Exxon Shipping Co. to provide a fit master and a sufficiently rested crew for the Exxon ***Valdez;***
- ***the*** lack of an effective vessel traffic service because of inadequate equipment and manning levels, inadequate personnel training, and deficient management overnight; and
- the lack of effective piloting services.

This incident is an example of a situation in which negative work schedule effects combined with other factors to bring about an event that had broad implications for the public well-being. Prominent among the NTSB findings were a number that concerned the policies of Exxon Shipping related to the manning of its tankers. The NTSB found that these policies created conditions that were conducive to fatigue among tanker crews. In the case of the Exxon ***Valdez, the*** result was that there were no rested deck officers available to stand watch while the ship sailed through Prince William Sound, and the ability of the third mate to corm the vessel was impaired by fatigue.

Among the NTSB's recommendations related to work hours were that Exxon Shipping and other oil shipping companies eliminate personnel policies that encourage employees to work long hours and implement manning policies that prevent long working hours. Also, the NTSB recommended that shipping companies forbid deck officers to combine both navigation and cargo watch duties using a schedule of 6 hours on, 6 hours off, The NTSB recommended that the U.S. Coast Guard develop means to enforce the rule that officers on watch during departures from port must be sufficiently rested; that it expedite study programs to establish manning levels and safeguards to use in the manning review process; and that it establish manning standards that will ensure crews are large enough to handle heavy workloads. Finally, the NTSB reiterated previous safety recommendations to the Department of Transportation that it expedite research programs to study the effects of fatigue, sleep loss, and circadian factors on transportation system safety; that it disseminate information and educational material to transportation industry personnel regarding these effects; and that it review and upgrade hours of service regulations in all transportation modes to ensure that they reflect the latest research on these factors.

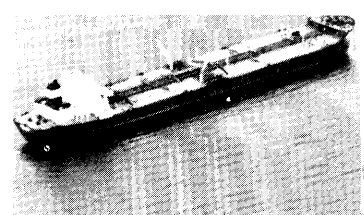


Photo credit: W.R. Woody, National Transportation Safety Board

The ***Exxon Valdez.***

SOURCE: National Transportation Safety Board, Marine Accident Report, *Grounding of the Exxon Valdez on Bligh Reef, Prince William Sound, AK, Mar. 24,1989,* NTSB/MAR-90/04 (Springfield, VA: National Technical Information Service, 1990).

of any particular work schedule are likely to be myriad and complex, potentially exerting a differential influence on the various parameters of worker physical, psychological, and social adjustment. As a consequence, the implementation of a specific work regime represents a compromise rather than an ideal' (28) (box 5-C).

The variable parameters of a schedule include fixed or rotating shifts, direction and speed of

Box 5-C—The Philadelphia Police Story

In 1983, a shift rescheduling program was conducted for the City of Philadelphia in an effort to enhance the work schedules employed by the city's police department. The two-phase project was carried out in one of the city's police districts. It consisted of an evaluation of the existing schedule and the design of an improved schedule (phase 1), as well as the implementation of the new schedule and an education program for the officers (phase 2). (Table 5-C-1 compares the old and new schedules.)

In phase 1 of the study it was found that the existing four-platoon work schedule had a number of deleterious effects on the officers. This included 50 percent of the officers reporting poor quality sleep; 80 percent reporting that they fell asleep at least once a week while on the night shift; 25 percent reporting that they had been involved in an actual or near-miss automobile accident due to sleepiness during the past year; over 75 percent of officers' families being dissatisfied with their work schedules; and 35 percent taking either an entire week to adjust or never adjusting to the weekly shift rotation.

In phase 2 of the study, a three-platoon system was initiated for 177 officers, and educational sessions were conducted during the implementation process. The new schedule incorporated proportional staffing (so the number of officers on duty was proportional to the number of calls for service), reversal of shift rotation from counterclockwise to clockwise, reduction in the rate of shift rotation from 1 to 3 weeks, and the elimination of regularly scheduled 6-day weeks (see table 5-C-1). Following implementation of the new schedule there was a fourfold decrease in the number of officers reporting poor sleep, twice as many reporting no daytime fatigue, a decrease in the number of sleep episodes on the job, a decline in the on-the-job motor vehicle accidents per mile driven, an increase in the level of alertness on the night shill, and a reduction in the use of sleeping pills and alcohol. Families of officers reported a nearly fivefold increase in satisfaction with the new schedule.

This study shows that considering biological rhythms when designing a shift schedule for a specific work setting can lessen the negative effects that can occur. It also points out the importance of coupling schedule redesign with educational programs for the workers to assist them in adjusting.

Table 5-C-l—Original and Newly Instituted Schedules for the Philadelphia Police Study

Characteristic	Schedule: Old	Schedule: New
Day off schedule	(6 on, 2 off)	(4 on, 2 off)
Shift length (hours)	8.0	8.5
Maximum consecutive workdays	6	4
Direction of rotation	counterclockwise	clockwise
Average workweek (hours)	40	39.8
Number of platoons	4	3
Average workdays per year	261	244
Total hours worked per year	2,080	2,068
Rotation cycle (days)	8	18
Rotation per year	46	20
Average number of days off per year	104	121
Average number of 12x8 shifts per year	92	80
Number of weekend days off per year	30	34-35

SOURCE: Center for Design of Industrial Schedules, *Final Report on the Philadelphia Police Department Shift Rescheduling Program*, prepared for the Fraternal Order of Police Lodge No. 5, Philadelphia, PA (Boston, MA: Center for Design of Industrial Schedules, 1988).

rotation, length of a shift, and the starting time of a shift. Fixed shifts should result in the least circadian disruption, assuming workers maintain the same schedule on days off as on workdays. They often do not, however, and under such conditions permanent shift schedules take on the nature of a rotating shift (56). Also, as discussed earlier, permanent night workers often suffer from chronic sleep disturbances and at-e permanently out of synchrony with the rest of society. This latter factor, depending on an individual's personality and family situation, may cause significant social and domestic strain.

Direction of Rotation

Based on the fact that under free-running conditions the human body clock has a natural tendency to run slow, with a preferred period slightly longer than the 24 hours of nature and society (176) (see ch. 3), the human circadian system appears to adjust more slowly to phase advances than to phase delays (13,81). From a circadian perspective, then, clockwise shift rotation (mornings, then evenings, then nights) should be easier to cope with than counterclockwise rotation (nights, then evenings, then mornings). Although this hypothesis still needs to be properly tested, there is some evidence to support it (36). However, a study that used survey data from a group of workers indicated that, in terms of the amount of time available for sleep, a counterclockwise schedule afforded more opportunity to prepare for and recover from the night shift (48). Furthermore, it is possible that the timing of a worker's actual sleep, which can be influenced by social demands, does not necessarily coincide with an ideal circadian schedule (160).

Speed of Rotation

The speed of rotation in a shift system is the number of days an individual spends on a particular shift before switching to a new schedule or to days off. There are a multitude of different shift schedules currently in use (85,150). Many of them approximate a weekly rotation, with an employee working from 4 to 7 days on a shift before changing. However, faster (1 to 3 days) or slower (more than 7 days) rotating systems may also be used.

A rapidly rotating system, as noted earlier, will result in the individual's circadian system remaining diurnal, since not enough time elapses for circadian rhythms to adjust to a new routine (56,105). This avoids the problems associated with a circadian system that is going through a phase adjustment to a new schedule. Also, the shorter rotation does not allow a sleep debt to accumulate, since the number of consecutive days when the worker has to engage in day sleep remains small. The tradeoff is that, while they are on night shifts, workers will be out of synchrony with their circadian systems and performance could be affected (56,105). Also, rapid rotation may have a greater impact on family and social interactions because of the continual schedule changes (56).

A slowly rotating schedule has the advantage of allowing greater time for circadian readjustment. A study of 42 shift workers at a surface mine showed that some measures of adjustment (mood, episodes of awakening during sleep) improved during the second week of a 2-week shift rotation (46). However, a slowly rotating schedule can result in sleep debt and fatigue due to more consecutive periods of day sleep. This problem can be exacerbated if the worker reverts to a diurnal schedule on days off.

Since a weekly shift rotation results in both insufficient time for the body clock to readjust completely and enough time to build up a sizable sleep debt (158), it is this schedule of rotation that is most likely to produce physiological problems (8,36,140,146). However, a weekly system may have the advantage of allowing a worker to engage more easily in social and family activities (56).

What is the best rotation system to use? Expert opinion is divided. Many favor rapid rotation with very short (1- or 2-day) rounds of duty on one shift before changing to a different one (3,140). Others favor much slower rotation speeds, with 3 weeks or more at one shift before moving to a different schedule (36,11 1). One factor that may help determine the most desirable speed of rotation is the task to be performed. As previously discussed, there is some evidence that different tasks not only have different best times during the circadian cycle, but also adjust at different rates to a change in routine (56,57). It may be that simple, repetitive tasks, which are performed relatively poorly at night and adjust rather slowly, would be best performed using a slow shift rotation, which allows circadian synchronization to be maintained for longer periods. Tasks involving immediate retention and high memory loads might be performed relatively well during the night shift, even in diurnally oriented individuals (107). In these cases, rapidly rotating shifts might be more suitable: the circadian system retains its diurnal orientation, and there is no gradual buildup of sleep loss (158). Further information is needed to determine whether the speed of shift rotation can have differential effects on various types of tasks. If the main goal is to" minimize physiological disruption, a weekly rotating shift seems to be the least desirable; either a more slowly (36) or more rapidly (83,179) rotating system may be preferred.

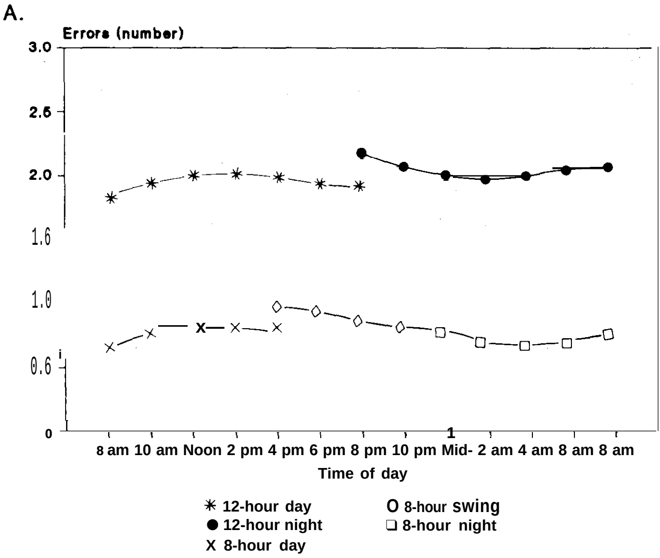
Shift Duration

In rotating shift systems, the length of a shift is typically 8 hours, although longer shifts, often 12 hours, are sometimes used. The advantage of 12-hour shifts is that the workweek is compressed into 3 or 4 days, giving the worker more days off for leisure and recuperation. The disadvantage is that the extra 4 hours of work per day could lead to increased fatigue and decreased alertness on the job. Such effects have been demonstrated in both laboratory (139) and field studies (134,138). In one field study, conducted at a nuclear powerplant, it was shown that workers on a 3- to 4-day, 12-hour shift system reported increased fatigue and performed more poorly on tests designed to measure alertness than did workers on a 5- to 7-day, 8-hour system (138). These effects were most pronounced in the 12-hour night shift, where there was an interactive effect between fatigue and the low point of the circadian cycle. Interestingly, despite these decrements, examination of performance on job tasks (e.g., filling out log books, occurrence of unusual events) conducted at the same time as the other testing indicated no difference between the 8- and 12-hour shift systems (96) (figure 5-10).

A comparison of the number of health complaints reported by workers in the chemical industry in Germany showed no difference between a rapidly rotating 12-hour and a weekly rotating 8-hour shift schedule (62). The use of a compressed workweek with 12-hour days is also becoming more common in nonrotating shift schedules (see ch. 4). While compressed workweeks are generally well received by workers, they raise concerns about fatigue effects, longer exposure to workplace hazards (e.g., noise, chemicals, repetitive motion tasks), and complications associated with workers holding a second job (29). Also, workers who have long commutes may be at greater risk driving on the highways. Additional studies are needed to fully evaluate these factors and to determine how the extended workday can affect performance and safety, especially in regard to night shifts, where circadian effects would also be present. As with speed of rotation, the type of job to be performed might affect whether 12-hour shifts are appropriate. Long shifts may be more suitable in jobs that do not require intense concentration, are not monotonous or dangerous, and do not involve heavy physical activity (102).

Figure 5-10-Measures of Performance on 8-Hour and 12-Hour Shifts

A.



B.

Shift	Mean	Standard error
8-hour, day	0.174	0.028
8-hour, swing	0.188	0.028
8-hour, night	0.164	0.022
12-hour, day	0.194	0.025
12-hour, night	0.112	0.014

A) Number of errors, by time of day, on a laboratory measure of performance (grammatical reasoning task) for workers on 8-hour and 12-hourshiftschedules. Significant performance decrements occurred on the 12-hour shift. B) The average number of errors of entering data into log books per hour on 8-hour and 12-hour shifts. There were no differences between shifts.

SOURCE: P.M. Lewis, D.J. Swaim, and R.R. Rosa, *Evaluation of the 12-Hour Shift Schedule at the Fast Flux Test Facility* (Richland, WA: Pacific Northwest Laboratory, 1986).

Extended duty hours almost invariably result in loss of sleep and fatigue. As previously described, extended periods of sustained work can lead to impaired performance in most psychological tasks. As a result, periods of extended duty hours without adequate time to recuperate from fatigue and lost sleep can have detrimental effects on worker performance and safety.

Because of their disruptive nature, schedules that divide the day into multiple work shifts interspersed with rest periods-namely, split shifts-are rare. The most common use of split shifts is for standing watch aboard merchant and military ships, where a 4-hours-on, 8-hours-off schedule is often employed. These schedules have been shown to result in performance decrements (32,142) as a result of circadian rhythm disruption and disturbed sleep. A more detailed discussion of the shipboard schedules used in the military is presented in chapter 9.

Sleeping and Napping Strategies

One of the major problems facing shift workers is loss of sleep and the resulting on-the-job sleepiness (5,29). Sleeping and napping strategies designed to optimize sleep could be useful interventions for the worker. It has been noted that the majority of night shift workers sleep after work, while day shift workers most often sleep before work (151). It has been hypothesized that delaying sleep after working a night shift is preferable, since such a schedule would maintain a normal work-off-sleep sequence and sleep would occur during a period in the circadian cycle more conducive to longer sleep (45). However, there is little empirical evidence available regarding this strategy. One survey of 328 workers at a surface mine and two powerplants found that those who delayed their sleep after a night shift were less sleepy than those who slept earlier, but they were also more likely to report health complaints (45). Since this was a survey study, it could not be determined if there was a causal relationship between the sleep schedule employed and the incidence of health complaints.

Napping strategies may be useful in two ways. Brief naps taken during temporary periods of extended work may enhance subsequent performance, and naps taken during time off may help to offset the sleep debt typically associated with shift work. With respect to on-duty napping, it is known that a sleep period of 1 to 4 hours can lessen sleepiness during a 24-hour period of continuous activity (44,91). One study has shown that airline pilots who were allowed to nap for a short time during a slack period in a flight were more alert when their workloads increased (during landings) than pilots who did not nap (68). Other studies have shown that naps taken early in a period of extended work (42,44) may be more effective in preventing sleepiness than naps taken later during the work period are in recovering from sleepiness (133). In prolonged work schedules (over 24 hours), measures of performance were improved following prophylactic naps, although performance did not return to normal levels (42,44). This indicates the usefulness of prophylactic napping during temporary periods of extended work. The placement of the naps in relation to the circadian cycle was not a factor in the ability of the naps to produce their effects. Also, the enhanced performance occurred only after the residual effects of sleep had worn off: performance decrements can persist for up to an hour after awakening (9) and may be a limiting factor in the use of naps in work settings where a worker must be fully alert on awakening.

Napping at appropriate times during time off may also enhance performance by offsetting the sleep debt that typically accompanies rotating shift work. Recent findings indicate that napping may be an integral component of the circadian sleep-wake cycle (22,25,26,41). Workers who cannot sleep for more than 4 to 5 hours during their initial attempt (a common complaint among shift workers trying to sleep during the day) (60,172) may be able to obtain a couple of additional hours if sleep is attempted again later in the day (9). It has been suggested that a rotating shift worker should not take a nap if the next major sleep period after a work shift is to be at night. A nap under these conditions could interfere with that night's sleep. If the next night is going to be another period of work, however, a nap maybe beneficial (9). Also, a nap taken regularly at the same time of day could act as an anchor, or synchronizing point, for circadian rhythms and might slow the adaptation of the rhythms to a new schedule. This could be advantageous to a worker on a rapidly rotating schedule but detrimental to one on slowly rotating shifts (135). Thus, naps can be beneficial and provide a period of additional sleep for shift workers under some conditions; however, napping during the day ultimately interferes with the ability of permanent night workers to get an adequate, extended period of sleep (154).

Light

As discussed in chapter 3, laboratory studies have confirmed that bright light (i.e., light that is equivalent to outdoor light at dawn) can act as a resynchronizing agent for the human circadian system (34,98,177). This has led to the investigation of whether exposure to light can facilitate the circadian adjustment of an individual to shift work (box 5-D). Rigorous use of goggles, lightproof bedrooms, and banks of bright lights has in some cases entrained subjects to non-24-hour routines (50,52).

A recent study of simulated shift work has shown that a fixed schedule of exposure to bright light

Box 5-D—Astronauts and Bright Light

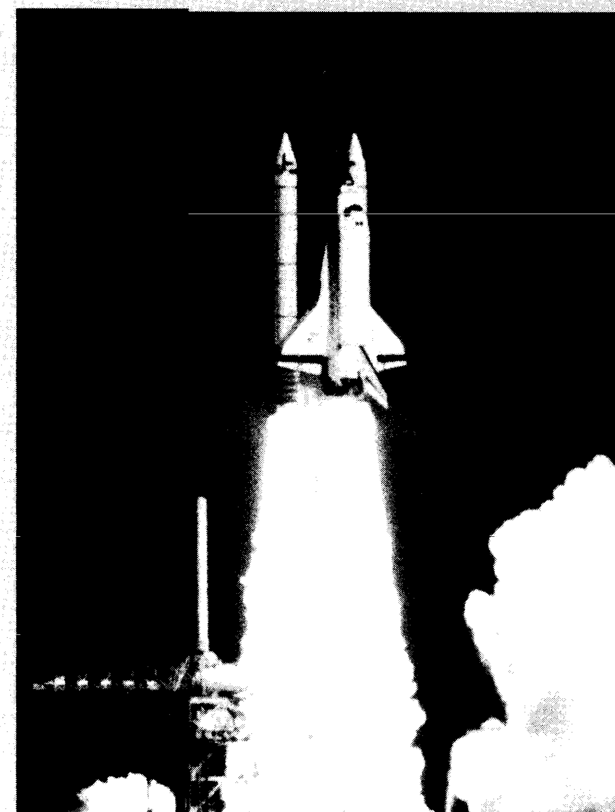


Photo credit: National Aeronautics and Space Administration

Recently, exposure to bright light has been used to help astronauts prepare for a space shuttle mission. The schedule for the December 1990 mission of the space shuttle Columbia called for half the crew to work the night shift, running the ship and carrying out experiments during their nighttime. The previous May, when the Columbia was originally scheduled to be launched, the astronauts had prepared for this schedule by staying up at night and sleeping during the day. Although that launch was canceled, the astronauts reported that simply adopting the new schedule for 2 weeks prior to the launch was not very helpful. One astronaut stated, "I didn't sleep well, I didn't eat well. I was exhausted." In preparation for the new launch date in September, a bank of lights was installed in the astronaut crew quarters, and the night shift crew not only adopted the night schedule but was exposed to bright light during the time they were awake. The September launch date was also canceled, and the bright light treatment was again used for 1 week prior to the launch of the Columbia in December.

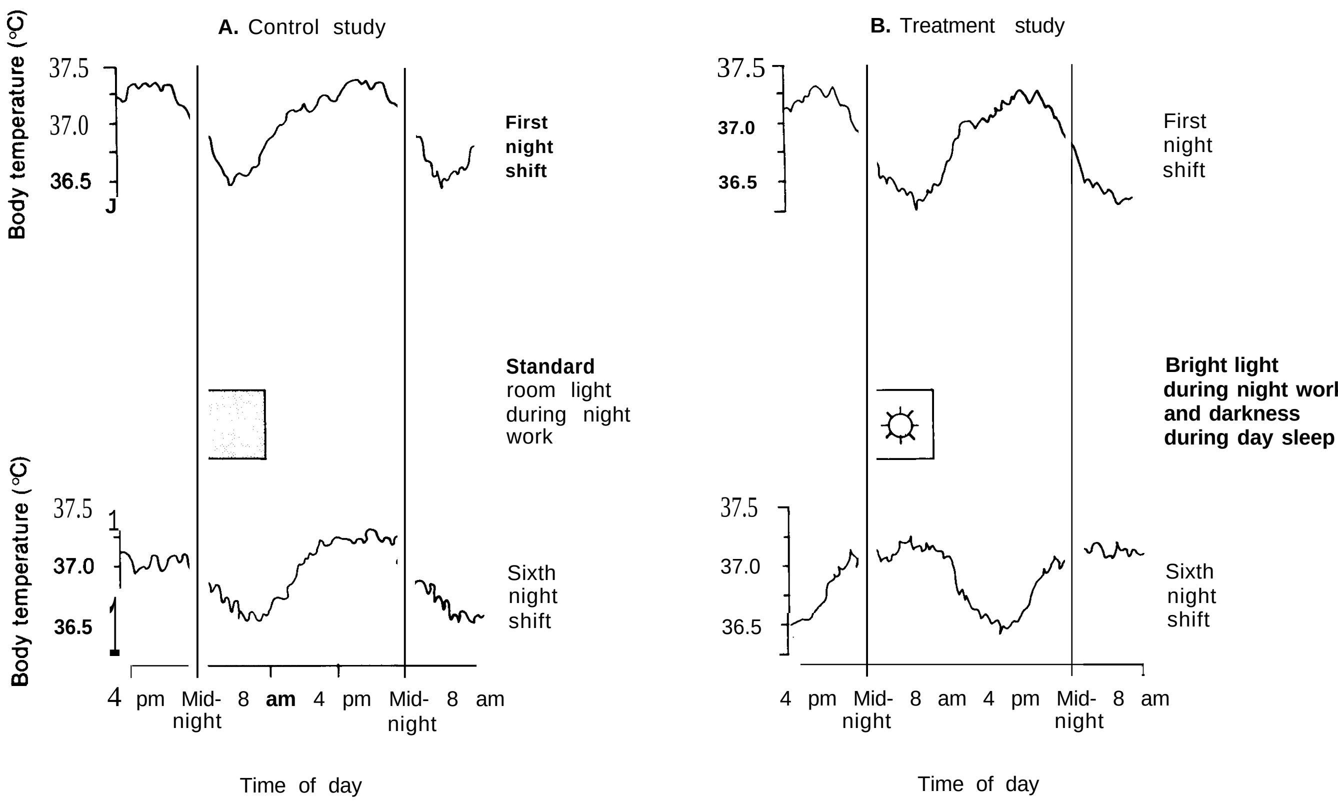
Subjective reports from the astronauts indicated that the bright light exposure, compared with their previous attempt to adjust to the schedule in May, allowed them to sleep more soundly during the day and remain more alert during the night, throughout the mission. As one astronaut said, "We all felt better. The lights did the trick." Operational constraints of the mission prohibited the collection of physiological measures of circadian rhythms which could be used to determine if the astronauts' circadian rhythms had actually been shifted. However, following the cancellation of the September launch, melatonin levels were measured in the astronauts on what would have been the third day of the mission. Melatonin levels were elevated during the astronauts' daytime sleep and suppressed during their waking night. Since melatonin is only released during the biological nighttime hours, this indicated that the astronauts' circadian rhythm of melatonin release had been shifted.

While more comprehensive laboratory and field studies have to be carried out to confirm and extend these observations, these results suggest that the use of bright light might have a role in helping astronauts adjust to their schedules during manned spaceflight. Based on this experience, the National Aeronautics and Space Administration plans to continue exposing astronauts to bright lights before missions that require major sleep changes.

SOURCES: C.A. Czeisler, A.J. Chiasera, and J.F. Duffy, "Research on Sleep, Circadian Rhythms and Aging: Applications to Manned Spaceflight," *Experimental Gerontology*, in press; E. Rosenthal, "Pulses of Light Give Astronauts New Rhythms," *New York Times*, Apr. 23, 1991, p. C1; M. Dunn, "Bright Light Helps Astronauts Adjust to Offbeat Hours in Orbit," *Associated Press*, Feb. 26, 1991.

during night work, combined with complete darkness during daytime sleep, enhanced circadian readjustment to night work, compared to exposure to normal room light at night and unrestricted sleep conditions during the day (35) (figure 5-1 1). The adjustment was observed in both physiological (body temperature, cognitive performance, urine production) and psychological (subjective alertness, cognitive performance) measures. While it has been noted that the design of this study did not preclude other factors, such as activity and sleep-wake schedules, from contributing to the circadian re-

Figure 5-1 l—Effects of Bright Light on the Adjustment of One Worker to Shift Work



The body temperature of a worker on the first and sixth nights of work A) with exposure to normal levels of light and B) with exposure to bright light during the second to fifth night of work. Exposure to bright light led to a shifting of the body temperature cycle to coincide with the night work schedule (midnight to 8 a.m.).

SOURCE: Adapted from C.A. Czeisler, M.P. Johnson, J.F. Duffy, et al., "Exposure to Bright Light and Darkness To Treat Physiologic Maladaptation to Night Work," New *England Journal of Medicine* 322:1253-1259, 1990.

adjustment (24), the results do indicate a role for exposure to light and darkness in circadian adaptation to night work. It is likely that exposure to light and darkness as well as activity levels can interact to affect circadian readjustment (164). It has been proposed that circadian adjustment to shift work might be facilitated by manipulating both sleep schedules and exposure to light (5 1). Another study of exposure to bright light during the night and complete darkness during day sleep showed that the timing of the exposure to bright light determined the direction of the phase shift in circadian rhythms (52,53).

Exposure to bright light may also enhance certain types of performance (23,61) during rotating shift work or extended duty hours. Thus, there is some initial evidence for the usefulness of bright light to enhance adjustment to work schedules; however, practical application in the workplace must await additional research.

Medication and Drug Therapies

Drugs might be helpful in counteracting the sleep and fatigue problems common to shift work. One possible intervention, then, would be to improve sleep by the use of hypnotic medication; however, there are two major problems associated with the use of hypnotics.

The first problem is that of residual effects, which leave a person drowsy after awakening. These effects (which are characteristic of long-acting hypnotics) can affect the person's performance and could therefore cause problems in shift work. The development of the short-acting benzodiazepines such as triazolam and brotizolam, which have a half-life of only a few hours (145), has to some extent overcome these problems. It has been shown that triazolam significantly increases the duration of day sleep, although this increase did not appear to increase phase adjustment of the circadian clock, which would have decreased the tendency to fall asleep in the early morning hours (169). This tendency was unaffected by triazolam. Although triazolam will improve daytime sleep for individuals on night shifts, it does little to improve alertness at night (associated with improved daytime sleep) and nothing to improve nighttime performance (170,171).

The second problem regarding the use of hypnotics by workers relates to the chronic nature of the sleep problems associated with shift work. No hypnotic drugs are recommended for anything other than occasional insomnia. The dual problems of tolerance and dependence make it likely that workers would derive little or no benefit from anything other than intermittent use of short-acting benzodiazepines. Moreover, long-term high doses of triazolam have in some cases been associated with amnesia and mood changes (l), effects to which shift workers are especially vulnerable. Thus, for a hypnotic drug to provide any lasting benefit, it would have to be totally benign when administered chronically. In specialized situations-for example, in the military-occasional use of hypnotics can be helpful in inducing sleep during a period of extended duty (e.g., to induce sleep during rest breaks for aviation crews exposed to extended periods of combat) (91). Residual effects are still a concern, however.

An alternative to more potent hypnotics may be mild over-the-counter sedatives, such as antihistamines. These drugs are used by millions of Americans and may aid individuals who have difficulty sleeping (30,92), though these drugs do have side effects which could limit long-term use.

An essential dietary amino acid, tryptophan, has been shown to be helpful in promoting the onset of sleep when administered in sufficient quantities (73,74) without causing a significant impairment in performance (99). Tryptophan is thought to “set the stage for more rapid sleep onset” (147) rather than directly inducing sleep. While tryptophan is a naturally occurring substance and is considered safe, the chronic nature of the sleep problems associated with shift work could limit its use. Whether the intake of a high dose of a single amino acid over an extended period can still be regarded as natural is debatable and has not been tested. Recently, there have been reports of increased incidence of a rare blood disorder associated with the use of tryptophan. This side effect has been traced to the presence of a contaminant that was inadvertently introduced during the manufacture of the compound and not to tryptophan itself. Currently, the sale of tryptophan in the United States is prohibited until its safety can be confined.

The regular use of stimulant drugs to maintain alertness (as opposed to maintaining or inducing sleep) in shift work also raises concerns. While there is some evidence that the use of caffeine can increase vigilance (99) and may help to increase alertness and performance on the night shift (18,168), its use can have detrimental effects on sleep and may cause anxiety, nervousness, and gastrointestinal discomfort in high doses. As with hypnotics, the occasional, controlled use of more powerful stimulants (e.g., methamphetamine, dextroamphetamine) has been studied to meet the demands of extended duty in military situations (39,91). But concerns about the possible abuse of these drugs and about the side effects associated with them, such as irritability, distorted perception, apprehension, rebound effects (e.g., depression, fatigue), and psychosis after long-term exposure, make their general use inappropriate. Further study is needed to determine the efficacy of short-term use of stimulants such as caffeine in shift work, especially in occupations in which optimal performance is necessary (e.g., pilots). Any potential benefits would have to be weighed against the problems associated with use.

As described in chapter 3, the ability to affect biological rhythms directly and facilitate the resetting of the body clock with drugs is being explored. Such drugs could be used to help the circadian system adjust to changes in work schedules. Both melatonin and triazolam have been studied for their ability to affect biological rhythms. While neither has been conclusively shown to have any such action in humans, there is initial evidence that melatonin has an effect on the circadian system (97,143). In the case of triazolam, the circadian effects that have been observed in experiments with hamsters (161,162) may be an indirect result of the effects the drug has on activity (114).

Currently, no effective pharmacological agents are available to assist workers in adapting to shift work. Long-term use of drugs to counteract fatigue and to ease sleep problems is probably not desirable, and to date no drugs have been conclusively shown to have an effect on the circadian system.

Monitoring

Another possible intervention is the use of monitoring devices and instruments to detect individuals who may pose a risk to themselves or others because their performance is impaired. A number of tests have been designed to detect decrements in performance. Some are being used in the workplace to identify individuals who are impaired due to substance abuse, but many are sensitive to other causes of decreased performance. The Automated Performance Test System is a computerized battery of tests that measures alertness and cognitive and psychomotor factors related to job performance. The system can detect impairment caused by sleep loss, drugs, and alcohol, but it does not indicate the cause of the impairment (77,78,124).

Another computerized test batter-y is the Walter Reed Performance Assessment Battery (157). This battery is designed to examine the effects of sleep deprivation, sustained performance, heat stress, physical fatigue, and physical conditioning in workers. Subjects are asked to undertake a variety of tasks, including ones that measure choice reaction time, time estimation, visual research, pattern recognition, sustained attention, short-term memory, mental arithmetic, and logical reasoning.

Other instruments to measure performance are geared more directly toward determiningg the effects of fatigue and sleep loss (43,136). The National Institute for Occupational Safety and Health, of the Centers for Disease Control in the Department of Health and Human Services, has developed a Fatigue Test Battery and a Daily Sleep and Habits Questionnaire. Included in the computerized Fatigue Test Battery are a number of brief performance tasks designed to evaluate a range of psychological functions, including cognitive abilities, perceptual-motor functions, motor skills, and sensory acuity (136-139). The Daily Sleep and Habits Questionnaire contains information on sleep and other personal factors known to be affectedly work hours. Some questions relate to the times of retiring and arising (including nap times), sleep latency, number of awakenings, depth of sleep, and quality of sleep for the 24 hours preceding the work shift. The workers are also asked to give their subjective evaluation of psychological stress and of gastrointestinal conditions, to report on personal schedule adjustments attributable to shift, adjustments of mealtimes, and exercise periods (138).

These testing instruments are designed to screen individuals to determine if their performance on a task is suboptimal. Other types of monitoring devices are designed to measure and record physiological and performance parameters as an individual actually goes about performing his or her job. These monitoring instruments are valuable for the collection of research and medical data (104). In addition, they provide real-time, on-the-job feedback to the worker, alert the worker to any decrements in performance that may occur, and enable the worker to respond appropriately. Such systems could be particularly useful in job settings where reduction in performance might have negative safety consequences. An example would be a detector that individuals could wear to alert them if they began to fall asleep (117). While such a device would not reverse the person's sleepiness, the feedback it would provide could be crucial in certain settings (e.g., truck drivers, railroad engineers). The design of workplace systems to provide workers with information to judge their performance and to respond to anomalous events would also be valuable (66).

While all of these monitoring procedures might be useful, it has been noted that on-the-job monitoring itself can induce stress (163). Such stress could compound the stress associated with work schedules. Additional research is needed to develop monitoring instruments and systems and to determine the role they could play in various job settings.

Employee Education and Clinical Support

Given the inherent nature of the stress caused by circadian rhythm disruption and the other factors associated with shift work, an important intervention is educational programs that provide workers with strategies to deal with the problems they face and to ease some of the consequences (109). Information such as the best timing of sleep, meals, and other activities to coincide with a given schedule could be helpful. Guidance on ways to make the home more conducive to daytime sleep and the need for cooperation among family members to ensure that the worker is able to get as much sleep as possible would also be beneficial. Finally, providing the entire family with support and guidance that will help them deal with problems that occur could result in a more supportive domestic environment for the worker. Further research is needed to determine what types of educational programs are most effective in helping workers cope with their schedules.

Support for shift workers is largely lacking in U.S. workplaces. Although sleep disorder clinics are available, most of these facilities are not designed to diagnose and handle the underlying problems that cause sleep and other related disorders arising from work schedules.

Fitness

The possibility that improved physical conditioning can increase the rate of adjustment to shift work or increase an individual's tolerance to it has been examined in a few studies (70,71). These studies were conducted on 75 female nurses engaged in shift work and sought to determine whether improving levels of overall fitness would facilitate their ability to cope with shift work. The 4-month exercise training program that was implemented elevated respiratory efficiency by 7 percent. Improvements were noted in self-reports of sleep length, night shift alertness, and general fatigue. Another study failed to show any effect of physical conditioning on the adaptation of wake-sleep and body temperature rhythms to a change in work schedule (135). Thus, the data collected so far suggest that the benefits of physical conditioning may be related to an increase in general strength and more positive subjective reports rather than to any direct facilitation of adjustment to shift work. While these studies indicate that physical fitness might be helpful, additional research is needed to confirm these results and to delineate clearly what mechanisms produce the observed effects. It has also been noted that while physical fitness may lessen the effects of physical and mental fatigue, it cannot protect against the effects of sleep loss (16).

RESEARCH NEEDS

Substantial progress has been made in understanding the underlying physiological mechanisms involved in the generation, entrainment, and expression of circadian rhythms in animals over the last two decades. Similar advances in the application of these data to workplace issues have not been made or supported in this country. A principal need is for research into how to apply basic knowledge on circadian rhythms and sleep to field studies in the workplace. Since demands differ from one workplace to another, research is needed to establish common chronobiological principles, as well as task-specific applications, that can be transferred from the laboratory to the workplace. While some research programs, notably those of the Department of Defense and NASA, use this approach, it is necessary to apply it also to civilian shift work—and not only in industrial settings, but in other settings as well (e.g., police work, long-distance transportation, and medical care). Physiological parameters, such as brain activity, temperature, and endocrine levels, need to be monitored and associated with psychological states and performance measures in order to better understand how functioning is perturbed and how perturbations could be ameliorated. While laboratory studies can attempt to mimic and isolate relevant variables, they cannot fully identify or simulate all the factors present in natural situations.

Research designs need to incorporate enough people over enough time to obtain statistically and biologically meaningful data. Furthermore, analytic models similar to those developed for operations research are needed to take into account the multiple input and output variables. The traditional experimental-control design may not be adequate for many of the research questions that need to be addressed.

Research is needed on the variables that contribute to difficulties in adjusting to shift work. Factors such as individual differences in circadian rhythms, sleep patterns, personality, and age may play a role in the ability of an individual to cope with a work schedule. Studies of the roles of familial and nonwork social demands on the shift worker are also needed. Living in a society that has a different timetable can impose extra burdens on the worker, producing additional stresses on his or her health and well-being.

Sleep loss and fatigue induced by shift work are dependent not only on duration of work, but also on time of day and time of cycle. These parameters need to be documented, and their roles in the ability of workers to perform safely and effectively need to be established. The complex effects of biological rhythms, health status, and drug and alcohol use on performance of workers exposed to the additional physiological stresses of disturbed sleep and circadian rhythms have largely been ignored by researchers.

In addition, there is a compelling need for more research on the interaction between work schedules and safety in the workplace. Central to this endeavor is more thorough collection of workplace data regarding hours of work and the occurrence of on-the-job accidents. Increased data collection by relevant Federal agencies would greatly facilitate this process.

All of the previously stated areas of research will contribute to the final area of research activity-the development of appropriate intervention techniques or countermeasures to promote coping and improve adaptation to shift work. Linked to this is the need for adequate surveillance of workplace performance and evaluation of the effectiveness of potential interventions.

SUMMARY AND CONCLUSIONS

The disruption of biological rhythms that occurs as a result of nonstandard work schedules can interact with other factors to degrade the sleep, health, performance, and well-being of individuals. Although the degree to which different schedules have these effects, which types of tasks are affected most, what variables make an individual susceptible to them, and what interventions can be taken to lessen the effects have not been clearly delineated, some general conclusions can be drawn.

The stresses associated with disruption of circadian cycles, sleep deprivation, and social disharmony interact and affect a number of areas. Shift work is associated with increased incidence of gastrointestinal problems, may be a risk factor for other health problems, and for some workers results in a general, chronic malaise. Performance on some types of tasks can be diminished, especially in those settings where sleep loss and fatigue compound the effects of circadian disruption. These performance decrements can compromise the safety of the worker and can threaten public safety as well.

While the most direct intervention is to devise schedules that do not lead to these consequences, the development of a single best type of schedule is not possible. The demands of a given job will help dictate what might be best in that situation. The avoidance of weekly rotating schedules maybe most preferable from a circadian perspective, and schedules that incorporate extended duty hours which result in sleep loss and fatigue should be avoided. Beyond managing schedules, implementing educational and support programs regarding biological rhythms, sleep, and family counseling may be a good way to improve the coping ability of shift workers. The development and use of such mechanisms as bright light and drugs to help the circadian system desynchronize and napping strategies to counteract the effects of sleep loss and fatigue would also be beneficial to workers. Finally, the development of monitoring devices and systems that could be used to assess performance capabilities could also play a role in intervention.

Thus, while general information is available on biological rhythms and shift work, specific information is lacking. There area number of areas in which there are gaps in the base of knowledge. The information derived from additional research will define the nature, characteristics, and magnitude of the effects caused by work schedules. This knowledge will guide the design and implementation of intervention measures, which are necessary to reduce job-related stress, health effects, and fatigue and to improve alertness and safety.

CHAPTER 5 REFERENCES

1. Adam, K., and "Oswald, I:, "Can a Rapidly Eliminated Hypnotic Cause Daytime Anxiety?" *Pharmacopsychiatry 22:115-119, 1989.*
2. Akerstedt, T., "A Questionnaire Study of Sleep/Wake Disturbances and Irregular Work Hours," *Sleep Research 12:358, 1983.*
3. Akerstedt, T., "Adjustment of Physiological Circadian Rhythms and the Sleep/Wake Cycle to Shift Work," ***Hours of Work: Temporal Factors in Work Scheduling, S.*** Folkard and T.H. Monk (eds.) (New York, NY: John Wiley & Sons, 1985).
4. Akerstedt, T, "Sleep/Wake Disturbances in Working Life," ***Electroencephalograph and Clinical Neurophysiology 39(supp.):360-363, 1987.***
5. Akerstedt, T., "Sleepiness as a Consequence of Shift Work," *Sleep* **11:17-34, 1988.**
6. **Akerstedt, T.,** and Gillberg, M., "Sleep Disturbances and Shift Work" *Night and Shift Work: Biological and Social Aspects,* A. Reinberg, N. Vieux, and P. Andlauer (eds.) (Oxford: Pergamon Press, 1981).
7. Akerstedt, T., and Gillberg, M., "Displacement of the Sleep Period and Sleep Deprivation: Implications for Shift Work" *Human Neurobiology* 1 :163-171, 1982.

8. Akerstedt, T., Patkai, P., and Dahlgren, K., "Field Studies of Shift Work: II. Temporal Patterns in Psychophysiological Activation in Workers Alternating Between Night and Day Work,' *Ergonomics 20:621-631, 1977.*
9. Akerstedt, T., Torsvall, L., and Gillberg, M., "Shift Work and Napping," ***Sleep and Alertness: Chronobiological, Behavioral, and Medical Aspects of Napping,*** D.F. Dinges and R.J. Broughton (eds.) (New York NY: Raven Press, 1989).
10. Angerspach, D., Knauth, P., Loskant, H., et al., "A Retrospective Cohort Study Comparing Complaints and Diseases in Day and Shift Workers," ***lnternational Archives of Occupational and Environmental Health 45:127-140, 1980.***
11. Angus, R.G., and Heslegrave, R.J., "Effects of Sleep Loss on Sustained Cognitive Performance During a Command and Control Situation,' ***Behavior Research Methods, Instruments, and Computers 17:55-67, 1985.***
12. Armstrong, B. G., Nolin, A.D., and McDonald, A.D., "Work in Pregnancy and Birth Weight for Gestational Age," ***British Journal of Industrial Medicine 46:196-199, 1989.***
13. Aschoff, J., Hoffman, K., Pohl, H., et al., "Re-Entrainment of Circadian Rhythms After Phase Shifts of the Zeitgeber," ***Chronobiologia 2:23-78, 1975.***
14. Axelsson, G., Rylander, R., and Molin, I., "Outcome of Pregnancy in Relation to Irregular and Inconvenient Work Schedules," ***British Journal of Industrial Medicine 46:393-398, 1989.***
15. Baker, D., "The Use and Health Consequences of Shift Work," ***International Journal of Health Services 10:405-420, 1980.***
16. Balkin, T.J., Department of Behavioral Biology, Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, DC, personal communication, Dec. 19, 1990.
17. Bjerner, B., and Swensson, A., "Shift Work and Rhythm," ***Acta Medicine Scandinavia 278:102-107, 1953.***
18. Borland, R.G., Rogers, A. S., Nicholson, A.N., et al., "Performance Overnight in Shift Workers Operating a Day-Night Schedule," ***Aviation, Space, and Environmental Medicine 57:241-249, 1986.***
19. Borowsky, M. S., and Wall, R., "Naval Aviation Mishaps and Fatigue," ***Aviation, Space, and Environmental Medicine 54:535-538, 1983.***
20. Breithaupt, H., Hildebrandt, G., Dohre, D., et al., "Tolerance to Shift of Sleep, as Related to the Individual's Circadian Phase Position," ***Ergonomics 21:767-774, 1978.***
21. Browne, R. C., "The Day and Night Performance of Tele-Printer Switchboard Operators,' ***Occupational Psychology 23:121-126, 1949.***
22. Campbell, S., "Duration and Placement of Sleep in a 'Disentrained' Environment," *Psychophysiology 21:106-113, 1984.*
23. Campbell, S., and Dawson, D., "Enhancement of Nighttime Alertness and Performance With Bright Ambient Light,' ***Physiology andBehuvior48:317-320,1990.***
24. Campbell, S., Eastman, C.I., and Lewy, A.J., "Light Treatment for Shift Work," *Light Treatment and Biological Rhythms--Bulletin of the Society for Light Treatment and Biological Rhythms 2:9-10, 1990.*
25. Campbell, S., and Zulley, J., "Ultradian Components of Human Sleep/Wake Patterns During Disentrainment," *Ultradian Rhythms in Physiology and Behavior,* H. Schulz and P. Lavie (eds.) (Berlin: Springer-Verlag, 1985).
26. Campbell, S., and Zulley, J., "Napping as a Biological Rhythm: Disentrainment of the Human Sleep/Wake System," *Sleep* '86, W.P. Koella, F. Obal, H. Schulz, et al. (eds.) (New York NY: Gustav Fischer Verlag, 1988).
27. Coffey, L. C., Skipper, J.K., Jr., and Jung, F.D., "Nurses and Shift Work: Effects on Job Performance and Job-Related Stress,' ***Journal of Advanced Nursing 13:245-254, 1988.***
28. Colligan, M.J., "Shift Work: Health and Performance Effects," ***Environmental and Occupational Medicine,*** W.N. Rom (cd.) (Boston, MA: Little, Brown, 1983).
29. Colligan, M.J., and Tepas, D.I., "The Stress of Work Hours," *American Industrial Hygiene Association Journal 47:686-695, 1986.*
30. Comperatore, C.A., U. S.Army Aeromedical Research Laboratory, Fort Rucker, AL, personal communication, Feb. 15, 1991.
31. Comperatore, C.A., and Krueger, G.P., "Circadian Rhythm Desynchronosis, Jet Lag, Shift Lag, and Coping Strategies,' ***Shift Work, Occupational Mealicine State-of-the-Art Reviews,*** A.J. Scott (cd.) (Philadelphia, PA: Hanley & Belfus, 1990).
32. Condon, R., Colquhoun, P., Plett, R., et al., "Work at Sea: A Study of Sleep, and of Circadian Rhythms in Physiological and Psychological Functions, in Watchkeepers on Merchant Vessels: IV. Rhythms in Performance and Alertness," ***International Archives of Occupational and Environmental Health 60:405-411, 1988.***
33. Costa, G., Lievore, F., Casaletti, G., et al., "Circadian Characteristics Influencing Interindividual Differences in Tolerance and Adjustment to Shift Work" ***Ergonomics 32:373-385, 1989.***
34. Czeisler, C.A., Allan, J. S., Strogatz, S.H., et al., "Bright Light Resets the Human Circadian Pacemaker Independent of the Timing of the Sleep/ Wake Cycle, " ***Science 233:667-671, 1986.***

35. Czeisler, C.A., Johnson, M.P., Duffy, J.F., et al., "Exposure to Bright Light and Darkness to Treat Physiologic Maladaptation to Night Work" New ***England Journal of Medicine 322:1253-1259,*** 1990.
36. Czeisler, C.A., Moore-Ede, M. C., and Coleman, R.M., "Rotating Shift Work Schedules that Disrupt Sleep Are Improved by Applying Circadian Principles," *Science 217:460-463, 1982.*
37. Czeisler, C.A., Moore-Ede, M. C., and Coleman, R.M., "Resetting Circadian Clocks: Applications to Sleep Disorders Medicine and Occupational Health," ***Sleep/Wake Disorders: Natural History, Epidemiology andLong-Terrn Evolution, C.*** Guilleminault and E. Lugaresi (eds.) (New York NY: Raven Press, 1983).
38. Dahlgren, K., "Adjustments of Circadian Rhythms and EEG Sleep Functions to Day and Night Sleep Among Permanent Night Workers and Rotating Shift Workers," ***Psychophysiology 18:381-391, 1981.***
39. ***DeJohn,*** C.A., *Effects of Psychophysiological Countermeasures on Performance Decrement During Sustained Flight Operations,* Research and Technology Work Unit Summary FY 89 Addendum, Accession No. DN 248502 (Pensacola, FL: U.S. Department of the Navy, Medical Research and Development Command, Aerospace Medical Laboratory, 1989).
40. DeVries-Griever, A.H.G., and Meijman, T.F., "The Impact of Abnormal Hours of Work on Various Models of Information Processing: A Process Model on Human Costs of Performance," ***Ergonomics 30:1287-1299, 1987.***
41. Dinges, D.F., "The Influence of the Human Circadian Timekeeping System on Sleep," *Principles and Practice of Sleep Medicine,* M. Kryger, T. Roth, and W.C. Demerit (eds.) (Philadelphia, PA: W.B. Saunders, 1989).
42. Dinges, D.F., Orne, M.T, Whitehouse, W.G., et al., "Temporal Placement of a Nap for Alertness: Contributions of Circadian Phase and Prior Wakefulness," *Sleep* 10:313-329, 1987.
43. Dinges, D.F., and Powell, J.W., "Microcomputer Analyses of Performance on a Portable, Simple Visual RT Task During Sustained Operations," ***BehaviorResearch Methods, Instruments, and Cornputers 17:652-655, 1985.***
44. Dinges, D.F., Whitehouse, W. G., and Orne, E. C., "The Benefits of a Nap During Prolonged Work and Wakefulness,' ***Work and Stress 2:139-153, 1988.***
45. Duchon, J. C., and Keran, C.M., "The Effects of Sleep Strategies on the Health, Length and Quality of Sleep of Rotating Shift Wokers on the Night Shift," ***Studies in Industrial and Organizational Psychology. Shift Work: Health, Sleep and Performance,*** vol. 9, G. Costa, G. Cesana, K. Kogi, et al. (eds.) (Frankfurt am Main: Verlag Peter Lang, 1989).
46. Duchon,J.C., and Keran, C.M., "The Adjustment to a Slowly Rotating Shift Schedule: Are Two Weeks Better Than One?" *Proceedings of the Human Factors Society 34th Annual Meeting* (Santa Monica, CA: Human Factors Society, 1990).
47. Duchon, J.C., and Keran, C.M., "Relationships Among Shift Worker Eating Habits, Eating Satisfaction, and Self-Reported Health in a Population of U.S. Miners," ***Work and Stress 4:111-120,*** 1990.
48. Duchon, J. C., Wagner, J., and Keran, C.M., "Forward vs. Backward Shift Rotation,' *Proceedings of the Human Factors Society 33rd Annual Meeting* (Santa Monica, CA: Human Factors Society, 1989).
49. Dwyer, T., ***Industrial Accidents and Nightwork in the Manufacturing Sector--A Research Project*** (Wellington, New Zealand: Department of Labour, Research and Planning Division, 1981).
50. Eastman, C.I., "Bright Light in Work/Sleep Schedules for Shift Workers: Application of Circadian Rhythm Principles," ***Temporal Disorder in Human Oscillatory Systems,*** L. Rensing, U. an der Heiden, and M.C. Mackey (eds.) (New York, NY: Springer-Verlag, 1987).
51. Eastman, C. I., "Circadian Rhythms and Bright Light: Recommendations for Shift Work," *Work and Stress 4:245-260, 1990.*
52. Eastman, C.I., "Bright Light on the Night Shift: Circadian Rhythms Can Advance or Delay," *Sleep* ***Research 20:318,*** 1991.
53. Eastman, C.I., and Miescke, K.J., "Entrainment of Circadian Rhythms With 26-Hr Bright Light and Sleep-Wake Schedules," ***AmericanJournal of Physiology 259: R1189-1197,*** 1990.
54. Ely, D.L., and Mostardi, R.A., "The Effect of Recent Life Events, Stress, Life Assets, and Temperament Pattern on Cardiovascular Risk Factors for Akron City Police Officers," ***Journal of Human Stress 12:77-91, 1986.***
55. Fitzpatrick, D.T., surgeon, U.S. Army Safety Center, Fort Rucker, AL, personal communication, Feb. 4, 1991.
56. Folkard, S., Minors, D. S., and Waterhouse, J.M., "Chronobiology and Shift Work: Current Issues and Trends," ***Chronobiologia 12:31-54, 1985.***
57. Folkard, S., and Monk, T.H., "Shift Work and Performance," *Human Factors 21:483-492, 1979.*
58. Folkard, S., Monk, T.H., and Lobban, M. C., "Short- and Long-Term Adjustment of Circadian Rhythms in 'Permanent' Night Nurses,' *Ergonomics 21 :785-799, 1978.*
59. Folkard, S., Monk, T.H., and Lobban, M.C., "Towards a Predictive Test of Adjustment to Shift

Work" ***Ergonomics 22:79-91, 1979.***

60. Foret, J., Bensimon, G., Benoit, O., et al., "Quality of Sleep as a Function of Age and Shift Work," ***Night and Shift Work: Biological and Social Aspects,*** A. Reinberg,N. Vieux, and P. Andlauer(eds.) (Oxford: Pergamon Press, 1981).
61. French, J., Hannon, P., and Brainard, G. C., "Effects of Bright Illuminance on Body Temperature and Human Performance," ***Annual Review of Chronopharmacology 7:37-40, 1990.***
62. Frese, M., and Semmer, N., "Shift Work, Stress and Psychosomatic Complaints: A Comparison Between Workers in Different Shift Work Schedules, Non-Shift Workers, and Former Shift Workers," ***Ergonomics 29:99-114, 1986.***
63. Gadbois, C., "Women on Night Shift: Interdependence of Sleep and Off-the-Job Activities," ***Night and Shift Work: Biological and Social Aspects,*** A. Reinburg, N. Vieux, and P. Andlauer (eds.) (Oxford: Pergamon Press, 1981).
64. Gander, P., and Graeber, R. C., "Sleep in Pilots Flying Short-Haul Commercial Schedules," ***Ergonomics 30:1365-1377, 1987.***
65. Gordon, N.P., Cleary, P.D., Parker, C.E., et al., ''ThePrevalence and Health Impact of Shift Work," ***American Journal of Public Health 76:1225-1228, 1986.***
66. Graeber, R. C., "HumanPerformance Issues in Shift Work and Extended Duty Hours," statement prepared for the Office of Technology Assessment workshop Shift Work and Extended Duty Hours, Washington, DC, May 23, 1990.
67. Graeber, R. C., Connell, L.J., Schreiber, H.G., et al., "Aircrew Sleep and Fatigue in Long-Haul Flight Operations," paper presented at the 40th Flight Safety Foundation International Air Safety Seminar, Tokyo, Japan, Oct. 26-29, 1987.
68. Graeber, R. C., Rosekind, M.R., Connell, L.J., et al., "Cockpit Napping," ***ICAO Journal 45:6-10, 1990.***
69. Hamelin, P., "Lorry Driver's Time Habits in Work and Their Involvement in Traffic Accidents," ***Ergonomics 30:1323-1333, 1987.***
70. Harma, M.I., Ilmarinen, J., Knauth, P., et al., "Physical Training Intervention in Female Shift Workers: I. The Effects of Intervention on Fitness, Fatigue, Sleep and Psychosomatic Symptoms," ***Ergonomics 31:39-50, 1988.***
71. Harma, M. I., Ilmarinen, J., Knauth, P., et al., "Physical Training Intervention in Female Shift Workers: II. The Effects of Intervention on the Circadian Rhythms of Alertness, Short-Term Memory, and Body Temperature,' ***Ergonomics 31:51-63,1988.***
72. Harrington, J.M., ***Shift Work and Health: A Critical Review of the Literature*** (London: Her Majesty's Stationery Office, 1978).
73. Hartmann, E., and Spinweber, C.L. "Sleep Induced by L-tryptophan: Effects of Dosages Within the Normal Dietary Intake," ***Journal of Nervous and Mental Diseases 167:497-499, 1979.***
74. Hartman, E., Spinweber, C.L., and Ware, C., "L-tryptophan, L-lucine and Placebo: Effects on Subjective Sleepiness," ***Sleep Research 5:57, 1976.***
75. Hildebrandt, G., Rohmert, W., and Rutenfranz, J., "Twelve- and 24-Hour Rhythms in Error Frequency of Locomotive Drivers and the Influence of Tiredness," ***International Journal of Chronobiology*** 2:175-180, 1974.
76. Jones, 1. S., and Stein, H. S., *Effect of Driver Hours of Service on Tractor-Trailer Crash Involvement* (Arlington, VA: Insurance Institute for Highway Safety, 1987).
77. Kennedy, R. S., Wilkes, R.L., Dunlap, W.P., et al., "Development of an Automated Performance Test System for Environmental and Behavioral Toxicology Studies," ***Perceptual and Motor Skills 65:947-962, 1987.***
78. Kennedy, R. S., Baltzley, D.R., Wilkes, R.L., et al., "Psychology of Computer Use: IX. A Menu of Self-AdministeredMicrocomputer-basedNeurotoxicology Tests," ***Perceptual and Motor Skills 67:1255-1272, 1989.***
79. Keran, C. M., and Duchon, J. C., "Age Differences in the Adjustment to Shift Work" ***Proceedings of the Human Factors Society 34th Annual Meeting*** (Santa Monica, CA: Human Factors Society, 1990).
80. Kerkhof, G., 'Individual Differences and Circadian Rhythms," *Hours of Work: Temporal Factors in Work Scheduling, S.* Folkard and T.H. Monk (eds.) (New York NY: John Wiley & Sons, 1985).
81. Klein, K.E., Wegmann, H.M., and Hunt, B. I., "Desynchronization as a Function of Body Temperature and Performance Circadian Rhythms, as a Result of Outgoing and Homecoming Transmeridian Flights, ' *Aerospace Medicine 43:119-132, 1972.*
82. Knauth, P., Erode, E., Rutenfranz, J., et al., "Re-Entrainment of Body Temperature in Field Studies of Shift Work," ***International Archives of Occupational and Environmental Health 49:137-149, 1981.***
83. Knauth, P., and Kiesswetter, E., "A Change From Weekly to Quicker Shift Rotations: A Field Study of Discontinuous Three-Shift Workers,' *Ergonomics 30:1311-1321, 1987.*
84. Knauth, P., and Rutenfranz, J., "Circadian Rhythm of Body Temperature and Re-Entrainment at Shift Change," ***International Archives of Occupational and Environmental Health 37:125-137, 1976.***
85. Knauth, P., and Rutenfranz, J., "Development of Criteria for the Design of Shift Work Systems,"

Journal of Human Ergonomics 11(supp):337-36'7, 1982.

86. Knauth, P., Rutenfranz, J., Hermann, G., et al., "Re-entrainment of Physiological Functions in Experimental Shift Work Studies," *Ergonomics 21:775-783, 1978.*

87. Knutsson, A., Akerstedt, T., and Orth-Gomer, K., "Increased Risk of Ischaemic Heart Disease in Shift Workers," ***Lancet*** 2:89-92, 1986.

88. Keller, M., Kundi, M., and Cervinka, R., "Field Studies of Shift Work at an Austrian Oil Refinery: I. Health and Psychosocial Well-Being of Workers Who Drop Out of Shift Work," ***Ergonomics 21:835-847, 1978.***

89. Kristensen, T. S., "Cardiovascular Diseases and the Work Environment-A Critical Review of the Epidemiologic Literature on Nonchemical Factors," *Scandinavian Journal of Work and Environmental Health 15;165-179, 1989.*

90. Kroemer, K. H.E., Kroemer, H.J., and Kroemer-Elbert, K. E., ***Engineering Physiology--Bases of Human Factors/Ergonomics (New*** York, NY: Van Nostrand Reinhold, 1990).

91. Krueger, G.P., "Sustained Work, Fatigue, Sleep Loss and Performance: A Review of the Issues," ***Work and Stress 3:129-141, 1989.***

92. Krueger, G.P., and Lieberman, H.R., U.S. Army Research Institute of Environmental Medicine, Natick, MA, personal communication, Feb. 15, 1991.

93. Lauber, J.K., and Kayten, P.J., "Keynote Address: Sleepiness, Circadian Dysrhythmia, and Fatigue in Transportation System Accidents," ***Sleep*** **11:503-512, 1988.**

94. ***Lee,*** K.A., "Sleep-Related Problems Among Female Shift Workers," ***Sleep*** *Research 18:369, 1989.*

95. *Levin,* L., Oler, J., and Whiteside, J.R., "Injury Incidence Rates in a Paint Company on Rotating Production Shifts," ***Accident Analysis and Prevention 17:67-73, 1985.***

96. Lewis, P.M., and Swarm, D.J., "Effect of a 12-Hour/ Day Shift on Performance," ***Proceedings of the Fourth Institute of Electrical and Electronics Engineers Conference on Human Factors and Powerplants,*** E.W. Hagen (cd.) (New York, NY: Institute of Electrical and Electronics Engineers, 1988).

97. Lewy, A., Sack, R., and Latham, J., "Circadian Phase Shifting of Blind and Sighted People With Exogenous Melatonin Administration: Evidence for a Phase Response Curve," Second Annual Conference of the Society for Light Treatment and Biological Rhythms, New York, NY, 1990.

98. Lewy, A., Sack, R., Miller, L., et al., "Antidepressant and Circadian Phase-Shifting Effects of Light,' ***Science 235:352-354, 1987.***

99. Lieberman, H.R., Corkin, S., Spring, B.J., et al., "The Effects of Dietary Neurotransmitter Precursors on Human Behavior," ***American*** *Journal of Clinical Nutrition 42:366-370, 1985.*

100. Mackie, R.T., and Miller, J. C., *Effects of Hours of Service, Regularity of Schedules and Cargo Loading on Truck and Bus Driver Fatigue* (Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, 1978).

101. Mahan, R.P., Carvalhais, A.B., and Queen, S.E., "Sleep Reduction in Night-Shift Workers: Is It Sleep Deprivation or a Sleep Disturbance Disorder?" ***Perceptual and Motor Skills 70:723-730, 1990.***

102. Meers, A., "Performance on Different Turns of Duty Within a Three-Shift System and Its Relation to Body Temperature-Two Field Studies," *Experimental Studies of Shift Work,* P. Colquhoun, S. Folkard, P. Knauth, et al. (eds.) (Opladen, Germany: Westdeutscher Verlag, 1975).

103. Melbin, M., "Night as Frontier," *American Sociology Review 43:2-22, 1978.*

104. *Miles,* L.E., and Broughton, R.J. (eds.), ***Medical Monitoring in the Home and Work Environment (New*** York NY: Raven Press, 1990).

105. Monk, T.H., "Advantages and Disadvantages of Rapidly Rotating Shift Schedules-A Circadian Viewpoint," ***Human Factors 28:553-557, 1986.***

106. Monk, T.H., "Coping With the Stress of Shift Work" ***Work and Stress 2:169-172, 1988.***

107. Monk, T.H., and Embrey, D.E., "A Field Study of Circadian Rhythms in Actual and Interpolated Task Performance," ***Night and Shift Work: Biological and Social Aspects,*** A. Reinberg, N. Vieux, and P. Andlauer (eds.) (Oxford: Pergamon Press, 1981).

108. Monk, T.H., and Folkard, S., "Shift Work and Performance,' ***Hours of Work: Temporal Factors in Work Scheduling, S.*** Folkard and T.H. Monk (eds.) (New York, NY: John Wiley& Sons, 1985).

109. Monk, T.H., Moline, M.L., and Graeber, R.C., "Inducing Jet Lag in the Laboratory: Patterns of Adjustment to an Acute Shift in Routine," *Aviation and Space Environmental Medicine 59:703-710, 1988.*

110. Moog, R., "Optimization of Shift Work: Physiological Contributions," *Ergonomics 30:1249-1259, 1987.*

111. Moore-Ede, M. C., and Richardson, G. S., "Medical Implications of Shift Work," ***Annual Review of Medicine 36:607-617, 1985.***

112. Moretz, S., "Rotational Shifts: Are They Harmful to Workers' Health?" ***Occupational Hazards*** **October**:54-57, 1987.

113. Morgan, J.N., "Child Care When Parents Are Employed," ***Five Thousand American Families: Patterns of Economic Progress, vol. 9, S. Hill,*** D.H.

Hill, and J.N. Morgan (eds.) (Ann Arbor, MI: University of Michigan Press, 1981).

114. Mrosovsky, N., and Salmon, P.A., "A Behavioral Method for Accelerating Reentrainment of Rhythms to New Light-Dark Cycles," *Nature 330:372-373, 1987.*

115. Mullaney, D.J., Fleck, P.A., Okudaira, et al., "An Automated System for Administering Continuous Workload and for Measuring Sustained Continuous Performance,' ***Behavior Research Methods, Instruments, and Computers 17:16-18, 1985.***

116. Nachreiner, F., Brand, G., Ernst, G., et al., "Zur Kontrolle von Hawthorne-Effekten in Feldexperimenten," ***Zeiter Arbeitswissenschaft 32:172-175, 1977.***

117. National Transportation Safety Board, Safety Study-- ***Fatigue, Alcohol, Other Drugs, and Medical Factors in Fatal-to-the Driver Heavy Truck Crashes,*** vol. 1, NTSB/SS-90/01 (Springfield, VA: National Technical Information Service, 1990).

118. Novak, R.D., Smolensky, M.H., Fairchild, E.J., et al., "Shift Work and Industrial Injuries at a Chemical Plant in Southeast Texas, ' ***Chronobiology International 7:155-164, 1990.***

119. ***N***urminen, T., "Shift Work, Fetal Development and Course of Pregnancy," *Scandinavian Journal of Work and Environmental Health 15:395-403, 1989.*

120. Olson, C.M., "Shift Work," ***Journal of Emergency Medicine 2:37-43, 1984.***

121. ***Ong, C.N.,*** Phoon, W. O., Iskander, N., et al., "Shift Work and Work Injuries in an Iron and Steel Mill," ***Applied Ergonomics 18:51-56, 1987.***

122. Orth-Gomer, K., "Intervention on Coronary Risk Factors by Adapting a Shift Work Schedule to Biologic Rhythmicity," ***Psychosomatic Medicine*** 45:407-415, 1983.

123. Ottman, W., Karvonen, M.J., Schmidt, K.H., et al., "Subjective Health Status of Day and Shift Working Policemen,' ***Ergonomics 32:847-854, 1989.***

124. Parth, P., Kennedy, R. S., Lane, N.E., et al., "Motor and Cognitive Testing of Bone Marrow Transplant Patients After Chemoradiotherapy," ***Perceptual and Motor Skills 68:1227-1241, 1989.***

125. Presser, H.B., "Working Women and Child Care," ***Women: A Developmental Perspective, NIH*** Pub. No. ***82-2298,*** P.W. Berman and E.R. Ramey (eds.) (Washington, DC: U.S. Government Printing Office, 1982).

126. Presser, H.B., "Some Economic Complexities of Child Care Provided by Grandmothers,' ***Journal of Marriage and the Family 51:581-591, 1989.***

127. Prokop, O., and Prokop, L., "Ermunudung und Einschlafen am Steuer," ***Zentralblatt fur Verkehrs-Medizin, Verkehrs-Psychologie und Angrenzende Gebiete 1:19-30, 1955.***

128. Redmond, D.P., and Hegge, F.W., "Observations on the Design and Specification of a Wrist-Worn Human Activity Monitoring System," *Behavior Research Methods, Instruments, and Computers 17:659-669, 1985.*

129. Reinberg, A., Andlauer, P., DePrins, J., et al., "Desynchronization of the Oral Temperature Circadian Rhythm and Intolerance to Shift Work," ***Nature 308:272-274, 1984.***

130. Reinberg, A., Andlauer, P., Guillet, P., et al., "Oral Temperature, Circadian Rhythm Amplitude, Aging and Tolerance to Shift Work" *Ergonomics 23:55-64,1980.*

131. Reinberg, A., Motohashi, Y., Bourdeleau, P., et al., "Alteration of Period and Amplitude of Circadian Rhythms in Shift Workers, With Special Reference to Temperature, Right and Left Hand Grip Strength," *European Journal of Physiology 57:15-25,1988.*

132. Reinberg, A., Motohashi, Y., Bourdeleau, P., et al., "InternalDesynchronization of Circadian Rhythms and Tolerance of Shift Work" *Chronobiologia 16:21-34, 1989.*

133. Rogers, A.S., Spencer, M.B., Stone, B.M., et al., "The Influence of a 1 h Nap on Performance Overnight," *Ergonomics 32:1193-1205, 1989.*

134. Rosa, R.R., and Bonnet, M.H., "Performance and Alertness on 8-Hour and 12-Hour Rotating at a Natural Gas Utility," *Ergonomics, in* press.

135. Rosa, R.R., Bonnet, M.H., Bootzin, R.R., et al., ''Intervention Factors for Promoting Adjustment to Nightwork and Shift Work," *Shift Work, OccupationalMedicine State-of-the-Art Reviews,* A.J. Scott (cd.) (Philadelphia, PA: Hanley & Belfus, 1990).

136. Rosa, R.R., and Coil.igan, M.J., ***The NIOSHFatigue Test Battery: Laboratory Validation of a Portable System for Field Study of Extended Workdays and Work Scheduling,*** NIOSH internal report (Cincinnati, OH: U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, 1986).

137. Rosa, R.R., and Colligan, M.J., "Long Workdays vs. Rest Days: Assessing Fatigue and Alertness With a Portable Performance Battery," *Human Factors 30:305-317, 1988.*

138. Rosa, R.R., Colligan, M.J., and Lewis, P, "Extended Workdays: Effects of 8-Hour and 12-Hour Rotating Shift Schedules on Performance, Subjective Alertness, Sleep Patterns, and Psychological Variables," ***Work and Stress 3:21-32, 1989.***

139. Rosa, R.R., Wheeler, D.D., Warm, J. S., et al., ''Extended Workdays: Effects on Performance and Ratings of Fatigue and Alertness," *Behavior Research Methods, Instruments, and Computers 17:6-15, 1985.*

140. Rutenfranz, J., Colquhoun, W.P., Knauth, P., et al., "Biomedical and Psychosocial Aspects of Shift Work A Review," *Scandinavian Journal of Work, Environment and Health 3:165-182, 1977.*

141. Rutenfranz, J., Haider, M., and Keller, M., "Occupational Health Measures for Night Workers and Shift Workers," *Hours of Work: Temporal Factors in Work Scheduling, S.* Folkard and T.H. Monk (eds.) (New York, NY: John Wiley& Sons, 1985).

142. Rutenfranz, J., Plett, R., Knauth, P., et al., " Work at Sea: A Study of Sleep, and Circadian Rhythms in Physiological and Psychological Functions, in Watchkeepers on Merchant Vessels: II. Sleep Duration and Subjective Ratings of Sleep Quality,' ***International Archives of Occupational and Environmental Health 60:331-339, 1988.***

143. Sack, R.L., and Lewy, A.J., "Melatonin Administration Phase Advances Endogenous Rhythms in Man," ***Sleep Research 17:396, 1988.***

144. Scherr, J., "Man's Work and Circadian Rhythm Through the Ages," ***Night and Shift Work: Biological and Social Aspects,*** A. Reinberg, N. Vieux, and P. Andlauer (eds.) (Oxford: Pergamon Press, 1981).

145. Seidel, W.F., Roth, T., Roehrs, T., et al., "Treatment of a 12-Hour Shift of Schedule With Benzodiazepines," ***Science 224:1262-1264, 1984.***

146. Smith, P., "A Study of Weekly and Rapidly Rotating Shift Workers,' ***International Archives of Occupational and Environmental Health 43:211-220,1979.***

147. Spinweber, ***C. L., L-Tryptophan, Sleep and Performance, NHRC*** Rep. No. 87-17 (San Diego, CA: U.S. Department of the Navy, Medical Research and Development Command, Health Research Center, March 1987).

148. Staines, G.L., and Pleck, J.H., ***The Impact of Work Schedules on the Family (Ann*** Arbor, MI: University of Michigan, Institute for Social Research, 1983).

149. Tarquini, B., Cecchettin, M., and Cariddi, A., ''Serum Gastrin and Pepsinogen in Shift Workers," ***International Archives of Occupational and Environmental Health 58:99-103, 1986.***

150. Taste, D.L., and Colligan, M.J., ***Health Consequences of Shift Work,*** Project URU-4426, Technical Rep. (Menlo Park, CA: Stanford University, Stanford Research Institute, 1978).

151. Tepas, D. I., Department of Psychology, University of Connecticut, Storrs, CT, personal communication, Jan. 9, 1991.

152. Tepas, D.I., Armstrong, D.R., Carlson, M.L., et al., "Changing Industry to Continuous Operations: Different Strokes for Different Plants," *Behavior Research Methods, Instruments, and Computers 17:670-676, 1985.*

153. Tepas, D.I., and Mahan, R.P., "The Many Meanings of Sleep," *Work and Stress 3:93-102, 1989.*

154. Tepas, D.I., Popkin, S.M., and Dekker, D.K., "A Survey of Locomotive Engineers on Irregular Schedules and Their Spouses: A Preliminary Report," *Studies in Industrial and Organizational Psychology. Shift Work: Health, Sleep and Performance,* vol. 10, G. Costa, G. Cesana, K. Kogi, et al. (eds.) (Frankfurt am Main: Verlag Peter Lang, 1990).

155. Tepas, D.I., Walsh, J.K., and Armstrong, D.R., "Comprehensive Study of the Sleep of Shift Workers," ***The Twenty-Four Hour Workday: Proceedings of a Symposium on Variations in Work-Sleep Schedules,*** L.C. Johnson, D.I. Tepas, W.P. Colquhoun, et al. (eds.) (Cincinnati, OH: U.S. Department of Health and Human Services, National Institute of Occupational Safety and Health, 1981).

156. Tepas, D.I., Walsh, J.K., Moss, P.D., et al., "Polysomnographic Correlates of Shift Worker Performance in the Laboratory," *Night and Shift Work: Biological and Social Aspects,* A. Reinberg, N. Vieux, and P. Andlauer (eds.) (Oxford: Pergamon Press, 1981).

157. Thorne, D.R., Genser, S.G., Sing, H. C., et al., "The Walter Reed Performance Assessment Battery," ***Neurobehavioral Toxicology and Teratology 7:415-418, 1985.***

158. Tilley, A.J., Wilkinson, R.T., Warren, P. S.G., et al., "The Sleep and Performance of Shift Workers," ***Human Factors 24:629-641, 1982.***

159. Torsvall, L., and Akerstedt, T., "Sleepiness on the Job: Continuously Measured EEG Changes in Train Drivers," ***Electroencephalograph and Clinical Neurophysiology 23:143-148, 1987.***

160. Turek, F.W., "Circadian Principles and Design of Rotating Shift Work Schedules," *American Journal of Physiology 251: R636-638, 1986.*

161. Turek, F.W., and Losee-Olson, S., "A Benzodiazepine Used in the Treatment of Insomnia Phase-Shifts the Mammalian Circadian Clock" *Nature 321:167-168, 1986.*

162. Turek, F.W., and Van-Reeth, O., "Altering the Mammalian Circadian Clock With the Short-Acting Benzodiazepine, Triazolam," *Trends in Neuroscience 11:535-541, 1988.*

163. U.S. Congress, Office of Technology Assessment, ***The Electronic Supervisor: New Technology, New Tensions, OTA-CIT-333*** (Washington, DC: U.S. Government Printing Office, 1987).

164. Van Cauter, E., and Turek, F.W., "Strategies for Resetting the Human Circadian Clock," New *England Journal of Medicine 322:1306-1308,* 1990.

165. Van Loon, J.H., "Diurnal Body Temperature Curves in Shift Workers," ***Ergonomics 6:267-272, 1963.***

166. Wagner, J.A., "Time-of-Day Variations in the Severity of Injuries Suffered by Mine Shift Workers," ***Proceedings of the Human Factors Society 32nd Annual Meeting*** (Santa Monica, CA: Human Factors Society, 1988).

167. Walker, J., "Social Problems of Shift Work," ***Hours of Work: Temporal Factors in Work Scheduling, S.*** Folkard and T.H. Monk (eds,) (New York NY: John Wiley & Sons, 1985).

168. Walsh, J., Muehlbach, M., Humm, T.M., et al., "Effect of Caffeine on Physiological Sleep Tendency and Ability to Sustain Wakefulness at Night," ***Psychopharmacology 101:271-273, 1990.***

169. Walsh, J. K., Muehlbach, M.J., and Schweitzer, P.K., "Acute Administration of Triazolam for the Daytime Sleep of Rotating Shift Workers," ***Sleep 7:223-229, 1984.***

170. Walsh, J., Schweitzer, P. K., Anch, A. M., et al., "Sleepiness/Alertness on a Simulated Night Shift Following Sleep at Home With Triazolam," ***Sleep*** 14:140-146, 1991.

171. Walsh, J., Sugerman, J., Muehlbach, M., et al., "Physiological Sleep Tendency on a Simulated Night Shift: Adaptation and Effects of Triazolam," ***Sleep*** *11:251-264, 1988.*

172. Walsh, J., Tepas, D. I., and Moses, P., "The EEG Sleep of Night and Rotating Shift Workers," ***Biological Rhythms, Sleep and Shift Work, L.C.*** Johnson, D.I. Tepas, W.P. Colquhoun, et al. (eds.) (New York NY: Spectrum Publications, 1981).

173. Watson, A.P., "The Importance of Work Shift in Determining Risk of Fatal and Lost Work Day Injury Accidents," ***Annals of the American Conference of Governmental Industrial Hygienists 14:125-130, 1986.***

174. Wedderburn, A., ***Studies of Shift Work in the Steel Industry*** (Edinburgh: Department of Business Organization, Heriot-Watt University, 1975).

175. Weitzman, E.D., and Kripke, D.F., "Experimental 12-Hour Shift of the Sleep/Wake Cycle in Man: Effects on Sleep and Physiologic Rhythms," ***Advances in Sleep Research, vol. 7, Variations in Work-Sleep Schedules: Effects on Health and Performance,*** L.C. Johnson, D.I. Tepas, W.P. Colquhoun, et al. (eds.) (New York NY: Spectrum Publications, 1982).

176. Wever, R.A., ***The Circadian System of Man: Results of Experiments Under Temporal Isolation (New*** York, NY: Springer-Verlag, 1979).

177. Wever, R.A., Polasek, J., and Wildgruber, C.M., "Bright Light Affects Human Circadian Rhythms," ***Pflugers Archives 396:85-87, 1983.***

178. White, L., and Keith, B., "The Effect of Shift Work on the Quality and Stability of Marital Relations," ***Journal of Marriage and the Family 52:453-462, 1990.***

179. Williamson, A.M., and Sanderson, J. W., "Changing the Speed of Shift Rotation: A Field Study," ***Ergonomics 29:1085-1096, 1986.***

180. Wojtczak-Jaroszowa, J., and Jarosz, D., "Time-Related Distribution of Occupational Accidents," ***Journal of Safety Research 18:33-41, 1987.***

181. Wojtczak-Jaroszowa, J., Makowska, Z., Rzepechi, A., et al., "Changes in Psychomotor and Mental Task Performance Following Physical Work in Standard Conditions, and in a Shift Working Situation," ***Ergonomics 21:801-809, 1978.***

182. Wojtczak-Jaroszowa, J., and Pawlowska-Skyba, K., "Night and Shift Work: I. Circadian Variations in Work" ***Medical Practice 18:1, 1967.***