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## The Human Factors Aspects of Shiftwork

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### I. INTRODUCTION

The usual concept of the normal workday is an 8-hour period occurring during the daytime; all other schedules are often viewed as abnormal, unusual, or unnatural [1]. The challenges an individual faces when working outside “normal” hours are complex and multidimensional [2]. Yet, extended and around-the-clock services are rapidly becoming a fact of life for many industries and workers. Work schedules encompassing hours other than daytime are becoming more, not less, prevalent for a greater number of workers. The notion of a “nine-to-five” work schedule may well be a thing of the past.

The term *shiftwork* is often applied to schedules that include hours of work other than daytime, but there is no universally accepted definition of the term [3]. The most comprehensive estimate of the prevalence of shiftwork in the United States is based on the 1991 Current Population Survey, a household sample survey conducted monthly by the Bureau of the Census. The data indicated that of the 80.5 million full-time wage and salary employees, about 18%, or 14.5 million people, had work schedules that differed from daytime hours. Of the 18%, evening schedules were most prevalent at 5.1%, night shifts and “employer-arranged irregular schedules” followed, each at 3.7%, and rotating shifts were reported for 3.4% of total workers [4].

The reasons for around-the-clock hours of work are varied. Economic factors such as recouping a large capital investment on equipment, production cycle time, a high demand for products and services, or lower utility costs during non-peak usage hours [5] may force 24-h operations. Shiftwork is also prevalent in various transportation-related occupations including trucking, railroad, airlines, and shipping. The business concept of just-in-time manufacturing requires a continual movement of product and raw materials. With an increasingly mobile society, airline flights at all hours of the day are extremely convenient for transporting both passengers and freight.

As a society, we are demanding that more services be available on a 24-h basis. Constant medical, police, and fire protection are a requirement in our contemporary society. We

realize the merit of grocery and drug stores, gas stations, and convenience stores that are open 24 h a day. During our relaxation periods, we enjoy having restaurants, entertainment, and recreational activities available at any time of the day or night. Nevertheless, in order to accommodate us, someone else must be at work to provide the services we desire!

For the individual, shiftwork can have biological, psychological, or social effects with both short- and long-term consequences. It is not possible within the confines of this chapter to provide an in-depth discussion of every variable that might affect a shiftworker. Those who wish to explore a particular issue in more detail should consult other reviews [3]. The purpose of this chapter is to highlight some of these issues and to alert the reader to things to think about when implementing or evaluating work schedules.

## II. BACKGROUND AND SIGNIFICANCE TO OCCUPATIONAL ERGONOMICS

Ergonomics is defined as “the analysis of problems of people in their various working conditions within their real-life situations” [6]. This may require investigations into the individual as well as into the individual’s living and working situations. All of these elements can relate to and influence each other. As will be discussed throughout this chapter, shiftwork does affect workers’ health and well-being and hence is a topic for ergonomic study. Nonwork activities such as the timing and placement of sleep or domestic responsibilities can also affect work performance. In certain instances, any of these influences upon job performance can pose an immediate threat to the health and safety of the individual worker.

In other extreme instances, the actions (or inaction) of the worker can have disastrous consequences for the greater society at large. For example, the near meltdown at Three-Mile Island occurred during the night shift when workers were presumably tired. Poor judgment related to sleep loss and shiftwork was also cited as a factor in the space shuttle *Challenger* accident [7]. Although shiftwork appears inevitable, interventions are possible to help the worker cope with unusual work hours. Work schedules can be designed to enhance the work environment for the individual worker.

## III. WORK SCHEDULING CONSIDERATIONS

### A. Types of Shift Schedules

The conventional approach to shiftwork is to divide the day equally into three 8-hr intervals spanning the daytime, afternoon-evening, and nighttime hours. Such a simplistic scheme implies little variety in work hours. But quite the opposite is true with hundreds, if not thousands, of work schedules of unknown origin and rationale in U.S. industry [1]; among U.S. firefighters, for example, over 150 different schedules have been documented [8]. Some of the complexity is due to inconsistent use of terminology. The following are some definitions to assist in describing and communicating work schedule information [1].

The fundamental definition is that of *shift*: the time of day a worker is required to be at the workplace. By this definition, all workers who are scheduled to be at a workplace on a regular basis, including day workers, are shiftworkers. *Work system* describes all the work schedules in the given workplace if formal methods ensure that work requirements are met. When a work system includes schedules for most operations on all seven days of a week, it is said to have *continuous work weeks*; *discontinuous work weeks* regularly exclude most Sunday and/or Saturday work. Workers who work at the same time of day and no more than one shift per day have *permanent work hours*. If the time of day that an individual works changes according to a planned schedule, the person is said to have *rotating hours*. Some work

systems require operations where the duration and time of day when the shift begins are not defined in advance because of unscheduled events; this work schedule is an *irregular shift*.

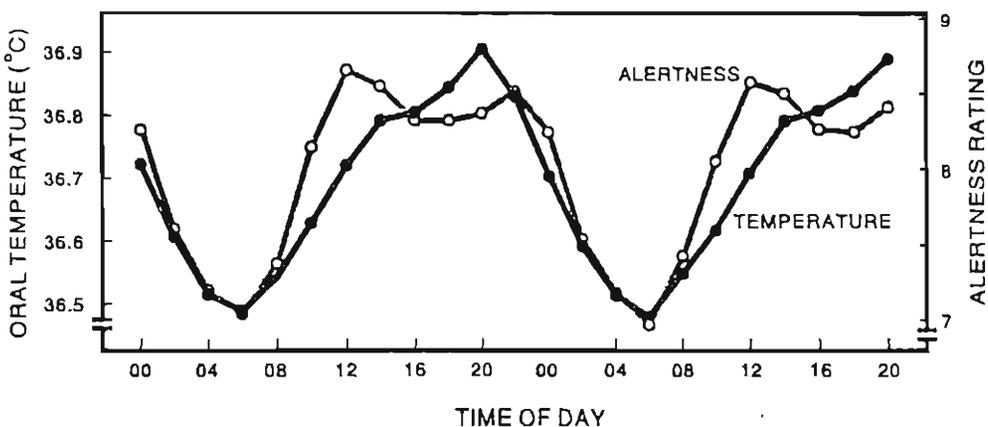
The *first shift*, also called the *day shift*, in most cases consists of at least seven consecutive hours somewhere between 0600 and 1600 hours (6 a.m. and 4 p.m.). The second or afternoon-evening shift, usually falls such that at least seven consecutive hours are between 1500 and 0100 hours (3 p.m. and 1 a.m.). The third or night *shift* usually falls so that at least seven consecutive hours are between 2200 and 0700 hours (10 p.m. and 7 a.m.). However, these shift designations are not universally accepted; shift designations in U.S. workplaces can vary from one location to another, so references to any work schedule should be as specific as possible.

## B. Brief Review of Chronobiology

Human beings are biological systems. Many of our physiological processes display a rhythmic fluctuation on a regular basis. The periodicity or time taken to complete one cycle varies greatly for different processes. Some cycles can be measured in seconds; an example is the electrical activity of the brain as measured by an electroencephalogram (EEG). Other cycles have a periodicity measured in days; the female menstrual cycle has a period of around 28 days.

Biological rhythms with a period of about 24 hr are very common [9]; they are called circadian rhythms, originating from the Latin *circa* (about) and *dies* (day). If left to run on their own accord in an environment without time constraints, circadian rhythms tend to have a cycle length of around 25 hr [10]. Body functions such as temperature, sleep/wakefulness, secretion of certain hormones, and the functioning of organ systems including the cardiovascular, pulmonary, renal, and immune systems display circadian rhythms. Certain psychological and mental functions also display a daily rhythmicity [11]. Figure 1 illustrates the circadian rhythms of oral temperature and self-rated alertness over a 48-hr period.

Two sets of components help maintain a daily rhythmicity; endogenous and exogenous oscillators [9,10]. The endogenous oscillators are internal to the body. Some researchers have suggested that one area in the brain, the suprachiasmatic nucleus, is the site of this internal biological clock [12]. However, the notion of only one internal clock has been questioned.



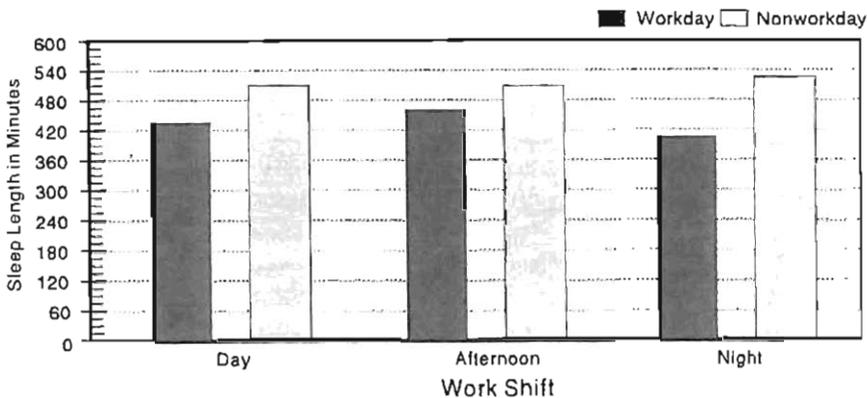
**Figure 1** The circadian rhythm of oral temperature (solid circles) and self-rated alertness (open circles). Two cycles of the 12 points defining each rhythm have been plotted. (Reprinted by permission from Ref. 29.).

Exogenous components of circadian rhythms are related to environmental and social cues outside of the body—the cycle of light and dark, social interaction with other people, and the timing of meals are some examples [9]. Exogenous cues act as entrainment agents or zeitgebers (German, time-giver) to synchronize the body's clock so it coincides with the 24-hr solar day [9,10]. Problems are thought to arise when an individual attempts to do activities at a time of day that is discrepant with the body clock activity, for example, a shiftworker on the night shift attempting to maintain alertness and wakefulness when the body clock indicates that it is time to be sleeping. This may result in feelings of fatigue, lethargy, or insomnia-like symptoms.

### C. Sleep

One of the most robust findings of shiftwork research is a reduction in sleep length associated with night shiftwork [13–18]. Afternoon-evening shiftworkers have the longest sleep length, and day workers sleep somewhere in between the two; Figure 2 is an illustration of sleep lengths for permanent day, afternoon, and night shiftworkers [17]. People who work on rotating shifts sleep even less on the night shift than permanent night workers. This sleep loss is cumulative, so that by the end of the week the night shiftworker has lost the equivalent of at least one night's sleep. The sleep quality of night workers may also be different from that of day workers [19].

The reason for shorter sleep lengths among night shiftworkers is twofold. First, night workers are attempting to take their main sleep period during the day when the body wants to be awake. Second, humans are also social creatures. In a day-oriented society, there are pressures to conform to the daily behavior of everyone else. Thus, many night shiftworkers may consciously elect to cut short their sleep time in order to spend more time interacting with family, friends, and society [20,21].



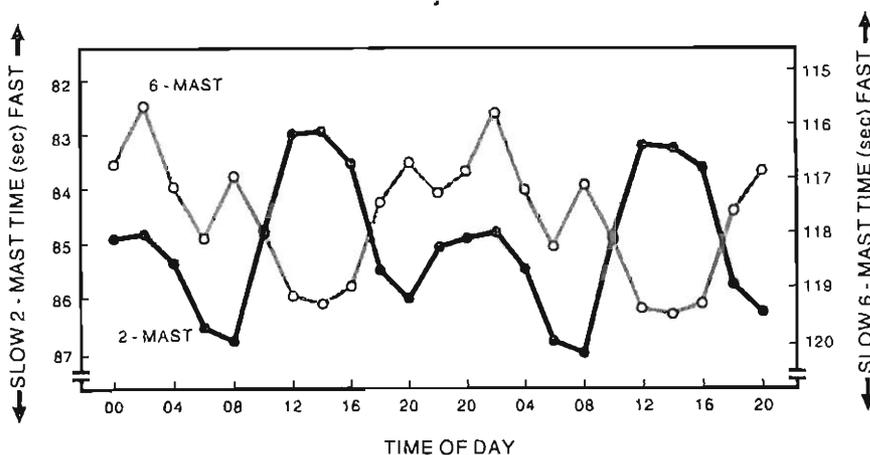
**Figure 2** Mean workday and nonworkday sleep length in minutes for a sample of 1262 permanent discontinuous day, afternoon-evening, and night workers. A statistically significant difference was found between workday and nonworkday sleep length. For workday sleep, statistically significant differences were found among the various combinations of shifts. Nonworkday comparisons did not result in differences between any of the shift combinations. (Data adapted and reprinted by permission from Ref. 17.)

A shorter sleep length for a single night may not be detrimental or have a noticeable effect upon performance the next day. In fact, acute sleep deprivation is quite easy to make up during the next sleep period [22]. However, cutting sleep periods short for an extended period of time, such as weeks or months, leads to a condition of chronic sleep deprivation (CSD). The effects of CSD are not as easy to recover from, if one can recover at all. A common but mistaken notion is that one can always catch up on sleep during nonworkdays. If this were true, short sleepers including night workers should sleep longer than day workers on their days off. Research shows, though, that everyone sleeps about the same length of time on days off [17]; this is illustrated in Figure 2.

Chronic sleep deprivation may have long-term effects on a worker's health. It may also affect a worker's job performance. Researchers have demonstrated a correlation between sleep differences and performance decrements [23]. Frequently, CSD can result in lapses of attention in which the individual actually falls asleep for a very brief period of time. This condition is known as a microsleep [22]. Depending on the job, brief inattention may have negative and quite possibly disastrous consequences.

#### D. Work Performance Effects

Cognitive activity, performance, and subjective feelings like alertness (see Figure 1) also show circadian rhythms and fluctuate with the time of day [24-27]. However, the optimal time of day for performance varies as a function of task demands. A parallel relationship between performance efficiency on a variety of perceptual-motor tasks and the circadian rhythm of body temperature have been demonstrated [28]. Also, reaction time [15] and vigilance may suffer during and as a result of night work. Similar patterns of time of day variation do not appear to be the case for more cognitive tasks. Figure 3 illustrates differences in performance for a memory-based task depending on the cognitive load of the task. Differences in peak performance time among different tasks further suggest that there may be more than one biological clock within the body [29-31].



**Figure 3** The circadian rhythms of low (solid circles) and high (open circles) memory load performance. The MAST (Memory and Search Task) is a task in which a certain number of items are held in short-term memory while being searched for within a larger list. The more items to be held, the higher the cognitive load. (Reprinted by permission from Ref. 29.)

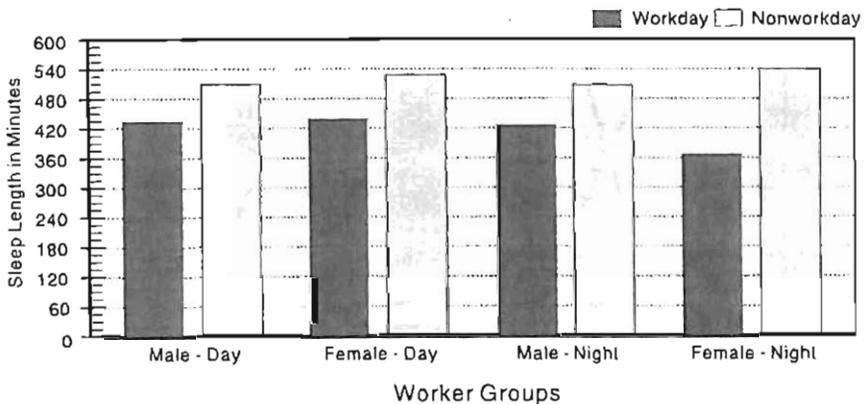
#### IV. LIFESTYLE ISSUES FACING THE EMPLOYER AND SHIFTWORKER

##### A. Gender Differences

As of 1991, in the United States, about 18% of all full-time employed women and 25% of all employed men aged 16 and over worked other than a regular day shift. Women with pre-school or school-aged children were over 50% more likely to work fixed nights than those with children over 14 years old [4]. Many European countries follow conventions proposed by the International Labor Organization (ILO) that either totally ban or severely restrict women from working during nighttime hours. A number of leading countries including the United States have never ratified these conventions, objecting that such restrictions lead to unfair employment practices. Amid this debate, the issue remains of whether there are differences between males and females in their job performance as well as in their reactions when working during nondaytime hours.

Gender difference studies of shiftworkers have investigated a wide variety of topics such as child care issues, domestic responsibilities, and time for family and leisure interests [32,33]. Yet with respect to the most robust finding in shiftwork research, sleep length, few studies have been done addressing gender differences. In a study of three samples totaling 2370 shiftworkers, Dekker and Tepas [34] found that women who work night shifts sleep even less than men on the same shift and report a greater amount of sleep difficulties, i.e., falling and staying asleep (Figure 4). Using same-sex day workers as a baseline, however, results indicated a greater percentage of sleep time loss for male night workers relative to their day shift counterparts. A difference score between day and night workers suggests that males may have a harder time than females adjusting to night work.

One factor that may affect sleep length is having a second job, and domestic responsibilities may be just like having a second job. In the previous study [34], over 75% of the females indicated that they had the responsibility for doing the housework whereas less than 20% of the males responded in a similar fashion. A shorter sleep length for females between 18 and 49 years of age was replicated in a recent study [35]. In the 50-59 age group, however, results indicated that males and females sleep about equal lengths of time. This is not surprising because the children of those around the age of 50 are usually leaving the home or



**Figure 4** Mean sleep length in minutes for four groups of 101 workers each who were matched on the basis of age and job tenure. These groups were defined as males and females on the day and night shifts. As shown in this figure, females on the night shift sleep the least amount of time on workdays. These results were replicated in two other samples of workers. (Data adapted from Ref. 34.)

are at least of an age where they are less demanding of their mother's attention for immediate care needs. Domestic activities are quite likely to compete for time available for sleep during nonwork hours. Thus, it is not only shiftwork but also nonwork factors that affect sleep behavior.

## **B. Aging Workers**

The question of whether older workers should work at night is a difficult one to answer for many reasons. First, there is considerable debate as to what constitutes "old." Second, there have been few longitudinal studies of the long-term effects of shiftwork, so the effects of working at unusual hours for an extended period of time are not completely understood [30,36]. Finally, many biological and behavioral processes that could be affected by shiftwork are also affected by the aging process itself, making it difficult to draw singular cause-and-effect conclusions.

Although primarily cross-sectional, a few studies that are both timely and commendable have addressed aging issues with respect to shiftwork. For example, using sleep length as a marker variable, Tepas et al. [35] reported that male workers on the afternoon-evening shift show a 50-min decrease in average sleep length from the 18–29 age group to the 40–49 age group; comparable results were found for both male and female night shiftworkers. As expected, age had a minimal effect on the sleep length of male and female day shiftworkers. Other research [18] has demonstrated a similar decrease in sleep quality and sleep length in workers after about the age of 45.

Many workplace practices in the United States allow workers to use seniority status to choose their shiftwork. Usually, senior workers bid out of night work to a more desirable daytime job. The exception to this practice may be the worker to remain on night shift if the plant management pays a high wage differential for night work. Then the earning potential for a worker may far outweigh any reason to leave the night shift. Although the wage differential is relatively small in the United States, averaging 5–10% more for night work, shift differentials in European countries are sometimes as high as 25%.

Studies of former shiftworkers who left shiftwork support the notion that people often leave night work because of a constitutional weakness and/or because shiftwork has a direct effect on their health. Workers who remain are referred to as a "survivor population." This implies that workers who cannot tolerate shiftwork will self-select out of a schedule they cannot tolerate, thereby eliminating the need to be concerned with issues related to shiftwork itself or tenure on a particular shift. Notions like the survivor hypothesis and other motivating factors such as high shift premiums may mask aging issues. Carefully controlled studies of aging and shiftwork are needed because the population in the United States is aging at a rapid rate.

## **C. Social Considerations of Shiftwork**

Although workers may complain about difficulties while working the night shift, people may choose to work the shifts they do for numerous reasons. For many dual-income couples with small children, it may be desirable or even necessary to stagger work hours between the two parents. One parent can then assume child care while the other parent works, with parenting responsibilities shared between the two. For single mothers, an advantage of night work may be easier child care accommodations when the children are sleeping, and the mothers can sleep during the daytime when the children are at school [37]. Other reasons people choose night shiftwork is the time it makes available to participate in daytime activities including taking

classes, having a second job for income, or the ease of making doctor, dentist, and other business and personal appointments [38].

At other times, advantages of night work may not outweigh the disadvantages. Further, many people do not have a choice of shift assignment. By far the most frequent complaint among night shiftworkers is the lack of nonwork time available for family and friends, placing a strain on other family members as well [1, 7, 38]. Workers on an afternoon-evening shift also experience social disruption, particularly if their children are school-aged. In this case, the worker is at work during the evening hours when the children are home. In the morning, little if any time is available to spend with the children before they must leave for school. People on afternoon shifts may not see their children at all until the weekend.

The time for socialization with non-family members is also compromised. Most night workers report that their friends do not work the same schedule as they do [14]. In order to interact with these individuals, night workers may elect to cut short their sleep time [20]. In households with children, workers incur an even greater sleep debt than workers without children because parents will delay their sleep until parenting responsibilities are completed [38]. Further, the night worker must sleep during the day at a time when there are external noises from other family members or from the outside, which may also shorten the length of the sleep period.

#### **D. Eating Behavior**

An obvious problem with respect to dietary concerns facing night workers is the timing of meals [7, 39]. Usually night workers are asleep during one major daytime meal, either breakfast or, more likely, the noontime meal. When night workers are on the job, eating a main meal during nighttime hours may not seem a natural thing to do. In addition, night workers may have limited access to food. Quite often, plant cafeterias are closed during the evening and night hours, with a limited amount of food choices from vending machines as the only alternative. Further, the timing of the ingestion of certain substances such as caffeine may have significant carryover effects to later times of the day or even to later days [40]. In a study of locomotive engineers on irregular work schedules [41], the effects of caffeine upon mood and sleep latency carried over from workdays to nonworkdays.

Many night workers are dissatisfied with their eating habits [39]. Some researchers have suggested that the diet and eating patterns of shiftworkers are out of phase with digestion-related circadian functions. On a long-term basis, these altered eating habits may eventually lead to medical problems. Although there have been some reports of a higher incidence of gastritis and ulcers among night shiftworkers [13, 16], other researchers cannot replicate those results. The relationships between night shiftwork, gastrointestinal complaints, and diet are not fully understood. Complaints by night workers of ulcers and gastritis may be due to a combination of stress, bad food, or other interactions rather than being solely caused by night work per se.

#### **E. Worker Training Programs**

Many work schedules can be improved by being redesigned. But if a work schedule cannot be redesigned or modified to worker needs, training is beneficial [22]. Training programs not only alert the worker to potential problems associated with unusual schedules but can also suggest ways to cope with these challenges. For a training program to be most effective, care must be taken in its design and implementation. Too often an encyclopedia of information is

thrown at the shiftworker with little attempt at application [42]. A better program is one where objectives are clearly stated and practical solutions are offered [1].

Although many educational programs are available on the market, to date no objective study with suitable experimental controls has been done to assess whether in fact these programs do promote adjustment to shiftwork [22]. Obviously, many techniques to help the worker cope with night work involve lifestyle changes. Such alterations to daily habits are very hard to accomplish and maintain on a long-term basis. What is needed are long-term studies including multiple follow-ups of the training's effectiveness [7].

## V. CURRENT STATUS OF SHIFTWORK RESEARCH

This section briefly discusses some of the current knowledge regarding shiftwork practices. A complete and exhaustive review is not possible or practical within the confines of a chapter. The topics selected for inclusion here represent some of the major concerns in regard to work schedules.

### A. Permanent Versus Rotating Shifts

One concern when implementing a work system is how to schedule the shifts for 24-hr coverage. There is considerable debate over permanent versus rotating work shifts. Rotating shifts distribute the less desirable work times more evenly among the workforce [38]. However, especially among night workers, a permanent work schedule may not be a permanent lifestyle schedule because nearly all night workers revert to a daytime routine on their non-workdays; permanent night workers are in essence rotating their sleeping and awake hours on a weekly basis [17]. The distinction between permanent and rotating shiftwork is not as absolute as the terms imply.

If rotating shifts are warranted, the next two decisions to be made concern the rate and the order of rotation through the shift schedule. It is generally recommended to rotate in a forward or clockwise direction [1, 7, 30, 43]. That is, regardless of where in the cycle one begins, shifts should move in the order of day, afternoon-evening, and night. The issue is not as clear-cut for rate of rotation. Arguments can be made for either a fast or a slow rotation [44].

In the United States, the two most common rates of rotation are either on a weekly ("fast") or a monthly ("slow") basis. In Europe, a fast rotation is defined as changing work shifts every 2 or 3 days, and a weekly rotation is considered slow. The purpose of a fast rotation is to get the worker through the dyssynchronous phase (i.e., night work) as quickly as possible. The few shifts of night work are not a problem because the individual's body clock continues to run on a daytime schedule. Two disadvantages of rapid rotations are very low nighttime alertness and poor daytime sleep because of the day orientation of the rhythm [7].

On the other hand, the argument for slow rotation is that when an individual is allowed to work for an extended period of time on one shift, the body clock has time to readjust to the new work schedule. Nonetheless, it usually takes about 21 consecutive days [7] on the same schedule for the body temperature circadian rhythm to adjust; other circadian rhythms may adjust at different rates. The problem for slow rotators is similar to that of permanent night shift workers—rarely does anyone work for 21 consecutive days without time off interspersed. On nonworkdays, people revert to a day-oriented routine that throws off the adjustment of the biological rhythms.

This debate on rotation rate has been addressed in a series of review articles [45–47]. Folkard [47] proposed a “best compromise” shift system. According to this advice, the individual designing and implementing a work system should analyze and identify the goals of the overall system and design a work schedule to achieve those goals. If safety is of utmost importance, such conditions might favor a permanent night shift. On the other hand, if social factors are a priority, then rapid rotation (less than three consecutive night shifts) may be more favorable.

### B. Should Workers Nap?

As night shift workers tend to have shorter sleep lengths, one way to increase the amount of sleep per 24-hr period is to take naps throughout the day. Depending on their placement, naps can serve various purposes. For example, a *prophylactic* nap is taken prior to beginning an extended work period or unusual work hour to help alleviate feelings of fatigue that may be encountered during the following work period. A *recuperative* nap is taken after the work period to compensate for previous sleep loss. *Maintenance* naps occur on the job during the work shift. Although maintenance napping is not a systematic practice in the United States, it is quite common in Japan [7].

The effectiveness of napping is not yet fully understood. Napping may be beneficial in the short term to maintain alertness, bridge low points in arousal, and provide better recovery than rest without sleep when a worker is changing from day or evening to the night shift. Conversely, napping can hinder adaptation to night work by providing an excuse for sacrificing regular sleep. A study of sleep inertia, the brief time period upon awakening when an individual is not fully functioning, suggests that the time period for sleep inertia may vary depending on when an individual awakens from various stages of sleep [48]. This could be detrimental in a situation where split second decisions are required. Naps can also hinder adaptation of the circadian rhythm because sleep can be an anchor point or zeitgeber for circadian rhythms [7].

### C. Do Workers Ever Adjust to Night Shiftwork?

The answer to this is a fairly definitive no [1, 2, 7, 15, 22, 30], although there are large individual differences in tolerance to shiftwork. The problems of reverting to daytime schedules during nonwork periods for night shift workers is a large obstacle to complete adjustment. In both a cross-sectional and a longitudinal study [2], results found no differences in reported workday sleep length for experienced versus inexperienced shiftworkers. Such results suggest that people do not fully adjust to shiftwork.

### D. How Should One Select, Implement, or Assess a Work System?

At present, there is no single best work schedule system for all industries, and no silver bullet to solve shiftwork problems for workers in every setting. Rather, we need to evaluate both work schedule problems and solutions on a site-by-site basis—different strokes for different plants [14]. Although customized solutions may not be profitable for some consultants if they are not able to take advantage of generic routines, a customized solution considers the specific needs of the client. Multiple solutions may be appropriate for any industry, and an individualized approach can evaluate all practical interventions and choose the one that shows the best solution to the problem.

The scheduling of work for the operations of any particular plant must take into consideration both the industry's profitability and the labor force's ability to perform in a particular environment. To accomplish this, representatives from both labor and management should be present and involved in determining or assessing any work schedule. The workers who will actually be practicing these schedules should be included among the labor representatives. A cooperative attitude will ensure that work schedules are accepted and adhered to.

Finally, the work system must be continually reevaluated [1]. When a new schedule is implemented, a follow-up study should be scheduled for at least 6 months to 1 year after the initial implementation. At that time, any necessary adjustments in the work schedule system should be made. It is well known among behavioral researchers that any intervention probably will show an initial improvement in behavioral response. This is called the *Hawthorne effect*, first demonstrated in a series of studies at a plant in Cicero, Illinois [49]. Hopefully, the behavior change will be in the direction the practitioner desires! What is more important, however, is to sustain the change for a long period of time. Long-term results are not as easy as they sound; most of the recommendations for coping with shiftwork require lifestyle changes on the part of the worker's and the worker's family.

## VI. FUTURE CONCERNS

### A. What Do We Still Need to Know About the Effects of Shiftwork?

Although the efforts of researchers to date have been highly commendable, there still remain gaps in our practical knowledge of the effects of subjecting workers to non-daytime work schedules. The following list of research needs is by no means exhaustive or comprehensive. However, it is a list of immediate needs and, it is hoped, ones that for all practical purposes can be implemented promptly.

First, we need more real-life performance studies of on-the-job behavior at all hours of the day and night. Most of the present performance studies are conducted in controlled environments using laboratory-based measures and, in many cases, with college-aged people as experimental subjects. Although this type of research is informative, the degree to which the results generalize to a population of workers is not known. Further, it is extremely difficult, and perhaps impossible, to reproduce in the laboratory the motivation, teamwork, practice, and realistic consequence of work in a factory. Studies that do use real shiftworkers and give them a standard laboratory task to perform before, after, or on top of their real work do not really overcome these problems: the task is still an artificial task rather than motivated and consequential work [46]. Field studies should also include longitudinal designs so that the long-term effects of shiftwork on both health and performance can be adequately assessed [38].

Before we can do controlled field studies, we must first operationally define variables of interest. For example, "fatigue" is a popular notion among lay persons and some researchers. However, an operational definition of fatigue along with measurement methods has yet to be proposed. Subjective measures of mood and alertness [50-52] attempt to quantify subjective feelings; often constructs like fatigue are inferred from these responses. Although these kinds of scales have been validated, one must recognize that they are subjective, state-dependent measurements and are prone to recall bias. Physiological measurements such as eye blink rate or EEG monitors [12] are promising lines of research; validation and practical applications of these methods are yet to be seen.

The prevalence and extent of shiftwork in the United States is not well documented. One reason for this is a lack of standard definitions of terms so that all involved are communi-

cating on the same level. In addition, a complete database of work schedules is not available. It has been recommended that the Bureau of Labor Statistics maintain such a registry of work schedules. We would highly endorse such a practice.

Another recommendation is that "hours of service laws" in all modes of transportation be reviewed immediately. These laws [3] attempt to regulate the number of hours worked for a defined period of time, usually on a weekly basis. Rest periods are prescribed by both the total hours worked during the entire weekly period and minimal off-duty time per 24 hr. For the railroad industry, rules regarding work schedules are documented in the *U.S. Code of Federal Regulations* 49 CFR 228; similar regulations are found in 49 CFR 395 for motor carrier operators. However, some of these laws are based on antiquated practices, if they are based on any practices at all! It is recommended that the laws be assessed and revised given the current state of knowledge regarding unusual work hours. Government, management, and labor support of research in this area is required.

Finally, ethical and public policy considerations of the effects of shiftwork must be addressed. Although disruptions caused by work schedules may seem to be of little immediate concern to the employer, ignoring the potential mishaps that can occur when workers are not performing at peak is unethical practice. For example, one small lapse of attention in either the transportation or nuclear power industries can seriously impair not only the health and well-being of the individual worker but also public safety. Shiftwork will continue to increase in the United States and in the global market. Problems and challenges for both workers and management will arise. These issues must be recognized and dealt with at once.

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# Occupational Ergonomics

Theory and Applications

edited by

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**Library of Congress Cataloging-in-Publication Data**

Occupational ergonomics : theory and applications / edited by Amit  
Bhattacharya, James McGlothlin.

p. cm. — (Occupational safety and health ; 27)

Includes index.

ISBN 0-8247-9419-2 (alk. paper)

1. Human engineering. 2. Industrial hygiene. 3. Industrial safety.

I. Bhattacharya, Amit. II. McGlothlin, James D. III. Series: Occupational  
safety and health (Marcel Dekker, Inc.) ; 27.

TA166.026 1996

620.8'2—dc20

96-5423

CIP

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122114

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MARCEL DEKKER, INC.

270 Madison Avenue, New York, New York 10016

Current printing (last digit):

10 9 8 7 6 5 4 3 2 1

**PRINTED IN THE UNITED STATES OF AMERICA**