ADAPTATION TO SHIFTWORK: FACT OR FALLACY?

Donald I. Tepas

Sleep Laboratory, Department of Psychology, Illinois Institute of Technology, IIT Center, Chicago, Illinois 60616, U.S.A.

Investigators in shiftwork-related research areas would agree that shiftwork problems are complex, multi-dimensional ones, involving a wide range of interaction variables. While there is general agreement on the range of shiftwork variables, there is no definitive data on the relative importance of specific variables in determining effects on shiftworker sleep, behavior and performance. With regard to the relative importance of specific variables, two emphases are prominent. The endogenous approach calls for intervention and research efforts aimed at changing or maintaining biological rhythms, suggesting that adaptation is possible and an experienced night worker may have normal sleep in quantitative as well as qualitative dimensions. The exogenous approach, on the other hand, calls for intervention and research efforts aimed at removing or preventing deficits and deficiencies, suggesting that complete adaptation is probably not feasible in a day-oriented society with adult workers. Shiftwork research to date has provided considerable scientific support for the fact that night work changes the life of workers. Unfortunately, it has not done a very good job identifying the direction of these changes. Which ones are signs of adaptation? Does complete adaptation ever occur, or is it a fallacy? What is the relative power for change of different variables? Answers to questions such as these are required if shiftwork research is to have any practical value.

Sophistication continues to grow regarding the range of variables associated with shiftwork problems. Examination of papers published after recent meetings of investigators in shiftwork-related research areas (Johnson et al., 1981; Reinberg et al., 1981) demonstrates quite well the wide range of problems and variables under investigation. As a rule, investigators would agree that shiftwork problems are complex ones, involving a wide range of interacting variables. Shiftwork is a multi-dimensional problem, and most models of shiftwork effects acknowledge this.

While there is general agreement on the range of shiftwork variables, there
is no definitive data on the relative importance or weight to be given specific variables in determining effects on shiftworker sleep, behavior and performance. Indeed, as Haidar et al. (1981) have pointed out, we are probably dealing with a complex matrix of variables which may also be an interactional one with effects which are time-contingent.

A MATTER OF EMPHASIS

Shiftwork investigations do vary significantly with regard to their view of the relative importance of specific variables. In an over-simplification, two emphases are prominent. Figure 1 provides a diagram of one of these emphases, an approach which I term the Endogenous emphasis. The Endogenous emphasis is a chronobiological approach which stresses circadian rhythms as the major and perhaps primary source of variance for shiftworker sleep, behavior, and performance. The social and work environments, as well as wellbeing (health), are to be viewed within this emphasis as interacting variables which modulate shiftwork effects but in most cases are not the major sources of variance. Figure 2 provides a diagram of the second of these emphases, an approach which I term the Exogenous emphasis. The Exogenous emphasis is an environmental emphasis, in a
broadly defined sense, which stresses social and work variables as the primary source of variance for the real-world active shiftworker. Chronobiological and wellbeing variables are to be viewed within this emphasis as interacting variables which modulate shiftwork effects but in most cases are not the major source of variance.

With regard to adaptation to shiftwork, the implications of these two forms of emphasis may in practice be quite different. The Endogenous emphasis in most cases appears to focus on adjustment and/or maintenance of biological circadian variables. This assumes that tolerance for sustained shiftwork is mainly related to the amplitude, frequency, and/or phase of certain biological circadian variables. From this perspective, one might also suggest that adaptation to shiftwork is possible even when circumstances are such that a normal social and work environment is not feasible. The Exogenous emphasis, on the other hand, is one which appears to focus on making sure that the biological and social needs of the worker are met or exceeded. Circadian factors might fall within the objective of this task, but one might suggest that adaptation to shiftwork may be possible even if some circadian variables are persistent and not subject to complete change as long as one lives on Earth. This approach assumes that tolerance for sustained shiftwork is for the most part related to the quality and quantity of social and work variables. Although in many respects these two forms amount to different descriptions of the same world, the immediate implications for research strategy are different and are worthy of serious discussion. The Endogenous approach calls for intervention and research efforts aimed at changing or maintaining biological rhythms. The Exogenous approach, on the other hand calls for intervention and research efforts aimed at removing or preventing deficits and deficiencies. One might perceive this contrast in goals as simply being a matter of semantic difference. However, I propose that the tactical implications of these two positions are for the most part quite different in an immediate and practical sense.

ADAPTATION OR CHANGE?

One common dictionary definition of “adaptation” is “to adjust (oneself) to new circumstances.” If one goes the next step further and looks for a brief but usual definition of “adjust,” it is “to change so as to fit.” These brief and certainly general definitions leave one with the idea that adaptation is to be viewed as a positive change. Although scientists are frequently more complex and specific in their definitions, the same underlying notion seems frequently to pervade studies and reports on shiftwork. Although we are now sophisticated enough to realize that there is no single best way to get night work done, some continue to look for ways which will allow workers to fit to night work. That is, there is an unstated (and perhaps sometimes unrecognized) assumption that somehow
Nightwork can become a normal thing to do.

Night workers are always part of a real world which is day-oriented. Although one might design a universe in which the social and work environments are nearly identical for both day and night, it is quite unrealistic to project this as a reality on Earth in the near future. Despite contemporary increases in the availability of around-the-clock services and work of all types, night workers are, and will be, people with day experience working at night in a society which is mainly aimed at meeting the needs of people who work during the day. It is important to remember this and not expect it to change dramatically in the near, or perhaps even distant, future.

After talking directly to a number of shiftworkers, one gets a fairly universal impression: How ingenious they have been in developing methods and techniques for attempting to resolve the problems resulting from night work! It is perhaps a trite point, but we must remember that shiftworkers must change if they are to function. What is not clear is the direction which these changes take in the real world. Perhaps too frequently we assume that the changes which the worker makes, or the shiftwork investigator introduces as part of a study are towards a day-worker-defined normal state. Also, we assume nearly always that a change towards a day-worker-defined normal state is a desirable and appropriate goal for shiftworkers. These changes can never be totally normal if we use the day worker as our definition or standard. Frequently, these changes represent not an attempt to adjust to the day-worker-norm but rather a change away from the norm, resulting in a deprived human.

If the world of the night worker can never be a normal one, just what are we looking at when we say that we are examining individual differences in adaptation? One possibility is that we are simply looking at how individuals react in general when faced with a deficit or handicap which will remain a disability as long as nights are worked. That is, we may be talking about a deficiency which can develop into a quite permanent disability should the condition continue an extended period of time. There may be no hope for a complete cure so long as the deficiency, working at night, continues. Since the deprivation may involve a host of variables, there is no reason to expect that permanent shiftwork results in a specific form of disease since the malady may have many forms, each of which is induced by a specific deprivation.

**IMPLICATIONS FOR SLEEP**

Differences between Endogenous and Exogenous emphases can be demonstrated best, perhaps, if one follows through a specific example for which one has a reasonable background of data. Sleep variables meet this criteria quite well. Numerous studies have associated shiftwork with sleep problems (Tepas, 1982a). One possible Endogenous scenario for this is as follows: Shiftworkers have prob-
ADAPTATION TO SHIFTWORK

Problems sleeping because they attempt to sleep at chronobiologically bad times of day. This initially results in difficulty in going to sleep and in staying asleep. With the proper chronohygiene, circadian rhythm peaks shift so that the worker is now trying to sleep at a chronobiologically better time. As a result, the night worker is now able to sleep in a more normal manner. If these circadian rhythm shifts do not occur, sleeping problems persist and increase. This disturbed sleep includes difficulty falling asleep, trouble staying asleep, and problems with early awakenings. These disturbed sleep characteristics are quite similar to the symptoms characteristic of some clinical sleep disorders. The worker may very well be spending as much or more time in bed but in fact be getting less polysomnographic total sleep time (TST), and one would not consider the night worker to be an efficient sleeper if there has not been a shift in the circadian rhythm peak.

Thus, the Endogenous approach suggests that TST will either increase or decrease as night work continues. One further point should be noted. Of the time available to night workers for sleep, some times are more favorable sleep times (TEPAS, 1982b). One might suggest that experienced night workers could learn, perhaps by trial and error, to select sleep time-of-day strategies which are chronobiologically appropriate since sleepiness is also a circadian function which should promote such learning. This suggests that the self-selected sleep strategies of experienced shiftworkers may differ from those of the inexperienced shiftworker.

An Exogenous emphasis scenario is quite different. It suggests that worker self-selected sleep times are mainly based on their social and work schedule requirements, rather than chronobiologically-appropriate times or circadian rhythm changes in sleepiness. Workers change their sleep and other behaviors in a vain effort to maintain their previously established social behaviors as well as the requirements of their work schedule. The existing demand characteristics of a society and work schedule are rigid in comparison to sleep behavior which can be pushed around and modified to meet these demand schedules. TST is driven mainly by the social and work demands upon the worker. The worker is an adult and a member of a day-oriented society with established social behavior patterns and obligations. Going on night work does not eliminate these patterns and obligations, but it probably does mean that many behaviors will be decreased or reduced. The Exogenous emphasis suggests that the initial effect of many shift schedules is a reduction in TST to allow the workers to maintain their old and established patterns and obligations, probably also at a reduced level. The result may not be a disturbed sleep but rather a more efficient sleep period. Workers can choose to reduce their sleep time, rather than sleeping longer and giving up other behaviors. Since sleep is much more of a solitary act than most other behaviors, it is the first to be reduced and reaches some minimal level almost instantly, given the social time demands of some shift schedules.

Thus, the Exogenous approach suggests that TST may be decreased by night work. It also suggests that continued night work will not result in further de-
creases in TST, if they have already been quickly driven to the minimum level of practical tolerance or they are short sleepers to start. This reduction in TST is sleep deprivation, and continued chronic sleep deprivation should result in decrements in performance and perhaps medical problems. Interventions aimed at increasing TST may minimize problems resulting from the chronic sleep deprivation. However, since the worker is still part of a fairly fixed day-oriented society, reductions in sleep would not be expected to vanish or become minimal simply on the basis of experience and/or circadian peak shifts. Changes in self-selected sleep strategies should not be expected in most cases since these sleep habits are subservient to other established social and work requirements.

In sum, the Endogenous emphasis suggests that adaptation is possible and an experienced night worker may have normal sleep in quantitative as well as qualitative dimension. Experienced night workers who do not adapt should manifest clinical sleep disorders of some sort. The Exogenous emphasis suggests that complete adaptation is probably not feasible in a day-oriented society with adult workers. With regard to sleep variables, experienced night workers should not differ from inexperienced night workers in that sleep decrements are easy to make and are perhaps the first to occur when social and work demands require reductions in many behaviors. The Exogenous emphasis does predict the occurrence of many secondary problems with continued sleep deprivation.

WHITHER SLEEP CHANGE?

Survey studies of shiftworker sleep length consistently report that night shiftwork results in the shortest main sleep periods whereas work on the afternoon/evening shift results in main sleep periods which are the longest. It is appropriate to note that this is true for both permanent shift workers as well as rotating shift (RS) workers. The data also suggest that RS workers while on the night shift sleep less than permanent night (PN) workers (TEPAS, 1982a). At first glance, this appears to suggest adaptation by the PN workers. It is, however, difficult to explain the sleep length of the afternoon/evening shiftworker using an Endogenous emphasis. Why does afternoon/evening shiftwork result in a main sleep period which is longer than that associated with day shiftwork?

Figure 3 suggests an interesting answer to this question. The solid line function in this figure is derived from AKERSTEDT and GILLBERG (1981). It is sleep duration when going to bed at different times of day under conditions in which sleep is allowed to end spontaneously. The asterisks also plotted in Fig. 3 are the sleep start times (TEPAS, 1982b) and sleep lengths (TEPAS et al., 1981) for permanent day (PD), permanent afternoon/evening (PA) and PN workers. This suggests that the PA workers are not sleeping longer, but rather just as one would predict on a simple chronobiological basis. The PN worker asterisk suggests once again some degree of endogenous adaptation. However, it is difficult
ADAPTATION TO SHIFTWORK

Fig. 3. Sleep length at different times of day. Data from Akerstedt and Gillberg (1981) indicated by the solid line. Asterisks indicate data points from Tepas (1982b) and Tepas et al. (1981).

to explain the PD asterisk on a simple chronobiological basis.

As I see it, an Exogenous emphasis explanation of the shiftworker data in Fig. 3 provides a more realistic interpretation which is also parsimonious with other shiftworker sleep data. These are job-bound (Webb and Agnew, 1975) workers in that they are required to report to work following a specific and inflexible time schedule. They also have social obligations and desires which govern their behavior. Our data suggest that more than 85% of this shiftworker population does not spontaneously awaken but rather uses some device or person to end their main sleep period. Given the work/sleep phases used by workers (Tepas et al., 1981), it is reasonable to argue that PD workers go to sleep late due to social demands but must terminate their sleep at a fixed point to go to work. In a similar way, PN workers start sleep at a point set by the end of their fixed work hours but terminate their sleep so they may respond to the social demands associated with the end of the PD workday and perhaps the return of children to the home. PN workers can sleep less than one might expect if there were complete chronobiological adaptation because they choose to be up! Since they are sleeping at an earlier time of day, PA workers need not end their sleep as quickly since the social demands are not as great around the middle of the day. Thus, the PA workers are the group whose sleep length is the closest match to what one would expect if spontaneous sleep termination were to be the rule.

The Exogenous emphasis is also supported by other shiftworker sleep and behavioral data. The sleep of PN workers shows a polysomnographic structure which resembles that of persons undergoing partial sleep deprivation, with no suggestion of an insomnia-like sleep (Walsh et al., 1981). When not compounded
by drug use, a poor sleep environment, or neurosis, experienced PN workers are perhaps more like efficient, rather than disturbed, sleepers. When tested on standard performance tasks, they do show significant decrements and these are present before and after sleep (TEPAS et al., 1981). This suggests a state of chronic sleep deprivation, rather than any sort of positive adaptation to night work. Unlike subjects living in an environment free to time (CZEISLER et al., 1980), the sleep length, sleepiness and mood of these shiftworkers cannot be directly predicted from body temperature measures (TEPAS and SULLIVAN, in press), a usual Endogenous chronobiology measure.

Perhaps a key question is: what happens to shiftworker sleep as exposure to night work increases? During the three months or longer period we study workers, sleep lengths from beginning to end are highly predictable (TEPAS et al., 1981). Figure 4 presents data from two additional analyses. For the first analysis, we have compared 50 PN workers with a matched sample of PD workers. Each of these groups was divided into subgroups of workers with more than, or less than, one year of continuous experience on the specific shift. In keeping with the literature, differences between PD and PN worker sleep length were significant. Differences within each of these groups, with regard to reported sleep length were not significant when the workers were divided into these relative experienced and inexperienced groups. Thus, this cross-section analysis reveals no significant changes in sleep length with shiftwork experience.

For the second analysis shown in Fig. 4, a longitudinal analysis of an inde-

<table>
<thead>
<tr>
<th>WORKDAY SLEEP LENGTH IN MINUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CROSS-SECTION (N=100)</td>
</tr>
<tr>
<td>PERMANENT DAY SHIFT</td>
</tr>
<tr>
<td>LESS THAN ONE YEAR</td>
</tr>
<tr>
<td>MORE THAN ONE YEAR</td>
</tr>
<tr>
<td>PERMANENT NIGHT</td>
</tr>
<tr>
<td>LESS THAN ONE YEAR</td>
</tr>
<tr>
<td>MORE THAN ONE YEAR</td>
</tr>
<tr>
<td>LONGITUDINAL (N=43)</td>
</tr>
<tr>
<td>ROTATING SHIFT</td>
</tr>
<tr>
<td>FIRST REPORT</td>
</tr>
<tr>
<td>AFTER 3 YEARS</td>
</tr>
</tbody>
</table>

Fig. 4. Workday sleep length in minutes: cross-section and longitudinal analysis of the effects of experience.
ADAPTATION TO SHIFTWORK

A dependent sample of experienced RS workers was made. Average three-shift sleep length estimates were collected by mail (ARMSTRONG et al., 1980) and we have just completed a three-years-later second collection of data from this sample. This analysis includes data from 43 workers who provided us with comparable sleep length data on both occasions. This is a fairly captive work group from which we had a fairly high response rate. Again, the differences in sleep length are not statistically significant. Thus, this longitudinal study also fails to reveal any significant changes in sleep length with, in this case, continued shiftwork experience.

A MODEL FOR SHIFTWORKER SLEEP PROBLEMS

Shiftworker sleep studies indicate that night work is associated with a decrease in sleep length. Current data imply that this decrease is immediate and the first instance in the evolution of a significant shiftwork problem. The immediate character of this change, and the long-term stability of the resulting sleep lengths, suggests that Endogenous social and work variables are the major sources of this impact, although chronobiological factors do play a role. Given an Endogenous bias, a model for the evolution of this shiftwork problem can be easily generated from the sleep literature. Such a model is outlined and proposed in Fig. 5. The sequence for development of this problem is: Night work decreases sleep length and thereby produces an 'acute sleep loss.' Continued exposure to night work results in this acute sleep loss becoming a chronic condition. At some point of exposure, one can begin to consider it to be a case of 'chronic sleep deprivation.' It is assumed that chronic sleep deprivation is a condition similar to that obtained with total sleep deprivation. Given this assumption, workers suffering from chronic sleep deprivation should manifest polygraphically-definable 'microsleeps' and drowsiness which increases in duration and frequency if chronic sleep deprivation continues. Microsleeps are said to be associated with 'lapses,' periods during which responses are not made and as a result performance is impaired. Impairment of this sort should be most evident in tasks which are not self-paced, and the worker may not be aware of either the microsleeps, the lapses, or the impaired performance. Thus, self-assessments of performance and fatigue may be invalid.

Fig. 5. Shiftworker sleep problem evolution.
This model for the evolution of a shiftwork problem is mainly a paraphrase of earlier sleep deprivation thinking (Williams et al., 1959) and it is certainly an approach which is open to criticism in that it is limited, maybe a bit inadequate, and perhaps too dated (Johnson, 1982). At the very least, one additional developmental step should be added to this model. This does not flow directly from human sleep deprivation research results, but may be a reality for the real-world problem of shiftwork. Thus, I further suggest that a long-term chronic sleep deprivation results in a condition of biological deficiency which in the long run may lead to serious medical disorders, as well as performance problems. It would seem to follow that these medical disorders may be quite diverse in form, since they evolve several steps after the initial problem of acute sleep loss and probably after the appearance of performance decrements.

It is important to note that, in presenting this chronic sleep deprivation model, no evidence was presented which might suggest that adaptive changes will occur normally as exposure to night work continues. As with toxic substances, intervention strategies are called for which might minimize the amount of sleep deprivation or limit night work to those with appropriate sleep characteristics. The Exogenous emphasis is not a denial of the interaction of circadian and/or other variables, but rather a heuristic approach of practical significance.

AN ENDOGENOUS ENVOI

The miniature model of shiftwork sleep effect presented is in no sense a comprehensive understanding of the shiftwork situation. It is a concrete and easy to understand approach which does suggest a number of problems for further study, and at the same time takes advantage of existing concepts and findings in other areas of research. Shiftworkers are recognized as established members of a structured society. The model starts with questions as to how these people, in practice, respond to night work, and then asks what the consequences are. Rather than assume or devise a norm, this approach: determines what the norm is, if there is a significant problem, and how significant problems might be solved.

Instead of attempting to expand this model into a more comprehensive one, this model is proposed as an example for the development of other miniature models for shiftwork problem areas. A number of targets for new miniature model building using an Exogenous emphasis can be identified. For example, let us consider food intake. There is reason to suggest that shiftworkers have eating habits which differ from those of the day worker, and to consider the possibility that these habits may lead to gastrointestinal disorders (Rutenfranz et al., 1981). An Endogenous emphasis suggests diet changes which might promote improved shiftworker chronohygiene (Ehret, 1981). An Exogenous emphasis as an alternative approach might examine when and what shiftworkers eat, consider or determine if there are any problems which evolve from this, and then look for
practical interventions which might minimize any problems identified.

Drug use provides a similar example. NICOLSON and STONE (1981) have conducted a number of studies aimed at finding out how aircrews operating on world-wide flights might benefit from hypnotic drug use. With an Exogenous emphasis, one might make a detailed study of when and what drugs are used by shiftworkers. Study of specific drug users within the shiftworker population would then determine the nature of the problems which evolve from this, and then look for practical interventions. Worker housing conditions, job transportation services, health care facilities, and many other shiftworker potential problem areas may also be appropriate for study using this miniature model analysis which recognizes the potential role of both Endogenous and Exogenous variables.

Many of the variables noted above have been studied, but there are few cases in which these variables have been followed through from the detailed observation stage to recommended interventions. Needless to say, documented systematic interventions in general are rare, complex and difficult (THIERRY and JANSSEN, 1981). Protocols for projects of this sort are demanding and time consuming. In most cases some longitudinal prospective study is called for if the validity of potential interventions is to be anticipated with a satisfactory degree of accuracy. Accurate forecasting of effects is desired given economic demands for workplace productivity.

Shiftwork research to date has done an excellent job in that it has provided considerable scientific support for the fact that night work changes the life of workers. Unfortunately, it has not done a very good job identifying the direction of these changes. Either our proof has not been convincing, or we have ignored these questions. Which ones are signs of adaptation? Can a non-adaptive change be good? Does complete adaptation ever occur, or is it a fallacy? What is the relative power for change of different variables? Answers to questions such as these, directed towards specific variables, are required if shiftwork research is to have any practical value. Convincing answers are required if shiftwork research is to continue to progress as a science.

REFERENCES


