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A USER ORIENTED REVIEW OF THE LITERATURE ON THE EFFECTS OF SLEEP LOSS, WORK-REST SCHEDULES, AND RECOVERY ON PERFORMANCE

Donald P. Woodward, et al

Office of Naval Research
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A User Oriented Review of the Literature on the Effects of Sleep Loss, Work-Rest Schedules, and Recovery on Performance

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This review provides a brief systematically organized account of the information from the scientific literature on the effects of sleep loss and work-rest schedules on performance. The orientation is practical, but consistent with the available data. A brief narrative description and a series of summary statements about the effects of sleep loss and work-rest schedules on human performance as they apply to operational settings is presented. Recovery from sleep loss effects as well as costs related to sleep loss effects are discussed briefly. Suggestions for future research are presented.

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EXECUTIVE SUMMARY

The intent of this review is to provide a brief systematically organized account of the information from the scientific literature on the effects of sleep loss and work rest schedules on performance. The orientation is practical, but consistent with the available data. It is hoped that readers might be able to use the information for planning purposes. Those readers desiring a more scientifically oriented review are referred to the recent NATO/AGARD AGARDOGRAPH No. 193, "The Operational Consequences of Sleep Deprivation and Sleep Deficit" by L. C. Johnson and P. Naitoh.

There are six broad questions implicitly addressed in the review. All of them have to do with minimizing the risks of sleep loss. These questions are:

1. In what types of jobs or tasks is performance impairment most likely to occur from sleep loss? For a summary answer see Table 1

TABLE 1

Tasks Most Vulnerable to Sleep-Loss Effects

- Uninteresting and monotonous tasks
- Tasks that are new or require learning on the job
- Work-paced tasks (as opposed to self-paced tasks)
- High-workload tasks that require time-sharing with other primary and secondary tasks
- Tasks that require continuous attention and steady performance
- Tasks in which the worker has little feedback on his performance

2. Under what types of work or duty schedules is performance impairment most likely to occur? For a summary answer see Table 2

TABLE 2

Work Schedules Most Vulnerable to Performance Impairment

- Continuous, uninterrupted time on task for several hours duration
- Work period between 0200-0600 hours (unless worker is specially prepared)
- Night-shift work with worker having had less than three to five days on the night shift
- Day and night shifts rotated on consecutive days
- Work periods of around the clock with 2-hour rest intervals
- First postsleep work period immediately following continuous duty

3. How much sleep can men go without before performance is impaired? For a summary answer see Table 3

TABLE 3

Amount of Sleep Loss Required to Impair Performance

- 24 hours on routine and monotonous tasks or new skills
- 36-48 hours on most tasks involving cognitive and perceptual skills
- 50 per cent/24 hours cumulative reduction of normal sleep time over one week
- 4-6 hours if working 0200-0600 watch after day of continuous work
- 24 hours if sleep loss is imposed on one week of "4 on - 2 off" work-rest schedule
- 24 hours if sleep loss is imposed on two weeks of "4 on - 4 off" work-rest schedule

4. How can the signs of sleep loss effects on performance be recognized? For a summary answer see Table 4

TABLE 4

Types of Performance Impairment Most Likely from Sleep Loss

- Slower reaction time, increased time to perform known tasks
- Short-term memory decrement, impairment in speed of learning
- Impairment in reasoning and complex decision chain
- Errors of omission, lapses of attention
- Increased feelings of fatigue, irritability, depression
- Erratic performance or increased variability in proficiency

5. How can the risks of incurring impaired performance due to sleep loss be minimized? For a summary answer see Table 5

TABLE 5

Procedures for Reducing Performance Impairment Risks in Continuous Operations

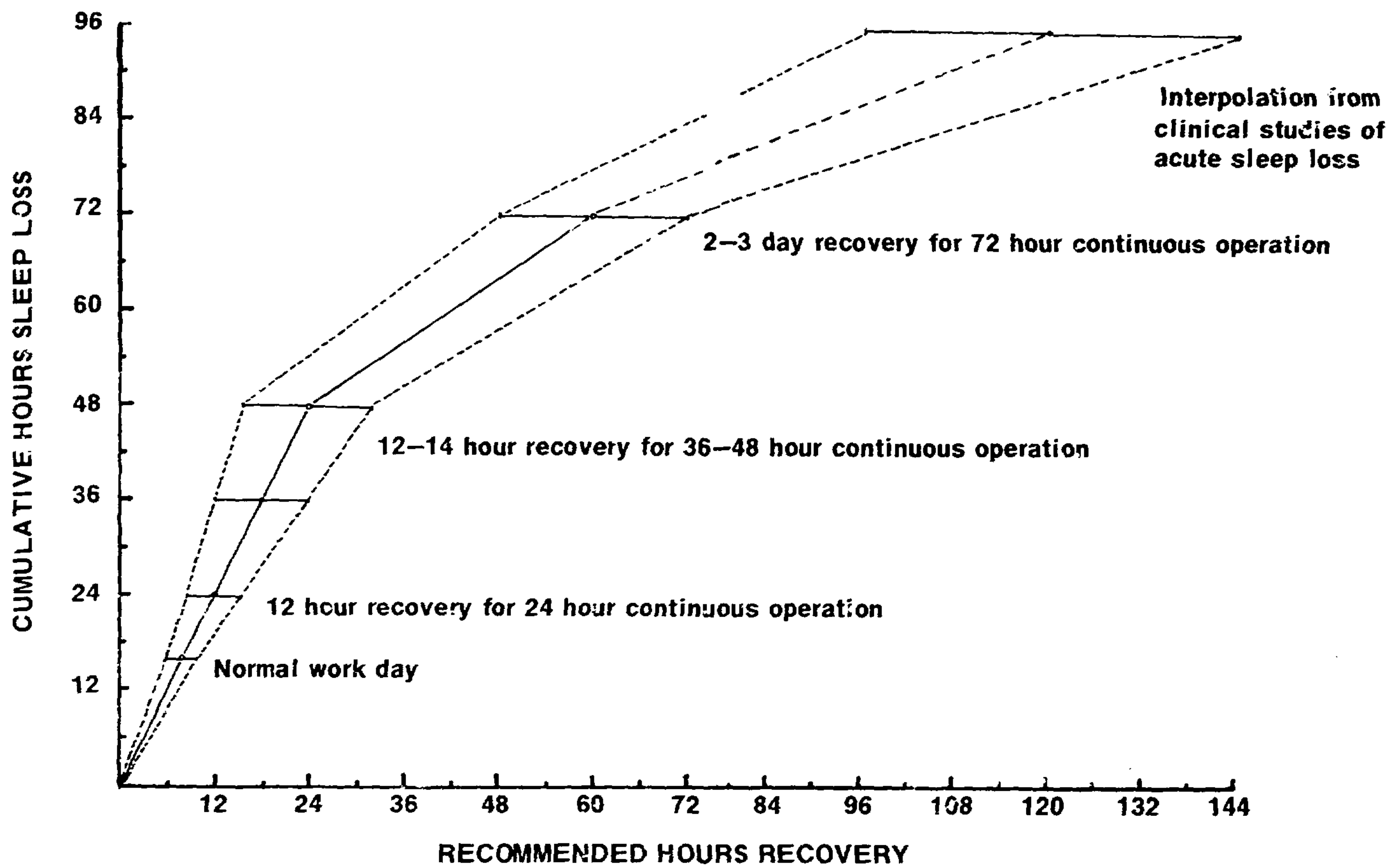
- Periodic breaks in task and mild physical exercise or recreation
- 6-8 hours continuous off duty time per 24 hour period
- Task rotation among cross-trained crew on relatively routine jobs
- Task rotation among crew on complex tasks only when members are highly trained to shift functions
- Selection of personnel who prefer and are able to adapt to different work schedules
- Training on complex tasks to degree of "over learning"
- System design to compensate for types of errors most likely to occur

6. How much time should be allowed for recovery from the effects of sleep loss? For a summary answer see Table 6, Figure 1

TABLE 6

Unusual Work Schedules: Time Required for Recovery and Adjustment

- 12 hours sleep/rest before prolonged work period
- 12 hours sleep/rest after 36-48 hours acute sleep loss (subjective fatigue may linger for three days)
- 24 hours sleep/rest after 36-48 hours sleep loss with high work load (12-16 hours per day)
- Two to three days time off after 72 hours or more acute sleep loss
- Three to five days to initiate biological adaptation and return to normal day/night cycle from night shift work
- Three to four weeks for full adaptation of biological rhythms to atypical work-rest schedules (as in night shift work)



Summary: As cumulative hours sleep loss increases, so does ratio of hours recovery/hours sleep loss (and its variability as a function of individual/situational differences)

Fig. 1

INTRODUCTION

In attempting to generalize about the effects of sleep loss or various work-rest schedules on man's performance, we are faced with a prime example of the complexity of human behavior. In almost any given instance, we must also account for man's motivation, his skills and knowledge relative to a job, his state of health and fitness, the nature of the tasks required by his job, and the social and physical elements of the environment in which the job is performed. Since our knowledge about the interactive effects of such variables on human performance is quite incomplete, it is extremely difficult to state lawful relations among sleep loss, work-rest schedules, and performance variables.

The synthesis of what knowledge we do have about the effects of sleep loss and work-rest schedules on performance is made even more complex because we have neither a standard taxonomy by which to classify tasks, jobs, systems or environments, nor a standard system for quantifying the human performance parameters related to them. The equivalence of knowledge gained from laboratory and field studies, from micro- to macro-criteria, is not at all firmly established. It does seem possible, however, to make qualitative assessments of certain relations on the basis of the knowledge available to us at present. Such assessments are admittedly more hypothetical than firmly established, but they may be useful and valid as guidelines for those in managerial positions who are responsible for planning operations and choosing among alternative courses of action.

In that spirit, we have formulated a brief narrative description and a series of summary statements about the effects of sleep loss and work-rest schedules on human performance as they apply to operational settings. The statements were derived, some directly and others inferentially, from publications dealing with the relations of sleep loss and work-rest schedules, to human performance. The specific references from which the statements were derived are cited in the summary statements. Additional source material may be found in the references listed in the bibliography.

The order of presentation of the material in this report is a reflection of our perception of the importance of the topics discussed. Thus the impact of sleep loss is viewed as primary, with work-rest schedules an important interacting factor but probably with less effect than complete sleep deprivation. Recovery from sleep loss effects must be considered if sleep loss is experienced, but one would be better advised to avoid sleep loss. The proverbial ounce of prevention may indeed be worth a pound of cure--if one reckons in the cost of degraded performance, missed opportunities, and increasing recovery time. The brief treatment of costs related to sleep loss effects is less a reflection of importance than it is of a relative paucity of data to report.

The Effects of Sleep Loss

The effect of sleep loss on performance varies widely from essentially no effect to an almost complete breakdown in performance. Effects are, of course, a function of many factors, including the individual experiencing the sleep loss, the time (phase) in the circadian cycle, the activity prior to and during the sleep loss period, the performance reserves remaining available to the individual, and the nature of the work being performed.

Task Interest and Complexity

Within broad limits, the crucial variable in predicting the extent to which sleep loss will affect performance is the factor of interest. The impact of sleep loss is more pronounced when the tasks involved cease to evoke interest. A word of caution is appropriate to avoid the danger of circular reasoning which would result if "interest" is identified as evidenced in no performance decrement, and "lack of interest" in measured performance decrements.

Ideally, some independent measure of interest should be obtained, but the nature of this measure is by no means readily apparent. The simplest procedure might be to ask participants to rate interest or, as an alternative, to have judges rate the willingness of the participants to perform with minimum incentive. Possible interest-generating techniques may be available in field investigations.

In general, performance on monotonous tasks involving relatively simple skills deteriorates markedly as a result of acute sleep loss greater than 24-hours duration. This tends to be less true as the tasks become highly automatic. Monotonous tasks requiring, for example, detection of faint or low level signals over several hours frequently show performance decrements greater than 50 per cent of initial capability. Increasing task complexity to the extent that it may serve to increase interest without raising difficulty to too high a level may often result in less severe sleep-loss effects.

Simply increasing task complexity, however, (such as by promoting stimulus and/or response uncertainty) without a concurrent increase in interest will result in greater performance decrement after sleep loss. At the same time, interesting tasks such as games or challenging tasks in which the participant knows how well he is doing and which involve common perceptual-motor skills, appear resistant to the effects of sleep loss for periods of as much as 60 hours.

Difficult tasks, those defined as involving high work load, will be more sensitive than easy tasks to the effects of sleep loss. One must be aware of interaction effects here, since a difficult but interesting task probably will be less affected than an easy but monotonous task.

Type of Task

The type of task in which the individual is engaged is a significant factor in judging sleep-loss effect. Conditions, such as extended periods of time spent on the task without rest or change of pace, are another significant factor. Tasks that tend to be repetitive, less immediately rewarding, and less interesting, are also most likely to show performance decrement as time on task increases and rest periods or breaks in routine are decreased or not permitted at all.

It is not advisable to ask individuals to learn new things, e.g., facts of a discrete nature, until they have fully recovered from sleep loss of 24 hours or more. Experimental data clearly show impairment in acquisition and immediate recall of newly learned material. At the same time, a 24-hour sleep loss appears to have little effect on the recall of material which was learned previously. The fact that skills which have achieved the status of being almost automatic or "second nature" suffer less from the effects of sleep loss than do newly learned skills suggests, of course, that the individual be very well trained in the execution of whatever tasks he will be expected to perform if the sleep-loss effects are to be minimized.

In contrast with its effect on the learning of discrete factual material, the major effect of sleep loss on the learning of new concepts is essentially one of increasing the amount of time involved. It takes longer to learn new concepts after 24 hours or more of sleep deprivation. This may be a result of perceptual lapses, memory disturbances, low motivation, or a combination of these elements.

The data on how sleep loss affects the quality of concept attainment appear to be equivocal. If the concept is relatively simple, there seems to be no significant impairment. However, if learning involves a long chain of reasoning and memory of complex decision chains, thus allowing for many points of possible confusion, it appears likely that the quality of concept attainment, as well as speed of learning, would be affected adversely.

In one study, after four days and nights without sleep, subjects were unable to read completely a sentence of more than 30 words; they would lapse before finishing it. A consistent finding in studies involving sleep loss is the occurrence in perceptual performance of brief intermittent lapses that increase in both frequency and duration as sleep loss progresses. A lapse is defined as a pause that is more than twice as long as the average or typical time taken to respond.

The specific effect of lapses on performance varies with the properties of the task and with the task environment. In subject-paced tasks (i.e., those in which the worker sets the pace of responding) speed of response seems to be critical: the subject tends to slow down while maintaining high accuracy. In experimenter or work-paced tasks, errors appear to be the critical measure. In such situations, errors tend to be of omission or missed signals.

The bulk of operationally meaningful tasks are experimenter or work-paced in nature (the work situation sets the frequency and timing of desired responses). If errors are of paramount concern, consideration should be given to ways of making work-paced tasks more like subject-paced tasks. In subject-paced tasks, the aspect of performance that is impaired will depend (a) on the way in which the task is structured, (b) on the places where the task permits relaxation of performance, and (c) on the opportunities and incentives to recover from or compensate for the occurrences of lapses.

Work-paced tasks with high work loads (e.g., situations in which frequent or rapid responses per unit time are required) are more negatively influenced by sleep loss than are those with low work loads. This is another way of saying that as the time available for response increases in work-paced tasks, the tasks become less sensitive to detrimental sleep loss effects.

Chronic sleep loss leads to performance impairment and to mood change if the loss is sufficiently great and the total time period sufficiently prolonged. Thus, reduction by 50 per cent of one's normal number of hours sleep per 24-hour period will result in significant performance impairment if the reduction is maintained for a week or more. Again, individual differences are great and the performance decrement varies with the type of task. Furthermore, the decrement may occur at different times during the work session; vigilance tasks, for example, appear to be impaired more early in the watch period when performance normally is best, and less later in the watch when performance is already typically poorer. Computational tasks involving rather simple addition are slower by about 30 per cent (as measured by problems completed per unit time), although accuracy appears to remain relatively unaffected.

Where impairment of vigilance performance is concerned, the major effect of sleep loss is an increase in missed signals (or errors of omission). As sleep loss continues, errors appear progressively earlier in the task and the benefits of breaks become increasingly short-lived. Extensive data from laboratory and simulated work sessions have recently been further supported by data involving real highway driving tasks; after sleep loss, the same sorts of effects are found in that more road signs are missed, normally detected and avoided obstacles (such as tires in the roadway) are struck more often, and weaving (or inadvertent lane changing) increases.

Sleep loss has a differential effect on various aspects of the communication tasks that have come to play an increasingly important role in most systems. In <u>giving</u> instructions, the time required for sending information increases with sleep loss; the number of errors made also increases significantly, although these errors typically are corrected.

On the other hand, in receiving instructions, errors of omission increase significantly with sleep loss.

This suggests that to have well-rested receivers is more important than to have well-rested senders (if you cannot have both). To paraphrase an ancient admonition: "It is easier to send than to receive."

Obviously, not all work situations will involve only tasks that are relatively sedentary; many will involve forms of physical activity. As might be expected, sleep loss has a differential effect in this regard. Tasks that require relatively high levels of varied physical activities (as in field maneuvers) are generally less likely to show performance decrements during continuous work periods of 36 to 48 hours (with no sleep) than are tasks that primarily require mental activity.

During one field experiment carried out over 44 hours of sustained operations, essentially no performance degradation was reported for infantry-type operations such as rifle firing, grenade throwing, use of the starlight scope, foot patrols, and truck riding. Similarly, in another study using real tanks and tank crews in a simulated field situation, no large performance decrements were observed as a result of a 48-hour sleep loss. In general, communication and gunnery showed no negative effects, while surveillance and driving possibly did show some.

The results of these two studies should be considered with caution for practical as well as theoretical reasons. Practically, the studies suggest that given good or perhaps outstanding leadership, highly motivated subjects, and good morale, it is possible to get good performance (that is, little performance decrement) after a 44- to 48-hour sleep loss. In essence, we are telling the field commander what is possible, but we are not telling him what he will get under ordinary conditions! We should also note that during the infantry study, there were opportunities for brief naps and although it was not reported whether the subjects took advantage of the opportunities, it is highly unlikely that none of them did.

Of equal significance in interpreting the results is the fact that the performance measurement periods were not continuous but rather occurred at intervals. Thus, the participants could be considered to have had "breaks" during which they could "let down". This might well have permitted them time to prepare for the next measurement period, or to "key up" for the measurement session itself.

Task Duration

Individuals involved in research on sleep-loss effects are frequently asked how long it is possible to continue working before performance decrement sets in. As with most questions of this sort, there is probably no single answer that will apply to everyone under all conditions and work situations. There is, however, an adequate body of data which indicates that during periods of 36 to 48 hours of continuous work, with no sleep, and a work period beginning between 0800 and 1200, major performance decrements first appear after approximately 18 hours. This coincides with the low segment of the typical circadian cycle which occurs at about 0200-0600 hours.

It is important to note the specificity of the starting time and the condition of continuous work. We should remember that measures of sleep-loss duration are based on reports of the hours of prior wakefulness and 16 or 18 hours of wakefulness are daily experiences for many of us. Continuous work, however, is probably less frequently encountered. Different starting times will result in different times of decrement appearance, most likely determined in part by the phasing of the circadian rhythm.

Experimental data from studies involving periods of 36 to 38 hours of continuous work with no sleep do suggest that performance is particularly sensitive to the fluctuation of circadian rhythm. Whether or not this relation is causal (i.e., the decrement's being caused by bodily changes) is not immediately apparent.

Performance during continuous work generally appears to show increasing impairment as the number of hours spent awake increases, but the impairment is subject to a superimposed variation from the influence of circadian rhythms. Again, individual differences are great, as is the influence of the type of task. Individual curves will quite often show rather sharp performance decrements at various points, following sleep loss of 24 hours or more. However, these points are not consistent. A useful guideline may well be to expect fairly steady performance decrement as the number of hours awake increases, with worst performance most frequently found between 0200-0600 hours.

In a simulated work situation involving a number of different tasks, it was found that average performance decrements as great as 40 per cent below baseline levels can be expected toward the end of a 48-hour period of continuous work with no sleep, breaks, or catnaps. Typically, the poorest performance can be expected during the early morning hours (0200-0600); the performance will be especially poor if the end of a 48-hour sleep loss period occurs during these early morning hours. It should be noted that the decrement is referenced to baseline performance, which itself may not represent the best possible performance. Thus, in terms of absolute performance change (e.g., total number of targets not detected, rather than the number below average), the decrement could be much greater. However, baseline comparisons are valid since they do refer to periods of stable performance, and, in that sense, may be more realistic than absolute values.

As noted above, there are wide individual differences in terms of the performance impairment effects of sleep loss. Investigators have attempted to relate these differences to standardized measures of personality or intelligence. Regretfully, no reliable correlations have been found to date. There is some indication, however, that sleep loss does have a negative effect on an individual's mood or disposition, as evidenced by subjective reports of increased hostility, irritability and depression. However, the data are suggestive rather than conclusive, and it appears that such changes may be as much a function of the individual's attitude toward the situation and the procedures employed as of sleep loss, per se.

A critical factor affecting performance after periods of sleep loss is the uninterrupted length of time that the same task stimuli occur and the same response is required. In a sense, this observation is consistent with the above observations regarding task duration and inherent interest, in that tasks involving the same stimuli and responses are more likely to be repetitive and boring.

The performance impairment associated with sleep loss are accentuated as a function of time on task during the continuous operation of a single task. There is an interaction between task duration and sleep loss in that the effects of acute sleep loss are generally greater for longer duration tasks. Experimental data indicate that following one night of sleep loss, performance will tend to "bottom out" after about 30 minutes time on task, and will show relatively little additional impairment during the next 30 minutes.

There are data which indicate that lapses similar to those resulting from sleep loss also occur under fatigue resulting from extended periods of time on a given task without rest or change of pace. This may be, in part, a function of the type of task and/or the variation or lack thereof in the task. However, both early laboratory work in the area of fatigue, and more recent data derived from studies of extended periods of highway driving, clearly indicate an increasing drop in performance, even though one is hard pressed to isolate a specific causal relation. To further complicate the situation, apparently similar lapses have been found under conditions of hypoxia (reduced oxygen supply) as well as under conditions of increased atmospheric pressure, as in deep sea diving. Again, the underlying dynamics are not clear but the practical effect is the same--performance impairment.

Breaks in a task appear to delay the occurrence of sleep loss induced performance lapses until the later stages of the work period. Such breaks apparently help to return performance to the initial level. Performance shortly after the break, however, again shows a decrement.

In general, lapses resulting from sleep loss are strongly affected by stimulus monotony in that the more monotonous tasks seem to be related to more frequent lapses. At present, it is not clear if this sort of lapse has the same underlying dynamic characteristics as those found with more varied stimulation.

As sleep loss increases, performance becomes more uneven, with periodic lapses in efficiency being more characteristic than a continuous depression of performance. This follows from the basic idea if a lapse were to occur at the time a signal was to be detected, the signal would be missed. Likewise, if the signal were presented during a non-lapse period, no performance decrement would be measured.

Because lapses increase in frequency and duration as a function of sleep loss, it is to be expected that performance will deteriorate over time. Performance may become less uneven as time progresses, but since people and tasks do vary so much, smooth curves of performance will probably be hypothetical for some time to come.

One of the more common measurements taken in field or laboratory experiments on sleep loss is reaction time (i.e., the time it takes a subject to respond to some designated stimulus). The popularity of this measure may result from the relative ease of measurement or its apparent relation to real-world tasks that demand rapid response. In any event, sleep loss persistently produces an increase in reaction time that is reflected in progressively greater unevenness of performance, and in an increase in the variability of the reaction-time distribution.

Increases in reaction time are strongly related to increasing hours of sleep loss: after 78 hours without sleep, average reaction time is twice as long as that noted on the day immediately prior to the start of the experiment. The word "average" is emphasized for a reason: when the best reaction time responses are examined, it seems clear that these increase only slightly over baseline, while the poorest performance become consistently worse. Therefore, when all the reaction times are evaluated, the average tends to increase or become longer.

Many work situations will involve more than one task. When this happens, one of the tasks is usually considered primary either by the investigator or by the subject. If the work is such that it is at or near the performance load capability of the operator, then performance on additional, or secondary, tasks will be especially susceptible to the deleterious effects of fatigue and sleep loss. The operator will attempt to maintain his level of performance on the primary task at the expense of poorer performance on secondary tasks. There are data, however, which suggest that when all tasks are weighted equally in importance, then performance decrements on all tasks will be about the same.

When performance decrement occurs, attempts are frequently made to explain the result in terms of some one cause. In considering experiments involving sleep loss, it is important to recognize that the loss occurs within a larger context that generally involves some sort of alteration between work and nonwork, that is, a work-rest cycle. Most normal adults are awake more than they are asleep, but not all of the awake time is spent working.

Ideally, an investigator would like to be able to state unequivocally that particular effects are due to loss of sleep or to a certain work-rest regime. Practically, however, it may be impossible to achieve such a formula. There are data which suggest that acute sleep loss (i.e., a loss of 24 hours or more) has a more deleterious effect on performance than an equivalent sleep loss spread over time such as one might encounter in a typical experiment on work-rest cycles. Another way of saying this is that the effects of acute sleep loss on performance will be noted sooner and may be more severe than chronic sleep loss of an equivalent number of hours.

Work-Rest Schedules and Performance

As previously noted, one of the factors that influences the effects of sleep loss on performance is the work-rest schedule followed before and after a period of acute sleep loss. The literature on work-rest scheduling is extensive in its own right, and will not be reviewed here. A few selected comments are appropriate. Work-rest schedules are presented, typically, in the format "4 on - 4 off," "2 on - 6 off," etc. This should be read in the first instance as "four hours on duty followed by four hours off duty" and in the second instance as "two hours on duty followed by six hours off duty." The majority of workers, military or civilian, probably work an "8 on - 16 off" schedule or some reasonable approximation thereof.

It is important to remember that specification of hours on/hours off says nothing about what the individual is doing during those periods. A task description will often be provided for the on-duty period, but little (if any) descriptive information for the off-duty period will be given. Only recently has the relevance of off-duty activity for on-duty performance been frankly recognized and incorporated into experimental investigations. Recognition of the varied range of activities engaged in during off-duty hours is critical, and so is appreciation of the subsequent impact on "work activity" during the following on-duty time. Clearly, it makes a difference if the rest or off-duty period is devoted to sleeping, watching television, reading, driving a motor vehicle, grocery shopping, lawn cutting, engaging in athletic activity, or what have you.

The possible similarity of off-duty and on-duty activity should also be noted. It should be equally clear that the nature of the work activity during an on-duty period is an important variable and should be considered in establishing a work-rest schedule. Further consideration would include the extent to which the work allows for breaks, i.e., brief nonwork periods, and whether the tasks to be performed are self-paced, or if the operator must perform in accordance with the demands of the task. The reader is asked to keep these caveats in mind as we consider some statements derived from the experimental literature.

Comparisons of Different Work-Rest Schedules

For periods of up to five days, work-rest schedules of "2 on - 2 off," "4 on - 2 off," "4 on - 4 off," "6 on - 2 off," "6 on - 6 off," "8 on - 4 off," and "8 on - 8 off," can be maintained equally well in terms of performance decrement.

Work-rest schedules of "4 on - 4 off" and "16 on - 8 off" can be maintained equally well in terms of performance effectiveness for a period of up to two weeks so long as no period of acute sleep loss is experienced, and none of the typical "housekeeping" extracurricular tasks have to be performed.

For periods greater than two weeks and up to 30 days, a "4 on - 4 off" schedule is superior to a "4 on - 2 off" schedule in terms of performance effectiveness. Under normal conditions, performance differences may not be great. Under stressful conditions, however, "4 on - 2 off" and "6 on - 2 off" schedules tend to result in poorer performance than do those which allow for longer off-duty periods. There are also data which suggest that for work periods over two weeks long, the "4 on - 2 off" schedule results in lengthening of the 24-hour circadian rhythm and a corresponding change, with about a 2-hour lag, in performance effectiveness.

When a period of acute sleep loss greater than 24 hours is experienced under continuous work-rest schedules of "4 on - 2 off" or 16 on - 8 off," the "4 on - 2 off" worker is most vulnerable, in terms of maintaining baseline performance, and slowest to recover, while the "16 on - 8 off" worker is least vulnerable and quickest to recover. In the study from which these data are derived, subjects were confined for a period of 12 days. They began with seven days on the assigned work-rest schedule which was immediately followed by 68 to 72 hours sleep deprivation, and finished with two days working on the assigned work-rest schedule.

The tasks performed during the study included vigilance, short-term memory, arithmetic problems, multidimensional compensatory tracking, and a continuous tracking task. Off duty activity was not specified. In this particular study, no difference in performance was noted as a function of the work-rest schedule as long as the schedules were the only experimental manipulation (i.e., the subjects were not sleep-deprived). The fact that the subjects on the 16/8 schedule recovered fastest is probably the result of their having eight uninterrupted hours for sleep.

Adaptation to Atypical Schedules

Adaptation in biological rhythms to atypical work-rest schedules generally requires a three- to four-week time period. Adaptation may be enhanced, however, if the individual can synchronize his sleep with the sleep phase of the atypical schedule as quickly as possible. It is obviously easier for a person to work when he is tired than it is for him to sleep when he is alert and rested; therefore, adaptation will be enhanced if he can start on the new sleep cycle as soon as possible. Probably the best way to maximize the likelihood of this happening is to have the person stay awake sufficiently long to ensure his being in a low-alertness condition when the sleep period of his new schedule comes around. This relatively simple solution to problems of adaptation to new schedules seems to work fairly well, especially in the case of transmeridian shifts such as are experienced in eastbound flights.

A period of three to five days typically is required for biological adaptation to night shift work to begin. The process of adaptation is reflected in a flattening of the normal circadian body-temperature rhythm. A complete phase shift, which would indicate rather complete biological adaptation, takes three to four weeks, on the average. There are data which suggests that readaptation to a "normal" day-night cycle, after having phase-shifted, can occur in three to five days. It would be advisable, in order to take advantage of whatever favorable aspects of biological adaptation there are, to maintain a stable work shift for as long as necessary and not to interrupt it with frequent changes.

Stable day-night shift workers generally perform more effectively than workers who rotate day and night shifts as they would if working a continuous "4 on - 4 off" schedule. There are, of course, individual, cyclical, situational and life-style variables that might equate the conditions, if the variables could be manipulated. We know, for example, that the ability to adapt to night shift work is partly a function of surrounding environmental variables such as the light-dark cycle and the activities of other people.

There is also some evidence which suggests that permanent night shift workers tend to be somewhat different in the cyclic secretion of hormones associated with performance effectiveness. Simply knowing that people differ in their preference for day or night shifts and in their ability to adapt to changes in shift work is important. Even more important is acting on this information by identifying individuals with known preferences, observing performance effectiveness under varied conditions, and using the data gained in making work assignments. For the average worker, night-shift work performance is generally poorer than day-shift work performance; the worst performance occurs between 0200 and 0600 hours. The stabilized night-shift worker, however, performs at night as well as the day-shift worker does during the day; indeed, night-shift workers may perform better if they represent a self-selected group.

Recovery From Sleep-Loss Effects

If we accept the fact that sleep loss - especially of an acute and prolonged nature - will have an effect on performance effectiveness, then it behooves us to consider ways in which performance degradation may be prevented or lessened. It is also of some importance to be aware of possible requirements for recovery from the effects of sleep loss. That is to say, given that sleep loss occurs, how long does it take to get over the effects and what conditions enhance recovery. The problem of recovery from sleep loss has not been explored nearly as extensively as have questions relating to sleep-loss effects or work-rest schedules. Correspondingly, the suggestions which follow will tend to have a smaller empirical (experimental) base.

Avoiding Performance Degradation

Clearly, the most direct way to avoid the performance degradation that results from sleep loss is to provide adequate sleep. One way of implementing this obvious fact is to arrange appropriate work-rest schedules which provide sufficient off-duty time in large enough blocks to permit adequate sleep. Frequently, in scheduling certain operations, it is possible to anticipate that a prolonged-work or sleep-loss period will occur. If this is the case, then it is recommended that the 12-hour period preceding such a prolonged-work or sleep-loss period be kept free of duties. Ideally, this time should be spent in sleep to build up performance reserves and thereby minimize the performance decrements during the later sleep-loss period. Operational requirements may preclude executing this recommendation, but it should be followed to the extent it is possible to do so.

If a period of acute sleep loss is experienced, the question naturally arises as to what should be done to return the personnel to what is essentially a presleep-loss condition. An estimate must be made on how much sleep is necessary to provide recovery from the effects of sleep loss. Once again, factors such as individual differences, circadian rhythm and duration of sleep loss, must be taken into consideration.

A few generalizations, derived from laboratory and synthetic-task investigations, appear to be valid. Less than six hours of sleep is usually inadequate for performance recovery following a period of 36 to 48 hours of continuous work with no sleep. In fact, for a large number of subjects in one study, eight hours of sleep was not adequate for performance recovery.

The recovery of performance from acute sleep loss of up to 48 hours is generally complete after 12 hours of rest, although subjective fatigue is reported until after the third full night of sleep. Sleep loss of more than 48 hours (i.e., on the order of 72 or 96 hours of sleep loss) probably will require more than one full night of sleep before performance recovery is complete, and most certainly will require more than one night for the circadian rhythm to return to "normal."

If a period of 36 to 48 hours of continuous work is imposed on a normal load of eight hours per day, e.g., a 4/4/4/12 or 8/16 work-rest schedule, 12 hours of rest appears sufficient for recovery to within five per cent of baseline performance. However, if the same load is imposed on a work load of 12 to 16 hours per day (as in a 4/4 or 4/2 work-rest schedule) it takes about 24 hours of rest for recovery to within five per cent of baseline performance.

On the basis of these data, it appears that performance recovery after acute sleep loss will not be achieved by most individuals unless they have at least eight hours of sleep. It is extremely important, therefore, that if men have endured a stressful period of sleep loss, then gone to sleep, they should not be awakened for duty until they have obtained adequate sleep unless one is prepared to accept very low performance efficiency in their work.

Data from laboratory studies indicate that the poorest performance is obtained during the first duty period following an inadequate sleep period for subjects who have been awake from 40 to 44 hours. The effectiveness of brief sleep periods (naps) in restoring performance after acute sleep loss has not been established. Naps reportedly are of value if they occur during what would otherwise be a work period. In this regard, it should be noted that the performance of individuals just after being awakened from a normal night of sleep typically will be below normal for at least 15 minutes. Some similar effect could reasonably be expected upon their being awakened from naps, but perhaps for a shorter period!

Methods for Overcoming Sleep Loss Effects

Research has demonstrated that a night's sleep is not uniform, but rather is composed of stages that can be categorized by the number and type of brain electrical activities recorded from the scalp. At one time, it was thought that certain stages of sleep, especially those classed as deep sleep, had greater recuperative effects than the less-deep stages. Recent data, however, suggest that it is the absolute amount of sleep, rather than the amount of time in any particular stage of sleep, that is critical for performance recovery.

Considerable publicity has recently been given to the possible use of meditative procedures and learned techniques for controlling physiological processes within the body as ways of overcoming the performance degradation resulting from various stressors, including acute sleep loss. The data from controlled investigations of the meditative techniques are, as yet, equivocal. Subjects report feeling better, more rested, etc., but the performance data do not reflect any beneficial effects.

Data from experiments in which individuals were trained to manipulate levels of electrical activity of the brain, or the electrical activity of selected muscle groups, indicate that such manipulation is possible to learn and, when learned, can be performed during a simulated-work task of a vigilance nature. The data show an effect on performance, but it will require considerably more research to demonstrate whether or not such procedures will be useful in combating the negative effects of sleep loss.

Rotation of tasks among cross-trained crewmembers is one technique that has been used to prevent fatigue and performance deterioration during work. The benefits to be derived from task rotation are influenced by the type of task involved, time on task, extent of sleep loss, and level of training of the various crewmembers. In general, performances on tasks that are relatively routine, boring, and not too demanding intellectually seem to benefit most from task rotation. This also seems to be true for work situations that normally involve extended periods of time on a task. In both instances, the benefits may be simply a result of a changed stimulus, and in that sense somewhat analogous to the effect of breaks on reducing the effect of lapses as discussed in the first section of this review. It is also possible that the benefits of task rotation in vigilance or monitoring situations are easier to demonstrate.

Rotation of tasks among cross-trained crewmembers during a given workshift is least beneficial, and may even be detrimental, if the tasks involved are of a complex cognitive nature involving decision making. This is not necessarily true when the crewmembers are well-practiced and expert at shifting functions, as would be the case with air traffic controllers, for example.

We should recognize that complex tasks are usually more interesting and/or stimulating, and are, therefore, more resistant to fatigue and sleep-loss effects. The benefits of task rotation would be more difficult to demonstrate for them than for vigilance tasks.

Performance effectiveness during continuous-work periods of 36 to 48 hours, with no sleep, may be facilitated by task rotation among cross-trained crewmembers, especially if such rotation results in a lower overall work load for the operator. There is, however, some questions as to how lasting the effect would be, as well as whether or not it would be effective with longer periods of sleep loss.

As a general rule, the use of stimulant drugs may obviate some of the drops in performance associated with sleep loss. D-amphetamine is probably the most powerful stimulant drug used to any extent. While there is little question that stimulants have an arousing effect and are generally beneficial in terms of improved performance, there are serious drawbacks to their use. For example, response to a stimulant is highly individual and dose dependent. Really effective use would require knowledge of the individual's reaction to a given dose under given conditions. Such information is rarely available in operational situations. Were the appropriate information available, however, stimulant drugs might well be an effective way to maintain alertness over periods of as long as 36 hours of continuous work without sleep. Mass administration of stimulants, or prolonged or frequently repeated usage, cannot be recommended, however, for we simply do not have sufficient information regarding such use.

It has often been observed during studies of sleep deprivation that a good way to revive a flagging subject is to take him for a walk or otherwise exercise him physically. The exercise should be of a relatively mild nature since rigorous or demanding physical activity is more likely to result in increasing the effects of sleep loss and possibly further depleting performance reserves.

Effect of Multiple Stressors

We might reasonably expect that adding another stressor to an already stressful situation would lead to greater performance degradation. Although all the data on combined stressor effects on performance are not unequivocal, there does seem to be sufficient data to indicate that the effects of multiple stressors are not simply additive. Laboratory studies have demonstrated that continuous or intermittent broad-band noise in the range of 95 to 110 dB tends to increase the error rate and variability in the rate at which work is completed on a variety of tasks. Acute sleep loss tends to have the same effect. However, combining the stressors will not necessarily result in a total number of errors equal to the sum of their individual effects.

There are some data which suggest that noise, as described above, may even counteract to some extent the effects on performance of up to 24 hours of sleep loss. It is doubtful that this would hold true for as much as 48 hours of sleep loss. This observation may not be pertinent if the operational situation is already rather noisy as when individuals are running various pieces of motorized equipment, rifle firing, and the like. In otherwise quiet situations, such as are found occasionally in monitoring tasks, it may have some validity.

Costs Related to Sleep-Loss Effects

An analysis in terms of monetary costs will not be attempted here, not because such an analysis would not be useful or valuable, but rather because it would require data that are just not available at the present time. Criteria to identify the sensitivity of a system are lacking; we do not know how many missed signals or false alarms, unfired weapons, etc. the system can tolerate.

As employed here, "cost" will be used in a more general and relative sense, and will not be referenced solely to monetary value. Because we are talking about people, there will be occasion to discuss costs in terms of individual performance and physiological costs to the individual. "Costs" in these terms will be referenced to the normal performance and physiological levels.

Sleep loss of 24 hours or more generally results in performance decrements ranging from 5 to nearly 100 per cent. The decrement typically becomes greater as sleep loss increases and as the time span of measurement becomes greater. Quite often, sleep-loss effects are not noted in an investigation because the period of measurement or test will occur at intervals rather than be continuous. Many, if not most, individuals can "get up" for a relatively brief test period. They probably do so by drawing upon some performance and/or physiological reserves. If the period of sleep loss is sufficiently long, however, and the measurement interval more continuous than episodic, the reserves will be depleted and decrements in performance will be observed.

In such instances, the physiological cost to the individual is likely to be great, perhaps on the order of a 150 per cent increase from normal levels, or more in some systems. Fortunately for the integrity of the individual, recovery (return to baseline normal levels) takes place quickly--shortly following the completion of adequate sleep. The recovery period is variable from person to person or situation to situation, but is not likely to exceed three to four days.

The observations above apply to single or one-time exposures, not to repeated exposures; for example, not to a three- to six-month period of alternation involving 48 hours of sustained operations without sleep, followed by 48 hours of rest and sleep. We do not know whether such repeated exposure would result in cumulative effects, and we know of no active research on this question at present.

In operational situations, neither sleep loss nor the fatigue associated with it will be the only stressors, and although the effects of combined stressors are not strictly additive, as was noted earlier, their joint occurrence does tend to make the situation worse--more stressful or difficult.

Some of the adverse effects of sleep loss could probably be avoided through identification and selection of personnel who are uniquely resistant to, or who operate or can be taught to operate on a reduced sleep regime. Likewise, extensive training probably would mitigate some of the adverse effects, since we know that well-learned, well-practiced tasks are more resistant to negative sleep-loss effects than newly learned tasks. The crossover point of the cost curves remains to be established.

Taking advantage of those planned or unplanned situations that involve varying periods of sleep loss is one possible way of estimating its cost. With adequate record keeping, we might begin to assess the costs of reduced sleep or sleep loss through indices based on cost-measurable behaviors such as acident rates, absenteeism, as well as on job performance, per se. The approach could be established in the model of the safety researchers and boards.

Summary Statements

The Effects of Sleep Loss

1. The effect of sleep loss on performance varies widely from essentially no effect to an almost complete breakdown in performance. (46)*

2. Within broad limits, the crucial variable in predicting whether sleep loss will have an effect on performance is the factor of interest. Interesting tasks involving relatively simple motor skills appear resistant to the effects of sleep loss for periods of as much as 60 hours. (45, 46)

3. Performance on routine, monotonous tasks tends to show rapid and severe decrements after periods of more than 24 hours without sleep. (50, 57)

4. Increasing task complexity or task difficulty, without a concurrent increase in interest, will result in greater performance decrement after sleep loss. (33, 46)

5. Newly learned skills, or skills that are not well practiced, are more affected by sleep loss than are skills that have become automatic or "second nature." (33)

6. Sleep loss of 24 hours or more impairs the acquisition and immediate recall of newly learned material (facts of discrete nature), but has little effect on recall of such material previously learned. (57)

7. After a sleep loss of 24 hours or more, it takes more time to learn relatively simple concepts. There is no significant impairment in quality of concept attainment. Both speed of learning and quality of concept attainment would probably be affected if a long chain of reasoning and memory of complex decision chains were involved. (57)

8. As sleep loss progresses, brief intermittent lapses in perceptual performance increase in both frequency and duration. (57)

9. Performance on self-paced tasks generally shows little loss in accuracy, but responses tend to be slower after sleep loss. (57)

10. High-workload situations are more affected by sleep loss than are low-workload situations; in general, as the time available for making responses increases, the task becomes less sensitive to sleep loss effects. (33)

*Numbers in parenthesis refer to bibliographic source

11. Chronic sleep loss will lead to performance impairment and mood change if the sleep loss is of sufficiently long duration and the total time period sufficiently prolonged (e.g., the chronic sleep loss represented by a reduction by 50 per cent in one's normal number of hours asleep per 24-hour period for seven consecutive days or more). (37)

12. Sleep loss consistently produces impairment of vigilance performance; the major effect is an increase in missed signals or errors of omission. (57)

13. Communications tasks are differentially affected by sleep loss. Typically, the time required for sending information increases with sleep loss, as does the number of errors, although the errors generally are corrected. In receiving information, however, errors of omission (of missing part of the message) increase significantly with sleep loss. (57)

14. Tasks that involve varied physical activities are usually more resistant to performance decrement during continuous work periods of 36 to 48 hours without sleep than are relatively sedentary tasks primarily requiring mental activity. (1, 10)

15. During a work period beginning between 0800-1200, major performance decrements first appear after approximately 18 hours of continuous work. (32)

16. Investigations of sleep loss effects have shown that the poorest performance frequently occurs between 0200-0600 hours, which corresponds to the low segment in the typical circadian rhythm. (7)

17. Typically, performance impairment during continuous work tends to increase as a function of the number of hours spent awake, but is subject to a superimposed variation from the influence of circadian rhythms. (46)

18. Average performance decrements as great as 40 per cent below baseline levels can be expected toward the end of a 48-hour period of continuous work with no sleep, breaks, or catnaps. (32)

19. The wide individual differences in performance induced by sleep loss are not related to standard measures of personality or intelligence. (46)

20. Sleep loss has a negative effect on an individual's mood or disposition, as evidenced by subjective reports of increased hostility, irritability, depression, fatigue, etc. (57)

21. A critical factor affecting performance after periods of sleep loss is the uninterrupted length of time that the same task stimuli occur and the same response is required. (46, 50, 57)

22. Breaks in a task appear to delay the occurrence of sleep-induced lapses until later stages of the work period. (57)

23. The performance effects of sleep loss are usually accentuated as time on task increases and rest periods or breaks in routine are not permitted. Almost any interruption of the task helps to return performance to the initial level, but performance tends to decline quickly if the task is immediately returned to after the break. (57)

24. Lapses resulting from sleep loss are strongly affected by stimulus monotony; the more monotonous tasks seem to be related to more frequent lapses. (57)

25. As sleep loss increases, performance becomes more uneven, with periodic lapses in efficiency being more characteristic than a continuous depression of performance. (46, 57)

26. Sleep loss consistently produces an increase in average reaction time to a designated stimulus. (57)

27. In work situations with several tasks that are differentially weighted in importance, the operator will attempt to maintain his performance on the primary or most important task at the expense of poorer performance on less-important or secondary tasks. This is especially true if the operator is at or near his performance-load capability. (7)

28. The effects of acute sleep loss on performance will be noted sooner and will tend to be more severe than the effects of chronic sleep loss of equivalent duration. (5)

Work-Rest Schedules and Performance

29. Work-rest schedules of "2 on - 2 off," "4 on - 2 off," "4 on - 4 off," "6 on - 2 off," "6 on - 6 off," "8 on - 4 off," and "8 on - 8 off" can be maintained equally well in terms of performance decrement for periods up to five days. (37)

30. Work-rest schedules of "4 on - 4 off" and "16 on - 8 off" can be maintained equally well in terms of performance effectiveness for periods up to two weeks, provided no periods of acute sleep loss is experienced. (25)

31. For periods greater than two weeks and up to 30 days, a "4 on - 4 off" schedule is superior to a "4 on - 2 off" schedule in terms of performance effectiveness. (4, 32)

32. Under stressful conditions, "4 on - 2 off" and "6 on - 2 off" schedules tend to result in poorer performance than do schedules which allow longer off duty periods. (25)

33. If an acute sleep loss period greater than 24 hours is experienced after working on a continuous work-rest schedule of "4 on - 2 off" or "16 on - 8 off," the "4 on - 2 off" worker is more likely to show performance impairment and will return to baseline performance more slowly. (25)

34. Adaptation of biological rhythms to an atypical work-rest schedule requires on the average a three- to four-week time period. (6)

35. Adaptation to a changed schedule will be enhanced to the extent that the individual synchronizes his sleep with the sleep phase of the new schedule. (6)

36. A period of three to five days typically is required for a beginning of biological adaptation of day-shift workers to night-shift work. (53)

37. Readaptation to a "normal" day-night cycle, after having phase-shifted, can occur in three to five days.

38. Stable day-night shift workers generally perform more effectively than do workers who rotate day and night shifts frequently. (50)

39. Individual differences exist in preferences for day or night shifts; when possible, such preferences should be identified and honored. (18)

40. For the average worker, night shift work performance is generally poorer than day shift work performance. The stabilized night shift worker, however, performs as well as the day shift worker. (7, 50)

Recovery from Sleep Loss Effects

41. To minimize the performance impairment resulting from sleep loss, the task should be structured to permit periods of relaxation of performance and opportunities to recover from or compensate for the perceptual lapses that can be expected to occur. (57)

42. The 12-hour period preceding a prolonged work or sleep loss period should be kept as free of duties as possible and, ideally, should be spent in sleep to minimize performance decrements during the later sleep-loss period. (24)

43. After 36 to 48 hours of continuous work without sleep, six hours of sleep (or less) is inadequate to return performance to normal levels. (32, 46)

44. Recovery of performance from acute sleep loss of up to 48 hours generally is complete after 12 hours of sleep/rest, although subjective fatigue is reported until after the third full night of sleep. (22, 32)

45. Sleep loss of 72 to 96 hours will require more than one recovery night of sleep before performance recovery is complete. (6)

46. If a period of 36 to 48 hours of continuous work is imposed on a normal load of eight hours per day, 12 hours of rest appears sufficient for performance recovery. If the same load is imposed on a work load of 12 to 16 hours a day, it may take as much as 24 hours of rest of performance to recover. (32)

47. After enduring a stressful period of sleep loss and having gone to sleep, men should not be awakened for duty until they have obtained adequate sleep, unless one is prepared to accept very low performance efficiency in their work. (55)

48. The performance of individuals just after being awakened from a normal night of sleep typically will be below normal for at least 15 minutes. (55)

49. The absolute amount of sleep, rather than a particular electroencephalographically defined stage of sleep, determines performance recovery. (27)

50. Task rotation among cross-trained crewmembers will reduce performance deterioration, especially for relatively routine, boring tasks. Complex tasks involving decision making will benefit least from crew rotation unless the men are well-practiced and expert in shifting functions. (11, 53)

51. Stimulant drugs will alleviate some of the performance-degrading effects of sleep loss. (33)

52. Mild physical activity, such as walking around, frequently will alleviate sleep-loss effects temporarily. (46)

Suggestions for Future Research

It should be clear from the previous sections of this review that we are still a long way from having the answers to all the questions on the effects of sleep loss on performance, on physiological response to sleep loss, and recovery from its effects. It would be presumptuous to suggest even that we know all the questions to ask, or that we have the techniques and methodologies at hand to provide in the laboratory and field all the needed meaningful answers.

The following suggestions for future research are presented as sets of questions pertaining to major areas where more work is needed. Most of the material described here was taken directly from published reports with minimum modification or elaboration.

Sleep Loss and Performance

A. Man's ability to maintain performance for extended periods of time:

1. Under optimum conditions, what is the maximum length of time man can conduct sustained operations?

2. To what extent are sustained-performance capabilities influenced by work-rest schedules during periods of continuous activity?

3. To what extent does napping or prone-position resting enhance performance during sustained operations?

4. To what extent are sustained-performance capabilities influenced by the level of energy expenditure during periods of continuous activity?

5. To what extent are sustained-performance capabilities influenced by the circadian rhythm?

6. What are the "total costs" to the human system of conducting sustained operations?

B. Time course of recovery from the effects of continuous activity and sleep loss:

1. What is the time course over which the "total costs" of sustained operations are repaid?

2. What is the minimum amount of sleep required for performance, physiological, and psychological recovery following sustained operations?

3. To what extent do the recovery functions interact with the circadian rhythm?

4. What is the relation between the recovery functions and the "costs" expended during previous sustained operations?

5. To what extent are the recovery functions influenced by factors in the environment that influence sleep quality?

6. What are the optimum conditions for recovery?

C. Miscellaneous problems related to the correlates of performance, individual differences, and to the enhancement of sustained performance and recovery:

1. To what extent may results from laboratory studies, field experiments, and full-scale field tests be generalized to the operational situation?

2. What are the psychological and physiological correlates of sustained performance? To what extent may such correlates be employed as predictors of possible performance decrements?

3. What critical "individual factors" (i.e., age, sex, psychological makeup, and sleep requirements) are related to man's ability to conduct sustained operations?

4. Is it possible, on the basis of identified critical individual differences, to select the "best" workers and to train others to improve performance during sustained operations?

5. To what extent may drugs, scheduling, selection of subjects, training, and other factors (e.g., biofeedback) be employed to enhance man's continuous-work and recovery capabilities?

Optimum work-rest schedules for continuous operations:

1. What are the effects of working repeated sustained-performance/recovery cycles on performance during successive work periods?

2. What are the effects of working repeated sustained-performance/recovery cycles on recovery from the costs imposed by successive cycles?

3. In light of the above, what is the range of optimum sustained-performance/recovery cycles for use in continuous operations?

Physiological Research

Physiological data are needed to answer such basic questions as:

A. Does prolonged wakefulness and physical activity inhibit the usual nocturnal rise in the circulating concentrations of agents, such as the growth hormone and insulin, which have a restorative effect on energy depots within the body?

B. Does the cardiovascular system lose any capacity for coping with increased circulatory demands? For example, can the heart continue to increase its output by a constant amount in response to intermittent applications of a constant work load during prolonged wakefulness? Can the heart and vascular system continue to maintain an adequate blood pressure during exercise and postural change?

C. What are the reactions of the musculoskeletal, renal, hepatic, gastrointestinal, and infection-combating systems to prolonged wakefulness and physical activity?

D. What are the reactions of the endocrine systems, other than the adrenal cortex and medulla?

E. Do men habituate to prolonged and repeated performance/recovery cycles? If so, how long does it take for habituation to occur, and how long does habituation persist after resumption of the normal 24-hour diurnal rhythm?

F. Are there pharmacological means for increasing the performance capabilities of men during periods of prolonged wakefulness and physical activity, or for decreasing the time necessary for recovery in the subsequent rest periods?

Needs to be Considered in Future Research

A. Taxonomic Classification System. The effects of sleep loss and varied work-rest schedules on specific types of tasks or human abilities (as typically measured in laboratory or field research) should be classified. The results can then be translated into information about performance on jobs significant in military operations (typically task combinations and requisite abilities as measured by synthetic work methods or in real-life situations).

B. Guidelines for Use in Decision Making. There is a need on the part of military commanders for various types of information and/or guidelines which can be used in making different sorts of decisions (for example, operational planning decisions versus front-line tactical procedures). The guidelines are especially necessary since the commanders may be faced with multiple options (alternative strategies, manning levels, mission envelopes), and with different cost priorities (immediate versus long-term costs to performance and fitness of their men).

C. Information about Sleep Loss and Work-Rest Schedule Effects. There is a need for more information about sleep loss and work-rest schedule effects on groups and team functions (typical in military operations) versus effects on individual performance (typical of laboratory research). We should know more about the effects on older, more experience, military personnel (who know how to pace themselves) as contrasted with their younger counterparts (who might be selected and trained for certain sustained operations).

D. Procedures for Evaluation of Operational Guidelines. Military commanders at various levels of organization need to know how to evaluate operational guidelines. Procedures should be developed so that the guidelines can be updated or modified as new data generated from critical research on sleep loss and work-rest schedules become available. However, we should remember that while new data may alter what we know specifically about human endurance, they may not necessarily alter critically the validity of more general operational guidelines derived from earlier research.

E. Information about Group Effects. While the isolated man performing a task is not an unusual work situation, the two man, or larger team is more common. We need to know much more about the interaction of sleep loss with interpersonal behavior and group performance.

Work - Rest - Sleep and Performance Bibliography

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