Sustained Military Performance in Continuous Operations: Combatant Fatigue, Rest and Sleep Needs (Reprint)

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Military forces have developed sophisticated night vision technology and other battlefield sensors, giving them the capability to fight through the night. These innovations bring about the tactical doctrine of continuous operations (CONOPS): fighting around-the-clock for successive days, even weeks at a time. CONOPS combatants, especially 'night fighters' who work during darkness and rest during the day, get only brief, scattered, fragmented sleep and often accumulate significant sleep debt. Sustained workload combines with fatigue, especially after one or more nights of complete sleep loss or longer periods of reduced or fragmented sleep, to degrade performance, productivity, safety, and mission effectiveness. Sleep loss interacts with workload, resulting in reduced reaction time, decreased vigilance, perceptual and cognitive distortions, and changes in affect, all of which vary according to circadian rhythm time-of-day effects. Research findings on the combination of sustained performance and sleep deprivation have implications for theoretical models of sustained perceptual and cognitive functioning. This chapter reviews these implications and suggests strategies for combatants who engage in continuous military operations.
Sustained Military Performance in Continuous Operations: Combatant Fatigue, Rest and Sleep Needs

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ABSTRACT
Military forces have developed sophisticated night vision technology and other battlefield sensors, giving them the capability to fight through the night. These innovations bring about the tactical doctrine of continuous operations (CONOPS): fighting around-the-clock for successive days, even weeks at a time. CONOPS combatants, especially 'night fighters' who work during darkness and rest during the day, get only brief, scattered, fragmented sleep and often accumulate significant sleep debt. Sustained workload combines with fatigue, especially after one or more nights of complete sleep loss or longer periods of reduced or fragmented sleep, to degrade performance, productivity, safety, and mission effectiveness. Sleep loss interacts with workload, resulting in reduced reaction time, decreased vigilance, perceptual and cognitive distortions, and changes in affect, all of which vary according to circadian rhythm time-of-day effects. Research findings on the combination of sustained performance and sleep deprivation have implications for theoretical models of sustained perceptual and cognitive functioning. This chapter reviews these implications and suggests strategies for combatants who engage in continuous military operations.

CONTINUOUS AND SUSTAINED OPERATIONS
Night battlefield tactics, making use of night vision devices, radar, and other technologically advanced sensor systems, permit military forces to wage war without respite, day and night, for weeks at a time. Even when military units spell one another in battle, such continuous operations require many soldiers, sailors, and airmen to sustain performance for long periods with little or no rest. Frequently, during CONOPS, small teams of combatants engage in sustained operations (SUSOPS), working steadily for long periods without relief. In SUSOPS, individuals typically do not know when they will be relieved on the job, or get an opportunity for sleep, and they work until an objective is reached. Such nonstop operations produce stress, sleep loss,

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and fatigue, which lead to poor performance, accidents, battle-weary psychological stress casualties, and ultimately reduced mission effectiveness (Krueger, 1989).

CONOPS planners, tacticians, and commanders are concerned about the impact of sleep loss and the related stresses of sustained operations on performance. They seek countermeasures to improve individual and unit effectiveness. This chapter reviews a number of psychological and physiological variables associated with sustained work which aid in predicting job performance in SUSOPS. General principles, drawn from this review, permit consideration of strategies for coping with the many stresses associated with CONOPS and SUSOPS.

CHARACTERISTICS OF THE JOB AND WORK TASKS

A number of factors associated with sustained work affect the psychological and physiological condition of workers and affect job performance during SUSOPS.

Continuousness of Tasks

The degree to which jobs require sustained effort, long hours of constant attention, prolonged uninterrupted activity, repetitiveness, and stamina, affects performance. Some tasks necessitate prolonged physical effort, e.g. long road marches, digging foxholes, or sustained artillery fire. Some require long periods of vigilance or passive monitoring, e.g. radar scope watches or sentry duty. Other jobs involve intermittent periods of continuous work interspersed with markedly reduced activity, e.g. performing reconnaissance, loading equipment aboard ships, or flying long overseas missions.

Individuals who perform continuous strenuous physical work eventually develop an oxygen debt, and because of lactic acid accumulation in the muscles, body movements are performed less accurately as the muscles become tired (Simonson, 1971). Endurance sporting activities (e.g. running ultramarathons) demonstrate that well-trained, physically fit, highly motivated people occasionally can endure 10–15 h of sustained aerobic physical effort, albeit at a pace that usually fluctuates in intensity and physical output (Thorion et al., 1987).

Personnel who continuously perform cognitive tasks for extended periods (e.g. in SUSOPS) show predictable performance decrements. In two experiments, Mullaney et al. (1983a, 1983b, 1985) tested male college students working 9+ of every 10 min, for 42 continuous hours on computer-driven pilot target tracking, pattern-memory, and addition tasks. Performance on each task improved the first 6 h, but then pattern memory and addition began to degrade. After 18 h on task, performance deteriorated moderately on the tracking task, but markedly on the memory and addition tasks. There were also large time-of-day effects on all three tasks, in that performance dropped slightly in the mid-afternoons and significantly from midnight to 0500 h. Subjects' sleepiness ratings were also highly elevated during the normal time for sleep (2300–0700 h).

Notably, in experiments such as these, subjects frequently are unwilling, or incapable of completing the demands of a lengthy protocol. Twelve of the 40 highly motivated participants failed to complete the Mullaney et al. (1983a, 1983b) protocol. Additionally, more than half the subjects experienced psychological disturbances, such as mild visual hallucinations, distortions, illusions, disorientation, and derealizations, most of which occurred after 18 h of continuous performance.

In another experiment involving high cognitive workload (Angus & Heslegrave, 1985; Heslegrave & Angus, 1985), 12 female subjects acted as operations duty officers to carry out 54 h of continuous work handling message traffic, processing information, and updating maps. Messages were computer-driven, but the subjects paced many aspects of the overall work. Cognitive performance tests were embedded in the overall scenarios. Reaction time, logical reasoning, encoding and decoding each degraded after 18 h of work and declined to 70% of baseline by 24 h. Auditory vigilance followed a similar pattern. The changes in performance were
attributed to a reduction in the number of correct responses per minute rather than to an increase in errors. All task performance was stable at 70% until about 36 h, after which it declined in a stepwise manner over the next 6 h to 40% of baseline, where it again stabilized. Deterioration of mood and motivation, and increases in subjective reports of sleepiness and fatigue paralleled the decrease in performance. The greatest reduction in performance over successive sleepless nights coincided with the circadian cycle trough (0300-0600 h).

Generally, the longer the task, be it physical or cognitive, the more likely performance decrements will occur, especially under conditions of significant sleep loss.

Vigilance and Attention

Mackworth (1957) refers to vigilance, or monitoring tasks, as requiring a state of maximum physiological and psychological readiness to react. Vigilance characterizes an observer’s ability to attend and respond to small stimulus changes over long, unbroken periods of time, such as when watching a radar screen (Mackworth, 1948, 1957; Davies & Parasuraman, 1982). Hancock & Warm (1989) remind us that many vigilance tasks demand considerable effort, produce significant cognitive stress and even elicit physiological stress responses. Thackray (1981) hypothesized that the stress of sustained vigilance comes from having to maintain a high level of alertness during a monotonous situation where there is no control over events that may occur.

Although many military jobs require continuous monitoring for 2 or more hours, the quality of sustained attention on such tasks wanes rapidly. Observers become progressively less efficient at detecting either visual or auditory signals as the task continues (Stroh, 1971; Mackie, 1977; Warm, 1984). This ‘vigilance decrement’ is characterized by a drop in the number of correct detections and/or by a rise in response time to correct detections. It can be expected as early as 20–35 min after initiation of a vigil depending on factors such as the background event rate, sensory modality, and amplitude of critical signals. In addition, environmental stressors of heat, cold, noise, and vibration, as well as the state of alertness of the observer, can affect performance during prolonged periods of sustained attention (Warm, 1984; Hancock & Warm, 1989).

Failure to maintain vigilance in military tasks, such as sentry duty, ship and air traffic control, and anti-aircraft and missile defense tracking, obviously can be disastrous, and minimally, can dramatically reduce mission effectiveness. For this reason short vigilance monitoring stints of less than 4 h are recommended (Warm, 1984), even though these are sometimes impractical for round-the-clock military scenarios.

Machine- or Event-paced Versus Worker-controlled Tasks

In machine-paced, or event-driven tasks, machines, events, or other persons control when a response is to be made. Tracking missiles, or vehicle movements, navigating in terrain flight, flying in military formation, rapidly rearming and refueling weapons, and other continuous attention demanding tasks control the soldier’s behavior. Generally, event-paced situations with shorter stimulus duration, and longer and more complex tasks, are more subject to sustained performance effects, especially after significant amounts of sleep loss. Reaction time, and motivation are important variables in event-paced task performance.

In a completely worker-controlled task, the soldier, sailor or airman determines when the significant stimulus appears, its duration, and the time within which the response must be made. Reaction time is therefore less important in worker-controlled tasks, task duration will be more variable, and such task performance is somewhat less affected by accumulating sleep loss. Examples of worker-controlled tasks include making radio-telephone calls, entering information into computers or performing vehicle maintenance.

Salvendy (1981) estimated that over 50 million civilian workers perform predominately machine-paced tasks, especially on factory assembly lines. In
training and in combat, military personnel are frequently required to carry out event-paced tasks, but conduct many worker-paced tasks as well. Event- and machine-pacing encourage consistent productivity rates, but they stress combatants. Tasks requiring vigilance and attention are often degraded by small amounts of sleep loss particularly leading to errors of omission (Williams, Lubin, & Goodnow, 1959), and thus in SUSOPS, sustained performance on event-paced tasks is affected by sleep loss earlier than it is on worker-controlled tasks.

Physical versus Cognitive Tasks

Some tasks, such as digging, lifting, or manipulating weapons and ammunition, require more physical effort, while others, such as plotting intelligence information on maps, or planning missions, require more cognitive performance. Sustained intense physical effort can lead to muscle fatigue and eventual failure to perform. Sustained cognitive work can lead to general feelings of fatigue or weariness, decreased output over time, and mistakes. In the chronic extreme, either can lead to ‘burn out’, a more generalized condition of chronic overwork and fatigue.

The sleep loss, often involved in SUSOPS, affects physical capability by slowing the biological recovery process in response to muscular exercise; thus, there is a need for a slightly longer recuperative period (McMurray & Brown, 1984). There are few measurements of physical endurance on sustained military tasks. In an almost continuous 8-day artillery scenario, Patton et al. (1989) found no changes in body weight or upper body anaerobic power from pre- to post-scenario; however, muscular strength and lifting capacity increased by 12-18% post-scenario. Artillerymen averaged 22 min and 2.9 min per day, respectively, at heart rates equal to or greater than 50% and 75% of their maxima. The soldiers, who obtained from 4 to 6.6 h sleep per 24 h, and performed at relatively moderate levels of physical intensity, showed no decrements in physical fitness capacity or other evidence of physical fatigue for 8 days of continuous artillery operations.

The principal effects of sleep deprivation combining with sustained workload are more on psychological or cognitive, rather than physical tasks (Haslam & Abraham, 1987; Haslam, 1982, Englund et al., 1985, Martin, Bender, & Chen, 1986). Sleep loss hastens the onset and increases the frequency of cognitive performance decrements, especially on vigilance tasks which demand attention during sustained work. Sleep loss impairs performance on tasks involving memory, learning, logical reasoning, arithmetic calculations, pattern recognition, complex verbal processing and decision making (Babkoff et al., 1985; Englund et al., 1985; Haslam & Abraham, 1987). The degree to which performance is impaired by sleep loss depends at least upon task variables such as duration, knowledge of results, difficulty of task, task pacing, proficiency level, task complexity, and memory requirements (Johnson, 1982).

RHYTHMIC VARIATIONS IN PERFORMANCE

Circadian Rhythms

Humans exhibit predictable physiological and behavioral rhythms, with a period of about a day, i.e. circadian rhythms. On a normal day-night schedule, alertness, motivation, initiative, and performance tend to be best when the body temperature is rising throughout the day. They decrease slightly in the late afternoon coincident with a moderate decrease in body temperature from about 1500 to 1700 h. Performance, particularly sustained cognition, vigilance, and quick response is especially low in the early morning, (0230-0600 h), coincident with the lowest point in the temperature rhythm (Minors & Waterhouse, 1985; Monk et al., 1985).

Work performance varies as a function of time-of-day, work schedule, and the nature of the task (Monk & Embrey, 1981; Monk et al., 1983). For example, rotating shift workers performed better in the early morning on high memory and search tasks than on tasks requiring lower utilization of memory (Monk & Embrey, 1981). Thus the simple
generalization that performance is poorest in the early morning must be qualified. Some work schedules result in the best performance for one type of task in the early morning hours and yield the poorest performance for another type task at the same time of day (Folkard & Monk, 1979). Further complicating the explanation, sleep deprivation may delay the maxima and minima of the circadian component of performance curves by 2 to 4 h (Babkoff et al., 1989).

Generally, day workers have difficulty adapting to night work because it calls for overriding bodily circadian variations and demands (Tepas & Monk, 1987; Monk & Embrey, 1981; Folkard & Monk, 1979). This presents a paradox for military personnel expected to sustain performance around-the-clock, particularly in instances where work schedules change daily. Changing from a day to a night work schedule, or from nights to days, results in circadian rhythm desynchronosis. Kogi (1985) calls this shift-lag because its symptoms of fatigue, lethargy, poorer mental agility, and insomnia are analogous to those of jet-lag (Comperatore & Krueger, 1990).

Around-the-clock and other military operations entail night work. In true CONOPS, when there are sufficient numbers of personnel available, military forces train teams of nightfighters, where large numbers of soldiers, sailors, or airmen operate on 'reverse cycles', fighting or working at night, and attempting to rest and sleep during daylight.

Ultradian Rhythms

One would be tempted to predict that over long periods, performance of well-practiced tasks should decline monotonically as a function of fatigue. However, research indicates the quality of the performance of some tasks varies in 90 min cycles (Lavie, 1982). Other cyclical variations in efficiency and alertness having a period of less than 12 h which have been called ultradian rhythms (Halberg, 1967), are also seen in sustained work (Lavie et al., 1981; Lavie, 1982; Hockey, 1986; Trumbull, 1966). Evaluation of rhythmic effects is not complete without consideration of such ultradian cycles.

Jet-lag

Aviation crews and aerial troop deployment passengers who make rapid flights across time zones, often experience circadian rhythm desynchronosis known as 'jet-lag'. Transmeridian travel brings an alteration in the environmental light–dark cycle and usually necessitates changes in activity–rest rhythms to match those of the new time zone. These factors affect both physiological and performance rhythms for several days until bodily adjustments are made (for review, see Comperatore & Krueger, 1990).

The major symptoms of jet-lag include a general feeling of malaise, disrupted sleep schedules, and often gastrointestinal disturbances. Some of the symptoms are merely viewed as a nuisance; however, in cases where individuals are required to carry out complex psychomotor or intellectual tasks, jet-lag can have operational significance. This is a common occurrence in the case of pilots who must continue their trip onward, or return across more time zones day after day. Psychomotor performance (e.g. simulator flying) after a 6 h transmeridian flight has been shown to suffer a reduction of 8 to 10% during the first day after arrival (Klein et al., 1976), with the most pronounced effects after travel is eastward. Elements of cognitive performance (reaction time, digit summation, and target cancellation), degrade during jet-lag much in the way they degrade during circadian lulls, but they are phase displaced according to the direction of travel—later for eastward, and earlier for westward flight, (Klein et al., 1976).

Since rapid long range deployment of military forces around the globe is now more frequently used, the influences of jet-lag on sustained military performance are becoming more apparent. Because of the requirement for intense planning and logistical considerations, soldiers typically work excessively long hours immediately preceding such deployment episodes, ride uncomfortably on troop transport planes, and then sometimes parachute directly into combat at the destination. Accumulated sleep loss and the onset of jet-lag can combine to noticeably degrade motivation, performance, and mission effectiveness.
FATIGUE, WEARINESS, AND TIREDNESS

Broadly considered, fatigue can imply: (1) muscular tiredness because of sustained strenuous physical activity, (2) feeling and acting tired after repeated performance of routine tasks because of boredom at the lack of novel stimuli, or (3) feeling weary or sleepy because of the effects of sleep deprivation. Bartley & Chute (1947) distinguished among (1) physiological fatigue as changes (impairment) made at the tissue level, including changes in neural and motor functions, (2) objective fatigue as changes in work output including declines in all types of overt activity, and (3) subjective fatigue as changes in feelings of comfort or motivation which may entail conflict between the demands of a task and a person's willingness to perform. Although volumes are written on fatigue (e.g. Bartley, 1965; Simonson, 1971; Simonson & Weiser, 1976; Hockey, 1983; Zinchenko, Leonova, & Strelkov, 1985), only three aspects of fatigue pertaining to sustained military performance are summarized here: physical, general, and phasic fatigue.

Physical Fatigue

'Physical fatigue' may be thought of as the temporary lessening or loss of power to respond, induced in a sensory receptor or motor end organ by continued stimulation (Webster, 1985). It is the muscular tiredness one feels after sustained vigorous exercise, repeated lifting, or digging. Physiologists describe it as a decrease in physical performance tied to developing oxygen debt and accumulating lactic acid in the muscles (Simonson, 1971; Simonson & Weiser, 1976). Behavioral scientists are quick to point out that such fatigue, prior to muscular exhaustion, seems to be partially controlled by cognitive components such as motivation, instructional set, and pain tolerance (Holding, 1983). For example, Caldwell & Lyddan (1971) showed that the perceived inability to perform muscular work (pulling a dynamometer handle) sometimes occurred well before the physiological limit had been reached. 'Maximal pull' was greater if subjects expected longer rest pauses between trials, demonstrating that expectancy will influence performance. Schwab (1953) required subjects to hang from a parallel bar for as long as possible, under different incentive conditions. Those promised a five-dollar reward managed to hang on almost twice as long as either controls or subjects who received only verbal encouragement (Holding, 1983).

The importance of the 'perception' of fatigue was illustrated in two studies with physically fit marines during two 20-h workdays. The marines carried 22-kg packs and marched 4 mile/h at up to 40% maximal oxygen consumption in eight 30 min sessions separated by 30 min cognitive test batteries. The two days were separated by either a 4-h nap or 4-h of rest (Ryman, Naitoh, & Englund, 1989). Most subjects could not maintain the 40% VO_2 max workload past the first eight sessions (1 day), and only half the participants completed the second day of exercise. However, when the treadmill grade and speed were reduced, almost all subjects who worked at 30% maximum oxygen consumption completed both days of the study. Subjective ratings of perceived exertion increased linearly in each day with submaximal exercise, even though the workload was decreasing. Ratings of exertion correlated positively with fatigue ratings, sleepiness, and negative mood, and correlated negatively with vigor in most periods on the first workday. Treadmill walking did not accentuate or attenuate sleep-loss effects on the cognitive performance tests (Englund et al., 1985).

Holding (1983) suggests peripheral physical fatigue is unlikely to be a factor in everyday performance, since no effect has been observed outside very high workload conditions. However, 'perceptual fatigue', less obviously physical, but consisting of physiological habituation or adaptation effects in which a sense organ literally stops performing until it is re-stimulated by novel events, can reduce 'physically-based' performance. Clearly cognitive factors like motivation and attentiveness play a role (Holding, 1983).

General Fatigue

'General fatigue', sometimes referred to as 'mental fatigue', is the subjective feeling of weariness which
accompanies repeated performance of almost any nonphysical task. Repeating similar tasks brings on feelings of monotony and boredom, which can be accentuated by tiredness, drowsiness, and sleep loss. Boredom can become apparent within minutes of the onset of a monotonous task (O’Hanlon, 1981), whereas genuine fatigue is typically a product of hours of continuous work.

Bartley (1965) viewed fatigue as ‘whole’ symptom felt throughout the body, emanating from the whole of body and mind, an interrelationship that governs the consciousness of tiredness. He said fatigue includes physiological changes in internal organs reflected as an overt behavior disorder in work decrement, or as psychological changes manifested in personal dissatisfaction. Alternatively, Grandjean (1968) interpreted general fatigue simply as a consequence of reduced afferent impulses or reduced feedback from the cortex to the reticular activating system.

As in the case of physical fatigue, the issue of central, cognitive control versus peripheral, ‘end organ’ control of general fatigue also arises. Bartley & Chute (1947) contend that fatigue represents a form of conflict between the demands of the task situation and the subject’s aversion to effort. After 24-32 continuous hours on a multiple-performance battery, fatigued subjects are more likely to choose a strategy of low effort/low probability of success even when probability of success corresponds to effort exerted (Holding, 1974). Hockey (1986) suggests that prolonged periods of cognitive overloading puts individuals into states where any further effort to meet task demands is aversive. This normally leads to shortcuts and inconsistent application of task-related behavior, and is considered a strategic change rather than a fundamental reduction in operating efficiency.

This notion of ‘aversion to effort’ is pertinent to both physical and mental fatigue. Feeling tired does not necessarily correlate with physiological impairment, nor with reduced efficiency in work output or other kinds of human performance. Fatigue can be quickly ignored in a state of emergency or an excess of enthusiasm (Holding, 1983). Fatigued workers can be seen to suddenly stop their work and vigorously participate in some sporting activity ‘on break’. Similarly, Haslam (1985a) showed that cognitive performance of ‘sleep deprived’ soldiers improved after being told that a nap would soon be permitted.

**Phasic Fatigue**

‘Phasic fatigue’ effects well may represent fundamental changes in the level of system efficiency. Hockey (1986) describes phasic fatigue as short-term fatigue resulting from prolonged vigilance work in which the worker occasionally exhibits an unusually long response time, misses signals, exhibits brief interruptions in performance (due to gaps or lapses in attention), or merely slows down, makes more errors of choice, or, maintains accuracy, but sacrifices speed of performance and consequently accomplishes less work per unit time. This form of fatigue generally occurs more frequently and is more pronounced as a function of the duration of sleep deprivation.

In addition to the more direct effects of fatigue, many studies, especially those of skill performance over prolonged periods, show that workers change their patterns of attention with prolonged work. As early as the 1940s Bartlett (1942) noted that fatigued pilots make larger control errors (though generally less often) and less accurate timing of coordinated movements and maneuvers as they get tired. Also, infrequently attended instruments and actions are more likely to be forgotten. Marked irritability is another concern. These earlier findings have been supported by more recent studies with military helicopter pilots (Lees et al., 1979; Krueger, Armstrong, & Cisco, 1985a).

In summary, since fatigue is predominately subjective, it is hard to quantify. Holding (1983) indicates experimentally that ‘fatigue’ may be regarded as an intervening variable or a hypothetical construct, similar to hunger or associate strength. If hours of food deprivation operationally define hunger, then hours on the job, or hours of performing work may be used to specify fatigue, even though this does not account for chronic fatigue or sleep loss.

One of the best ways to overcome the effects of fatigue is change per se, i.e. novel stimuli. Thus,
work breaks, pauses, and split shifts have been used to break up a workday to overcome acute fatigue effects. In the extreme, long holidays, vacations, even a change of jobs may be necessary to remedy chronic mental fatigue or 'burn out'.

REST BREAKS, WORK SHIFTS AND WORK/REST CYCLES

There are many different possibilities for rest breaks or work shift schedules to introduce novel stimuli, or provide proper rest, to break fatigue effects.

Work-Rest Breaks

The limited evidence available on rest breaks supports the assumption that short rest breaks in 'machine-paced' jobs do not reduce output even though less time is worked (Alluisi & Morgan, 1982). Short breaks are beneficial in terms of alleviation of fatigue and in some cases they promote increased productivity and employee satisfaction. Even as early as the Hawthorne experiments (Blum, 1956; Mayo, 1960), studies of work breaks in typical 'worker-controlled' industrial jobs consistently showed improved worker performance and increased productivity. Rest pauses need not be periods of inactivity, because gains may also be experienced from breaks that merely consist of changes in the type of work.

The benefits of rest pauses in most sedentary and light physical activities may derive more from subjective factors such as relief of boredom. Where repetitive, heavy physical activities such as lifting are involved, rest or change-of-activity breaks can preclude physiological stress, muscle fatigue, and cardiac strain (McCormick & Tiffin, 1974).

Optimum schedules of rest pauses have not been determined for different kinds of work, workers, and work conditions. With the present occupational trend toward information service jobs requiring more cognitive work, rest breaks deserve new examination. General models of optimal rest-break scheduling have been suggested (Janaro & Bechtold, 1985), but both theoretical and research efforts are needed to establish schedules for the diversity of conditions associated with CONOPS and SUSOPS.

Work Shift Schedules

If the work plan includes sufficient personnel to maintain continuous productivity, individual workers can follow alternating work shift schedules (Johnson et al., 1981; Colquhoun & Runtenfranz, 1980; Folkard & Monk, 1985). This is usually the case for naval ship duty, military police, communications personnel, etc. Daily shifts may vary from 8 h on/16 h off duty, 12 h on/12 h off; or more continuously, to alternating sequences of 4 h of work with 4 h off, or 4 h work with 2 h off, (Chiles et al., 1968; Alluisi, 1969). Depending upon the nature of the work, and especially upon the availability of sufficient numbers of personnel, many alternative work shift schedules permit continuous operations.

In 1890, blast furnaces kept men working 12 h per day, 7 days per week for 84-h workweeks. Gradually, from the late nineteenth century to the mid-1920s, industries cut the workweek from 60 to 48 h with resultant decreases in accidents and absenteeism and in some cases, increases in productivity. There were differences if the workers were doing handwork or machine-paced assembly-line work. Since they maintained at least the same level of productivity, the inference was that workers got more efficient in shorter work weeks.

Since World War II an 8-h workday, 5-day, 40-h week has generally been the standard in Westernized societies (Kossoris & Kohler, 1947). However, many military forces use five 10-h training days per week in peacetime, and six 12-h days per week in actual operations and in combat. The effects of total hours of work on human performance and productivity interact with many factors, both temporal and nontemporal. For this reason, Alluisi & Morgan (1982) state that no single work schedule is likely to be optimum for all tasks or all military missions and industrial settings.
Work/Rest Cycles: Sustained Performance in Small Teams

Continuous operations using man–machine systems, especially military weapons, usually means employing small teams or crews of two to three persons charged to provide sustained performance 24 h per day. Although military operations are not always analogous to industrial factory shift work, the basic tenets are similar. Instead of going home at shift change, the military crew member assigned to replace a team member on the job ("shift workers") usually rests or sleeps nearby, or even in the crew compartment or work station itself.

Much of the literature on sustained and continuous operations and unique work/rest cycles comes from military behavioral scientists. Accordingly, this research, rather than emphasizing long individual sustained performance with total sleep deprivation, stresses varied work/rest schedules that permit at least short sleep periods. Careful scheduling ensures that individuals work on and off again for long periods of time and evenly share the workload of a small team of workers.

Operation of ships or submarines under way requires around-the-clock activity. The scheduling of ship watches has always been a concern. A number of studies (e.g. Kleitman & Jackson, 1950) focused on sleep and body temperature in identifying advantages and disadvantages of various shipwatch schedules, beginning with rotating shifts of 4 h on and 8 h off duty. Colquhoun, Blake, & Edwards (1968a; 1968b; 1969) carried out navalwatch studies on stabilized 4-h, 8-h, and 12-h shifts to examine watch schedule problems aboard naval vessels. They compared a three-person rotating shift (8 h each) and a two-person stabilized shift (12 h each) for efficiency in maintaining daily 24-h operations on predominately mental tasks. The two-person shifts exhibited higher performance efficiency, better adaptation, and better maintenance of the 24-h work requirement relative to the three-person schedules.

In anticipating the manned space program, Chiles et al. (1968) conducted a comprehensive program to analyze work–rest schedules. Subjects in experiments of work-to-rest ratios of 1 : 1, participated in one of four work–rest cycles for 4 continuous days (96 h): (a) 2 h on duty and 2 h off, (b) 4 h on and 4 h off, (c) 6 h on and 6 h off, or (d) 8 h on and 8 h off. Performance scores on a multiple task performance battery (watchkeeping vigilance, computational, target identification, and crew procedural functions of code-lock solving) improved throughout the 96 h test and no significant differences were found between the schedules.

In a study of work–rest ratios of 2 : 1, subjects followed a schedule of 4 h on duty and 2 h off around the clock for 4 days. For a ratio of 3 : 1, subjects were scheduled 6 h on and 2 h off for the same duration. Both schedules gave clear evidence of time-of-the-day effects on all performance measures, but neither schedule was significantly better than the other. The subjects preferred the 4–2 over the 6–2 schedule and the former averaged 5.5 h sleep per 24 hr period, whereas those on the 6–2 schedule averaged less than 4 h sleep (Chiles et al., 1968).

Subsequently, subjects completed a 15-day (360 h) confinement study using the 4–2 schedule, (Chiles et al., 1968). When a second group of subjects was shown the psychophysiological and performance data of the first group and was told one of their goals was to prevent the appearance of circadian low points, they were able to do so, implying information and motivation can intercede to replace expected circadian variations in performance.

Chiles et al. (1968) then conducted a 4 h on/4-h off, around-the-clock, 30-day confinement study with air force officers. Performance was again quite acceptable, and although circadian variations were somewhat more evident, they were less pronounced than for the earliest groups of 4–2 subjects. The subjects on the 4–4 work–rest schedule maintained consistently better levels of performance than in those on the 4–2 schedule.

Chiles et al. (1968) summarized: (1) subjects working 12 h per day on a 4-4 schedule can maintain generally higher levels of performance than those working 16 h per day on a 4–2 schedule; (2) some subjects can work 16 h per day on a 4–2 schedule with essentially no decrements over a period of at least 15 days; (3) when subjects are
highly motivated, performance over a period of 30 days on a 4-4 schedule is indistinguishable from the levels maintained by subjects on a stabilized 8-h split-shift in a nonconfinement situation; and (4) 16 h per day on a 4-2 schedule appears to be the maximum feasible number of hours per day a man can work for extended periods of time.

Chiles et al. (1968) conducted another study to look at 12-day scheduling of the 4-2 and 4-4 work-rest cycles with an ‘emergency’ 40-44-h period of continuous work and associated sleep loss during the sixth and seventh days. The 40-44 h of continuous work and sleep loss resulted in greater performance decrements for subjects on the 4-2 schedule than for those on 4-4. Circadian variations in performance measures of the 4-4 subjects generally were not evidenced except during the stressful period of continuous work and its associated sleep loss.

In a summary of their 8-year research program Chiles et al. (1968) concluded that two men can satisfactorily handle 24 man-hours of work per day, even on a long-term basis (30 days or longer). On a shorter-term basis, if the likelihood of an additional stressor is low, three men can handle 48 man-hours of work per day for periods of 15 days or slightly longer. With tasks that are not intrinsically interesting, briefer work periods (e.g. 4 h) are preferred. Subjects preferred duty periods no longer than 4 h during prolonged periods of testing. This preference was expressed despite the fact that brief work periods necessitate correspondingly short rest periods (2-4 h). The 4-4 work-rest schedule, with confinement, was no more demanding than the normal 8-h, split-shift work days without confinement. A 4-4 schedule had substantially fewer deleterious effects on performance than did 16 h of work per day on a 4-2 schedule (Chiles et al., 1968). Lastly they point out that there are important individual differences in the adaptability of workers to such brief rest and sleep periods.

EFFECTS OF SLEEP LOSS

The most important concern in sustained work is the effect of sleep loss. When workers perform for extended periods to the point where they miss normal amounts of sleep, the accumulating sleep loss degrades performance, mood, and attitude. In instances where limited amounts of intermittent and broken sleep are obtained, that sleep generally is of insufficient quality to restore cognitive function and performance to peak levels.

Amount of Sleep Normally Anticipated for Alertness

Young adults require 7 to 9 h sleep per 24-h period to remain suitably alert and to function at their best (Coleman, 1986). When one obtains less than his or her required amount of sleep, we say the individual has built up a sleep debt of the number of hours of sleep missed. Although there are wide individual differences, when an individual’s sleep debt accumulates, he or she feels fatigued, exhibits gradual performance degradation, and eventually performs as poorly as if he had been totally sleep deprived for one or more nights. Such sleep debts often build up in military CONOPS (Krueger et al., 1988).

Volumes are written on sleep and sleep loss (e.g. Kleitman, 1939; Webb, 1968, 1982) and on human performance in work settings (e.g. Dunnette, 1976; Salvendy, 1982, 1987; Boff, Kaufman, & Thomas, 1986). Although attempts to merge the two topics began about the turn of the century (Patrick & Gilbert, 1896), applications of research on the effects of sleep loss and sustained performance in the working world, particularly for the military, have been rather recent (for background, see Harris & O’Hanlon, 1972; Englund & Krueger, 1985; Krueger & Englund, 1985; Krueger, Gardenalez-Ortiz, & Loveless, 1985b; Krueger & Barnes, 1989; Krueger, 1989; Cox & Krueger, 1989).

Lapse Hypothesis and Sleep Loss Decrement in Performance

When an individual is required to sustain work and is sleep deprived, it is common to witness occasional ‘blocks’ or brief periods of no response that increase in frequency and duration with continued
mental work, while performance between blocks is maintained at close to initial levels (Bills, 1931). Bjerner (1949) introduced the more general term 'lapses' for 'blocks' and found them in the form of long reaction times coinciding with long periods of reduced arousal. He regarded lapses during sleep deprivation as reflecting brief intermittent periods of sleep, or a condition like ‘microsleeps’ (1-10 seconds of drowsiness polygraphically defined as Stage 1, sometimes progressing to Stage 2 sleep), an approach followed by Williams et al. (1959) in their seminal work on the topic.

Williams et al. (1959) kept subjects awake for at least 72, and sometimes as many as 98 h. In simple experimenter-controlled (machine-paced) reaction time (RT) tests, they found the difference between slowest and fastest responses became greater as lapses increased in duration; and as lapses increased in frequency, the distribution of reactions showed more long RTs. Williams and his associates determined that although sleep deprived subjects are capable, on some trials, of coming very close to their best baseline RTs, there is a significant increase in the duration of the longest reaction times. Subjects’ poorest performances become progressively worse, even though their best performances remain close to original levels. Continuing sleep loss produces an increase in the frequency and duration of lapses, but performance between lapses is at an acceptable but generally reduced level.

Sleep loss also consistently produces impaired performance on experimenter-controlled vigilance tasks using auditory, visual, or vibratory stimuli. Performance lapses are related directly to speed and only indirectly to accuracy (as errors of omission). As sleep loss progresses, errors appear earlier in the task, and the benefits from feedback of initial successes, or a break between parts of the task, become increasingly less effective (Williams et al., 1959).

On a variety of tasks (addition, communication, and concept attainment) in which the subject controlled the time a response was made or the interval between responses (worker-paced jobs), the consistent result was again a change, not in accuracy, but in the rate of performance or speed of response. These slower speeds stemmed from an increase in the frequency and duration of lapses. They are affected by the same task properties that give rise to little or no change in accuracy: the subject has unlimited response time which allows for the delay of a response or for the correction of errors, and the emphasis on correctness prompts the subject to sacrifice speed for accuracy (Williams et al., 1959). Williams et al. (1959) studied additional conditions that affect decrements attributable to the lapse hypothesis, and found: (1) altering the level of motivation, especially by providing knowledge of results, tended to reduce impairment, but the differences were small and inconsistent; (2) exhorting subjects to perform better produced only slightly better performance and only on single stimulus tasks; (3) increasing the complexity of a communication-receiving task resulted in more errors of commission; (4) with increasing sleep loss, subjects more frequently failed to acquire and recall information quickly, and this led to an increasing number of items ‘missed’; (5) there was usually a decline in EEG alpha amplitude associated with errors of omission; and (6) there was significant recovery after sleep.

In addition to bringing about intermittent lapses, sleep deprivation slows down overall cognitive task performance in a more general way. In a 72-h total sleep deprivation study (Thorne et al., 1983; Babkoff et al., 1985), subjects were tested hourly on a variety of computerized perceptual and cognitive tasks requiring 30 minutes to complete. The tasks ranged from simple to complex and included logical reasoning, memory, serial addition-subtraction, pattern recognition, complex verbal processing, and vigilance. No attempt was made to record lapses. As sleep deprivation continued, the average time on task increased at an accelerating rate. The rate of increase differed among tasks, with longer tasks showing greater absolute and relative increases than shorter ones. Performance on all tasks deteriorated in parallel with declines in mood, motivation, and initiative. Performance on the cognitive tasks, principally in terms of task completion speed, declined roughly 25% for every 24 h of semicontinuous work without sleep. As the subjects became more tired, the cognitive testing, which initially took only 30 minutes out of each hour,
took longer to complete, so, by 72 h, subjects were working continuously, maintaining reasonable accuracy, but accomplishing less work per unit of time. Such increases confound sleep deprivation and workload effects with length of duty cycle.

There are many other studies on the effects of sleep loss on sustained performance. In general these studies suggest that: (a) workers do not adapt well to restricted sleep schedules though they may think they do (Carskadon & Dement, 1979, 1981); (b) prior experience with sleep loss does not train one to cope with the deleterious effects of sleep loss on performance (Webb & Levy, 1984); (c) higher rates of sleep fragmentation lower the recuperative value of the sleep and minimize restorations in cognitive functioning (Stepanski et al., 1984); (d) particular sleep stages are relatively unimportant to performance (Johnson et al., 1974; Johnson & Naitoh, 1974); (e) naps often benefit subsequent task performance (Naitoh, Englund, & Ryman, 1982; Naitoh & Angus, 1987; Dinges, Orne, & Orne, 1985; Dinges et al., 1988); and (f) the degree to which sleep loss impairs performance on a variety of tasks increases with age (Webb & Levy, 1982; Webb, 1985).

The importance of obtaining sufficient amounts of restful sleep to maintain alertness, and the potential deleterious effects of the failure to do so cannot be emphasized enough in discussing CONOPS/SUSOPS.

Researchers present conflicting interpretations about the effects of the duration of naps on performance, recommended timing or placement of naps in the work/rest schedule, quality of rest/sleep obtained during naps, and sleep inertia effects. Many authors use ‘naps’ to refer to short periods of sleep even when that is the only sleep obtained in a 24-h period. Thus, the use of the term ‘nap’ may mean a ‘short night’s sleep’ depending upon the literature. Most sleep researchers agree naps restore degraded functioning and 4-5 h of sleep should be taken in an uninterrupted period to prevent impaired performance. The continuity of sleep theory (Naitoh & Angus, 1987) postulates that continuous sleep has greater recuperative power, based on notions of importance of the duration of various stages of sleep. If sleep occurs in short pieces over 24 h it is generally presumed less effective, even if the total sleep time is the same, although some data conflict on this point (Naitoh, 1981; Mullaney et al., 1983a, 1983b; Naitoh & Angus, 1987; Hartley, 1974). Stampi (1989) indicated that best performance of solo sailors in distance races was by those sleeping for periods between 20 min and 1 h for a total of 4.5 to 5.5 h of sleep per day, prompting renewed attention to the study of ultra-short naps.

Sleep Inertia

Immediately upon awakening from a nap, one frequently feels groggy or sluggish, and performance decrements occur, lasting up to 15-30 min after awakening. Sleep inertia effects have been found on a wide variety of tasks, and they depend, in part, upon the stage of sleep associated with awakening (Dinges et al., 1985). Sleep inertia is increased by the depth of sleep. Awakenings from non-REM sleep stages, especially slow-wave sleep (predominant in the first few hours of nocturnal sleep), yield the greatest decrements; and sleep following prolonged wakefulness yields decrements greater than sleep prior to deprivation (Dinges et al., 1985, 1988). Sleep inertia effects should be anticipated if a worker is expected to wake quickly and respond to immediate performance expectations.
Sleep Management/Sleep Logistics

Naitoh & Angus (1987) discuss naps in the context of sleep management, a program to maintain human functioning by preplanned sleep periods during prolonged work episodes. They contend a nap is effective in maintaining performance and mood when it is taken prophylactically before anticipated sleep loss and fatigue. Generally, if the work schedule permits, it is preferable to sleep while the body temperature is low (between midnight and 0600 h, or during the late afternoon) and to be awake and working when the body temperature is rising (e.g. 0600-1200 h).

Perhaps because of the importance of remaining vigilant on sentry duty, military forces generally regard nap taking as 'unsoldierly'. The notion that 'it is not macho for a soldier to take a nap' held true in the US Army for years. However, with increased attention to sleep requirements, CONOPS soldiers are encouraged to obtain sleep when they safely can. To improve the acceptability of the notion, regularly scheduled short sleep periods are often referred to as taking 'power naps'. Modern military forces are gradually adopting sleep discipline plans to insure that all personnel, particularly key command and control personnel, obtain sufficient sleep to maintain needed levels of alertness during CONOPS/SUSOPS (Krueger et al., 1987; US Army Soldier Support Center, 1983, 1991; Woodward & Nelson, 1974).

OTHER FACTORS

Worker performance during SUSOPS is also influenced by the interaction of other factors: (1) prior rest quantity, (2) physical fitness, (3) endurance or stamina, (4) environmental conditions, (5) number of sustained work episodes, (6) time of day of performance, (7) task type, (8) workload, and (9) motivation (Englund et al., 1983). For example, although one should be rested before engaging in sustained operations, we cannot store up sleep, but prior rest will stave off the detrimental effects longer. All other things being equal, the state of physical fitness of individuals will affect stamina in many sustained work efforts, particularly those with extensive physical components. Acoustical noise can lessen the effects of sleep loss in auditory vigilance tasks. Tasks of high interest can prolong motivation to perform.

SUSTAINED AND CONTINUOUS PERFORMANCE STUDIES

Some military studies have been done on continuous work schedules involving sleep loss. A sampling of these is reviewed here to provide additional reference to a variety of military SUSOPS applications.

Armor Operations

Drucker, Cannon, & Ware (1969) required two-man armor teams to continuously track a road in a tank driving simulator and to perform target detection for a 48-h period. Both tasks degraded significantly during the first night without sleep, recovered somewhat during the second day, but deteriorated even more markedly during the second night without sleep. Rotation of tasks between members of teams did not enhance performance or abate declines. Abilities to remain awake 48 hours varied widely among the 140 soldiers.

Ainsworth & Bishop (1971) studied four-man tank crews doing offensive, defensive, and retrograde movements for 48-h SUSOPS. Crews performed communication, obstacle course driving, target surveillance, dynamic gunnery, and maintenance without serious performance decrements. The authors concluded that activities demanding a protracted high level of alertness or complex perceptual-motor activity, such as surveillance on the move, and driving, were most sensitive to loss of sleep, but all tasks were performed acceptably for a 48 h stretch without sleep, albeit at a slower pace.

Infantry

In a series of 36 to 48 h SUSOPS field studies, performance on three infantry tasks (surveillance-target acquisition with a night vision device, rifle
firing, and grenade throwing) was fairly stable, with individual variations gradually attributable to fatigue during vigilance (Banks et al., 1970).

Three parachute regiment platoons participated in a field study of continuous infantry operations (Haslam et al., 1977; Haslam, 1978; 1985b; Haslam & Abraham, 1987). One platoon was permitted no sleep, another was allowed 1.5 h sleep, and the third was permitted 3 h sleep per 24 h in a 9-day exercise. Military performance, including shooting, weapon handling, digging, marching, and patrolling, was assessed throughout the 9 days. Subjects completed daily batteries of cognitive tests, which included map plotting, encoding/decoding, short-term memory, and logical reasoning. The platoon allowed no sleep was militarily ineffective after 3 nights, and all members of the platoon withdrew from the exercise after 4 nights without sleep. Thirty-nine percent of the 1.5 h sleep platoon withdrew after 5 nights, and this platoon was judged to be militarily ineffective after 6 days. The platoon sleeping 3 h per night remained effective the entire 9 days.

In a second study, infantry soldiers were scheduled no sleep for 90 h of continuous activity, and then allowed 4-h blocks of sleep in every 24 h for the next 6 days (Haslam, 1978; Haslam & Abraham, 1987). All ten subjects completed these trials. Four hours of sleep each of 3 nights was sufficient to restore performance and mood to the average control level on the following day. After the first 4-h block of sleep, performance improved to 60% of control values and after the third 4-h block of sleep, performance improved to 80% of control values where it remained for the last 3 days of the trial. The exception to this overall positive effect was that performance on the cognitive tests initiated immediately after awakening remained low (sleep inertia) even after several nights in which 4 h sleep were obtained. The utility of obtaining 4 h sleep within each 24-h period for restoring and sustaining performance was confirmed (Haslam, 1982, 1985a). Four hours of sleep divided into four 1 h blocks was as restorative as 4 h of continuous sleep. Further, after 3 days without sleep, anticipation of a 2-h nap produced a substantial improvement in performance.

In both studies the main effect of sleep deprivat-
psychomotor component of flight performance did not degrade to unacceptable levels, by the fourth day, pilots adopted a more passive flight control strategy, making less frequent, but larger cyclic control inputs. More important, by the fourth day, pilots made occasional errors of omission (possibly lapses), like forgetting to make safety or communication checks, and simulator copilots occasionally fell asleep in their less active role as navigator. These studies indicate that with just 3.5 to 4 h sleep per night, trained soldiers can control and maneuver complex man-machine systems for 12–14 h a day for at least 5 days, albeit at a cost of efficiency and safety.

Command and Control Activities

Artillery fire direction center (FDC) teams participated in a 3-day simulation of sustained tactical battle operations working on maps, plotting preplanned and unplanned targets, with concurrent fire missions that were often superimposed with calls for preplanned artillery fire (Bandaret et al., 1981). Degradation of performance was evident within the first 24–48 h. All four teams elected to withdraw from the study by 48 h. Teams made more errors as time passed, but generally remained effective until the time of their withdrawal. Performance of individual self-initiated activities (e.g. working out preplanned fire missions, revising preplanned data on the basis of new information, and keeping up the situation map) deteriorated most. As in the Haslam studies, teams in which leadership and cohesion were good functioned better and persevered longer. Thus, generally it can be said that under sleep deprived conditions, a well-led unit may outperform an indifferently led one. However, superior leadership cannot overcome large quantitative differences in sleep obtained or lost (Belenky et al., 1987).

Confinement Studies

Morgan, Brown, & Alluisi (1974) studied work efficiency on a multiple task battery during a 7-day study consisting of 4 h on duty, followed by 4 h off duty, 4 more h on duty, and then 12 h off duty for each of 2 days; then continuous work for 48 h followed by a 24-h period of rest, and 2 additional days of work according to the 4–4–4–12 schedule. Performance during the embedded 48-h SUSOPS exhibited significant circadian rhythm time-of-day effects, dropping in the middle of the night, and in the late afternoon. Decrements first occurred after 18 h of continuous work and performance decreased to an average of 82% of baseline during the early morning hours of the first night. Performance improved to 90% of baseline during the second day, but decreased to approximately 67% that night. All performance recovered to baseline levels following the 24-h period of rest.

Driving

A number of automobile driver fatigue studies (e.g. Brown, 1965; Brown, Simmonds, & Tickner, 1967) conclude that a continuous 12-h period of driving during the normal working day need not affect either perceptual or motor skills adversely. In a simulation study of sustained driving, psychomotor performance was studied with 15 young adult males who performed a primary tracking task and a variety of secondary tasks over a 15-h period (Ellingstad & Heimstra, 1970). Tracking performance decreased significantly over the 15-h period. Secondary-task performances were markedly variable over the 15 h, with no clearly established decrements in performance. However, in a review of sustained truck driving studies, McDonald (1984) concludes that fatigue and falling asleep at the wheel are important contributors to long-haul driving accidents in industrialized countries.

Chemical Protective Clothing

In a highly specialized set of continuous operations studies, military laboratories examined the abilities of soldiers and airmen to sustain task performance while they wear chemical protective clothing. The individual clothing ensembles (designed to keep
chemical agents off the wearer), are impermeable, bulky, cumbersome, and hot. Generally, wearing such protective clothing and gas masks imposes dramatic decremental physiological and psychological effects upon individuals. Work with helicopter pilots (Knox et al., 1982), tankers (Knox et al., 1987), artillerymen (Rauch et al., 1986; Knox et al., 1989; Headley, Brecht-Clark, & Whittenburg, 1989), and infantrymen (Mitchell, Knox, & Wehrly, 1987), demonstrates that in relatively hot, humid environments of 29-31°C wet bulb globe temperature, soldiers accomplishing relatively moderate physical workload withstand the test only a limited number of hours.

Wearing protective clothing is frequently accompanied by body perspiration, perceptions of mental fatigue, mood changes, anxiety over breathing through gas masks (Munro et al., 1986), and a tendency to quit working earlier (Rauch et al., 1986; Headley et al., 1988). These limitations differ according to the particular clothing ensembles, workload required, operational scenarios, and environmental conditions.

**Conclusion on CONOPS/SUSOPS Studies**

In reviewing the literature, sustained operations studies seemingly exhibit conflicting results. Wide differences in study designs, levels of experimental control, fidelity of simulation, measurement methodology and technology, choices of dependent variables, and subject variables, make it difficult to determine general principles or to extrapolate from basic studies to predict real-world sustained work performance. More quality CONOPS/SUSOPS research is required since there are implications for theoretical models of sustained perceptual/cognitive functioning which have obvious application to sustained military operations and to civilian industrial operations.

**PHARMACOLOGICAL INTERVENTION**

Various military research programs are examining the potential for pharmacological intervention to sustain or enhance performance in CONOPS.

**Sleep Inducers**

Hypnotic drugs can induce sleep in the off-duty shift in conditions which may not be conducive to sleep. Baird, Coles, & Nicholson (1983) documented use of a benzodiazepine (temazepam) for aviation crews in the off-duty hours to induce sleep before returning to flying duties in the Falkland Islands conflict. Storm & Parke (1987) cite sleep and operational performance data from fighter pilots after temazepam-induced sleep in the off-duty period. The Israeli forces administered hypnotics to promote sleep among troops (passengers) during the air deployment portion of the Entebbe raid. O’Donnell (1986) proposed the use of benzodiazepines in military aerial deployments across multiple time zones as a prophylactic to jet-lag, and experiments on the topic have begun (O’Donnell et al., 1988; Penetar, et al., 1989).

The major concerns with hypnotics include the amount and quality of sleep/rest obtained with particular drug doses, and whether or not users can easily awaken from drug-induced sleep and quickly respond normally in the event of an emergency. Other concerns include the possibility of lingering performance effects after awakening; and the potential for adverse effects of repeated use. By contrast, some researchers promote ‘nonsedating’ sleeping aids like the amino acid l-tryptophan (Spinweber, 1986), or the hormone melatonin (Comperatore & Krueger, 1990) for military use.

**Alertness Enhancers**

In select circumstances, stimulants can be used to maintain alertness to meet extended performance demands. Jones (1985) indicates that during World War II Soviet personnel used drugs to stave off fatigue and drowsiness and to improve memory and concentration. During the US-Vietnam War, methylphenidate and dextroamphetamine were carried by US long range reconnaissance patrol soldiers. These soldiers found it most efficacious to use the drugs upon completion of a mission to counteract fatigue while rapidly returning to base camp (Jones, 1985). While the initial effects were
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good, the use of stimulants resulted in mild depression and fatigue after drug administration was discontinued. Ultimately, serious problems with the abuse of stimulants by soldiers brought about their discontinuation (Holloway, 1974).

Concerns with stimulant drugs include their wide-ranging and poorly understood effects on body biochemistry and physiology, and especially on performance of all types of tasks. Some stimulants distort perception and affect safety, produce rebound effects like depression and fatigue; require subsequent increased doses to produce the same effects, and are likely to be addicting.

STRATEGIES FOR SUSTAINING MILITARY PERFORMANCE

This chapter reviewed many basic principles concerning sustained performance, especially that of military workers, during CONOPS. The data show that sustained performance fluctuates as a function of many psychological and physiological factors, notably circadian rhythmicity, cumulative sleep loss, and fatigue. Alertness and performance decline rhythmically at predictable times of the day, and are particularly susceptible to circadian effects during sleep deprivation. Mental performance, especially that involving initiative, integration of information, planning, plan execution, and quick responses, declines sooner than physical performance. With partial sleep deprivation, alertness and performance decline more gradually, but after several days of sleep debt, degrade to nearly the same levels seen following 1-2 days of total sleep deprivation. Careful assignment of work–rest scheduling, and judicious use of napping, can assist in preventing performance decrements.

Military forces must develop strategies to maximize capabilities in CONOPS and to assist combatants in coping with stresses required by sustained combat. Drawing from several lessons found in the scientific literature and from personal participation in numerous field and laboratory studies of CONOPS/SUSOPS, (Krueger et al., 1987) the following strategies are offered:

Personnel Staffing

To fight CONOPS, and to cope with their detrimental performance effects, military units must organize and staff their organizations with sufficient personnel to ‘do the mission’. There should be personnel redundancy to allow soldiers, sailors or airmen to work in shifts, especially in select high cognitive workload organizational elements (i.e. communications, and command and control personnel), and in transportation, support, and logistics elements.

Modify Tasks, Divide Workload, Cross-train

When sufficient personnel are just not available—and even if they are—tasks should be modified to minimize effects of sleep loss (e.g. design vigilance tasks which permit the operator to take breaks). Cognitive workload should be reduced as much as possible and equitably divided among members of teams so everyone gets chances to rest. Team members must be cross-trained to do each other’s jobs; and they should ‘overlearn’ select tasks so as to be less subject to performance decrement during sustained efforts.

Soldier Load, Physical Fitness, Training

Planners should also lighten mission-essential load-carrying requirements to permit soldiers to conserve physical strength. High levels of physical fitness should be attained before beginning an operation. ‘Training as you plan to fight’ should include exercise for load carrying muscles in rehearsals.

Create ‘Night Fighter’ Teams

Given sufficient personnel staffing, teams can be selected and trained to work the ‘night shift’. Measures should be taken to allow night fighters to pre-adjust to night work rhythms, and especially to promote quality sleep during the day.
Rest and Sleep Discipline Planning

Commanders and leaders should develop, practice, and adhere to unit rest and sleep management plans. Issues of rest and sleep should specifically be addressed during mission planning. Naps should be encouraged when combatants or leaders determine it is safe to take them. Leaders, and command and control personnel, who do much cognitive work, are susceptible to sleep deprivation effects, and should therefore adhere to their own rest plans. All combatants should practice common courtesy in not interrupting others attempting to sleep.

Recovery Sleep between Combat Episodes

Historically, combat episodes occur in pulses; interludes between battles offer opportunity for some recuperation. Those who have engaged in SUSOPS should be permitted ‘recovery sleep’ to restore alertness and recharge motivation.

The Charge to do More Research

As for the biomedical and behavioral research communities, the charge is to continue to do more research with direct applications for meeting military SUSOPS/CONOPS concerns. Additional field studies can determine which personnel positions require large amounts of sustained performance, and which are more likely to suffer from extensive amounts of sleep loss. This would help planners assign additional personnel in the right places to enhance mission performance. More basic laboratory research is needed to elucidate neurobiological mechanisms of rest, sleep and alertness. Carefully controlled experiments are required to identify how best to ensure optimum alertness for combatants in military CONOPS missions. The efficacy and procedural guidance (e.g. dose response considerations) concerning pharmacological intervention should be determined in simulation experiments in the laboratory. Researchers should translate their scientific findings into practical generalizable principles that military commanders and their staffs can appropriately use. Lastly, military doctrinaires, tacticians, and other leaders should insure that behavioral and biomedical principles regarding CONOPS/SUSOPS are taught in military training and adhered to in operations.

REFERENCES


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