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# Effects of Continuous Operations (CONOPS) on Soldier and Unit Performance: Review of the Literature and Strategies for Sustaining the Soldier in CONOPS

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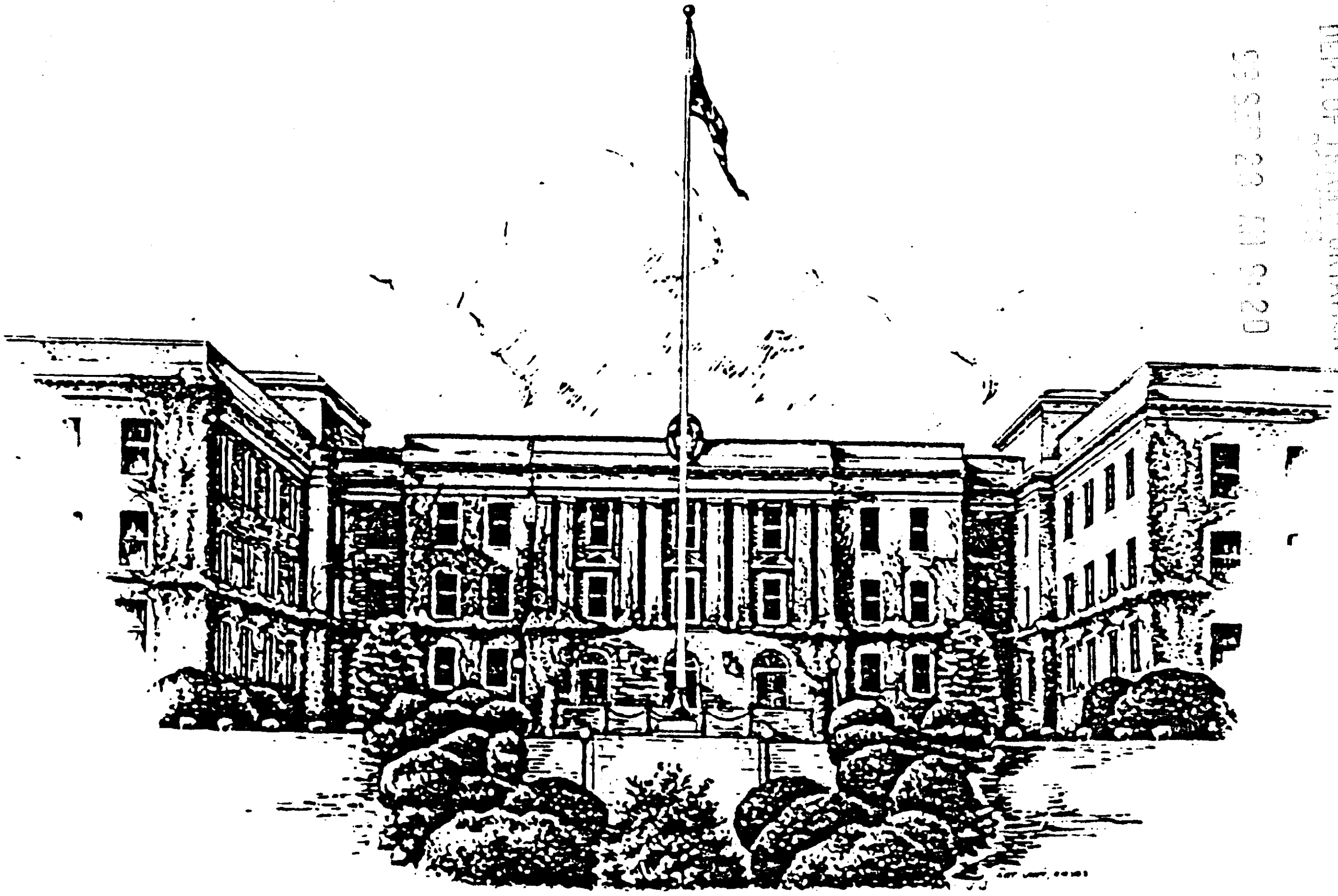

A Joint WRAIR/ARI Report

Department of Behavioral Biology
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Washington, D.C. 203074100
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Two chapters submitted in special study of Army conduct of continuous operations. Contains a detailed review of the literature on effects of sleep deprivation and requirements for sustained performance on the ability of soldiers to conduct continuous operations. Subjects covered include: adaptation to restricted sleep, effects of fragmented sleep, sleep timing, importance of sleep stages,circadian rhythms, effects of age, wearing chemical protective clothing, the nature of optimum alertness. Also covered are short descriptions of soldier sustained

performance studies from various military labs.

The second chapter contains a detailed list of human factors principles and recommendations for sustaining performance of soldiers in continuous operations (CONOPS) and includes coverage of topics like: training and preparation for CONOPS; sleep scheduling, recovery sleep concepts, work/rest scheduling, naps and sleep discipline, sleep-inducing drugs for use in long range deployments, alertness sustaining drugs for use in CONOPS, lightening the soldier's load, nutrition, and physical fitness for military tasks.

# Effects of Continuous Operations (CONOPS)
# on Soldier and Unit Performance:
# Review of the Literature and
# Strategies for Sustaining the Soldier in CONOPS

## Preface

In February 1986, the Army Studies Group at the Department of the U.S. Army evaluated the Army's posture for conducting sustained and continuous operations (CONOPS). These issues were discussed with particular reference to the latest Air Land Battle doctrine as described in the U.S. Army Operations Field Manual 100-5. As a result of these discussions the Vice Chief of Staff directed the commander of the Training and Doctrine Command (TRADOC) to perform a special staff study on CONOPS. TRADOC in turn convened a Study Advisory Group (SAG) on CONOPS and enlisted the assistance of representatives of thirteen organizations for the study.

Members of the Walter Reed Army Institute of Research (WRAIR) and the Army Research Institute (ARI) for the Behavioral and Social Sciences. agreed to jointly take on two significant efforts for the SAG: 1) to review the scientific and technical literature to determine what previous studies tell about soldier/unit performance in CONOPS; and 2) to present a compilation of general human factors principles that can be applied in planning, preparation and conduct of sustained and continuous military operations, and a description of research planning underway to enhance the Army's CONOPS posture.

These efforts by WRAIR and ARI personnel resulted in submission of two technical reports and formal briefings of results, one for each Phase of the staff study, to the SAG, the first in October and the second in December 1986. These two reports were subsequently incorporated into the SAG's overall final report: Continuous Operations Study (CONOPS) Final Report. (TRADOC CACDA Report # ACN 073194; DTIC Report # AD-611 1-424L). Fort Leavenworth, Kansas: U.S. Army Combined Arms Combat Development Activity, April 1987.

The two reports, as submitted to the SAG, are reproduced here as a two-chapter review for our research program on sustained soldier performance in continuous operations. The chapters are 1) Review of the Literature, and 2) Strategies for Sustaining the Soldier in CONOPS. Hopefully, they serve as a "state-of-the-art" indicator of what we know, where we are, and where we are headed in our continuing search for explanations of how and why people perform the way they do when they are asked to maintain effective performance while sleep deprived.

# Effects of Continuous Operations (CONOPS)
# on Soldier and Unit Performance:
# Review of the Literature
# and
# Strategies for Sustaining the Soldier in CONOPS

A Joint **WRAIR/ARI** Report

**WRAIR** Technical Report No. BB - 87 - I

Department of Behavioral Biology
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April, 1987

# EFFECTS OF CONTINUOUS OPERATIONS (CONOPS) ON SOLDIER AND UNIT PERFORMANCE

## CHAPTER I:

## REVIEW OF THE LITERATURE

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Phase I Report Submitted to
the TRADOC Study Advisory Group on Continuous Operations (CONOPS)

JOINT WRAIR/ARI REPORT

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## Table of Contents

## 1 Definitions (U.S. Army Field Manual 22-9)

Continuous operations (CONOPS) is continuous land combat with some opportunity for sleep, although this sleep may be brief or fragmented. Sustained operations (SUSOPS) is continuous land combat with no opportunity for sleep. Within any CONOPS there are likely to be periods of SUSOPS.

## 2 CONOPS in Combat Operations

CONOPS can reinforce the application of maneuver warfare to land combat by increasing the tempo of operations and taking advantage of new technologies for night, all weather, and deep operations (US Army Field Manuals 100-5 & 22-9, Simpkin, 1985). At the same time CONOPS (particularly by virtue of extended periods of continuous work compounded by brief, fragmented or no sleep) can increase what Clausewitz has termed the friction of war (Howard & Paret, 1976). Successful application of CONOPS to maneuver warfare entails successful development and application of a doctrine for managing sleep and alertness in CONOPS.

## 3 CONOPS in the U.S. Army

Ideally, CONOPS would be carried out with adequate personnel and doctrine to allow for 6-8 hours sleep in every 24 hours for all personnel. Such CONOPS are routinely executed by U.S. Navy, U.S. Air Force, and U.S. Army Aviation units; and have been carried out on a limited basis by some U.S. Army Divisions, Brigades and Battalions. However, even the Soviet Union with its relative abundance of personnel and equipment does not consider the provision of adequate rest for all personnel in CONOPS feasible. Soviet doctrine calls for units to fight without rest for approximately 2-3 days and then to be replaced by a fresh unit coming forward in the next echelon.

From the perspective of the Soviet soldier and his unit, CONOPS is a 2-3 day SUSOP, after which he and his unit will stand down to rest, reorganize, and re-supply. For a variety of reasons ranging from specific (e.g. inability to rotate tank crews efficiently) to general (e.g. the numerical superiority of the Soviet Union and its allies in men and materiel) the U.S. Army cannot conduct CONOPS by rotating personnel in shifts or by fighting soldiers and units to exhaustion and replacing them with fresh personnel. So for the U.S. Army, CONOPS de facto means continuous land combat with some opportunity for brief or fragmented sleep interspersed with periods of SUSOPS where no sleep is possible.

The essential element of analysis (EEA) that is the subject of this report asks: What insights can studies provide on soldier and unit performance in CONOPS? Given the definition and implications of CONOPS outlined above, the question becomes: What is the impact of no sleep and brief or fragmented sleep on soldier and unit performance? The amount of brief or fragmented sleep and the duration of the periods of SUSOPS determine whether CONOPS is a war winner or a war stopper, i.e., whether CONOPS increases the tempo of operations or slows the tempo of operations secondarily to the performance degradation attending extended periods of continuous work.

## 4 Differential Effects of CONOPS on Physical and Mental Performance

Tasks that require primarily physical performance are relatively immune to the the effects of sleep loss. Is it well established that sleep loss does not impair the capacity for physical endurance to any measurable extent (Martin, Bender, & Chen, 1986). The only effect of sleep loss on physical capability is a subsequent need for a slightly longer recuperative period following physical exertion (McMurray & Brown, 1984,).

The relationship between sleep loss and performance decrements on various cognitive tasks is well established. There are three mechanisms by which sleep loss causes decrements in performance: (a) by causing brief "lapses" in EEG defined wakefulness (microsleeps of 1-10 sec duration), (b) by causing a steady state of reduced arousal during EEG defined wakefulness (i.e., between "lapses") that is manifested by a reduced capacity for sustained selective attention, and (c) by lowering mood and motivation levels, thereby reducing morale and initiative. Each of these mechanisms include factors that differentially contribute to impaired performance on all tasks during sleep loss. However, the degree to which each of these mechanisms affects performance depends upon the nature of the task.

Tasks such as monitoring a radar screen or standing watch, that is, those tasks which are uninteresting and of long duration, are extremely conducive to sleep. For this reason, they are also especially sensitive to sleep loss ( Wilkinson, 1961) because those performing them are particularly susceptible to microsleep episodes. On these tasks performance decrements will be primarily the result of brief "lapses" (The Walter Reed Lapse Hypothesis, Williams & Lubin, 1967) or "microsleeps". During the lapses (microsleep episodes) performance ceases. As the duration of the sleep loss period is extended, the frequency of microsleep episodes increases, resulting in further deterioration of performance. Despite the fact that the soldier standing watch also suffers from a reduced capability to engage in higher level cognitive processing, his performance as a sentry would not be impaired to a great extent because of this reduced ability. Performance would be at adequate levels (between microsleep episodes), because the task requires minimal amounts of higher-level cognitive functioning.

As discussed above, tasks which have a large physical component (e.g., loading ammunition onto trucks), though perhaps boring and monotonous, are not conducive to sleep because physical activity is itself antithetical to falling asleep. Therefore, the soldier loading the truck is likely to be able to withstand longer periods of sleep deprivation without experiencing microsleep episodes than the soldier standing watch.

Sleep deprivation results in a steady state of reduced arousal which is manifested by a decreased capacity for sustained selective attention, and therefore a diminished capacity for efficient performance of higher level cognitive tasks (Kjellberg, 1977). Performance on cognitive tasks requiring calculations, creativity, and the ability to "plan ahead" effectively are especially sensitive to sleep Loss. Again, however, the nature of the high level cognitive task determines the extent to which performance will be impaired by sleep Loss. For example, performance on an addition task that is externally paced degrades rapidly with extended sleep loss (Williams & Lubin, 1967) but under similar sleep loss conditions accuracy of arithmetic calculations can be maintained at the expense of "speed of calculation" in self-paced arithmetic tasks (Thorne et al., 1983). The implications of these studies are particularly important for command and control personnel because the abilities that enable soldiers at all levels of command and control to respond quickly and effectively to constantly changing battlefield conditions -- abilities to quickly anticipate, recognize, and correct areas of weakness in their own defenses, as well as to anticipate, recognize, and take advantage of opportunities to seize the initiative from attacking forces -- are the abilities that will be degraded by sleep loss.

Within the realm of primarily cognitive tasks there are differential susceptibilities to the effects of sleep loss. Johnson (1982) catalogued those aspects of a given task which make it sensitive to sleep Loss:

Duration of the task. There is a positive correlation between the length of a task and its sensitivity to sleep loss. Those tasks which take a long time to complete or by their very nature require sustained concentration and effort (such as monitoring radar) are especially affected by sleep loss (Donnell, 1969; Wilkinson, 196 1; 1965).

Task difficulty. The more cognitively demanding the task, the greater its sensitivity to sleep loss. One way to increase the difficulty of a task is to decrease the time alotted to complete that task. For example, increasing the rate at which a subject is required to perform a series of mental arithmetic problems will cause performance decrements faster under sleep deprived conditions (Williams & Lubin, 1967). In many tasks, performance levels (in terms of accuracy) can be maintained under sleep deprived conditions if the speed at which those tasks are completed is slowed. On those tasks which are externally paced (e.g. coding and decoding) accuracy is compromised more quickly under sleep deprived conditions.

Feedback. Perhaps by helping to maintain interestand by providing a gauge against which performance levels can be self-monitored, tasks for which immediate feedback is given are more resistant to the effects of sleep loss.

Practice. Those tasks which have been well-learned and repeatedly practiced are more resistant to sleep loss effects.

Complexity. Those tasks which are more complex by virtue of requiring a sequence of mental operations or division of attention are especially sensitive to sleep loss.

Learning and Memory. Those tasks which require short term memory utilization are also very sensitive to sleep loss (Williams, Geiseking, & Lubin, 1966; Williams & Williams, 1966). This suggests that the soldier's ability to learn new information will also be compromised with sleep loss -- therefore the soldier's ability to learn and benefit from combat experience will be degraded if that experience occurs concomitantly with sleep loss. This aspect is particularly important during the first few hours and days of combat, when even the most highly trained but combat inexperienced soldiers go through a period of rapid learning and adaptation to the actual exigencies of combat.

Work/rest schedule. It is clear that "workload" interacts with sleep deprivation, and the presence of rest periods (without sleep) between performance tests helps to maintain performance levels during sleep deprivation. Angus and Heslegrave (1985) showed that performance on several tasks (including reaction time, logical reasoning, and encoding/decoding) decline especially quickly when subjects are required to work continuously during the sleep deprivation period. This finding is especially relevant to the present discussion because it suggests that during continuous military operations, the degree of performance impairment will depend not only on the amount of sleep loss, time of day, and the type of job being performed, but also on the degree to which the operations being performed truly require continuous concentration by the individual. Their findings suggest that even if sleep is not possible, rest periods will help slow the inevitable decline in performance which results from sleep loss.

Other Factors. In addition to the task-related factors listed above, Johnson (1982) points out that: (a) High levels of interest in the task will partially offset the deleterious effects of sleep deprivation (Wilkinson, 1964). (b) High levels of motivation can also improve performance under sleep-deprived conditions. However, it is important to note that no amount of interest, motivation, or personal effort of any kind will be completely effective in counteracting the effects of sleep loss. (c) A noisy environment, brief exercise breaks, splashing cold water on the face can all help maintain alertness. (d)

Stimulant drugs may be useful to sustain performance acutely during SUSOPS. Short-acting sleep-inducing drugs may improve the quality of sleep, thus making naps more restorative.

Regardless of the susceptibility of a particular task to sleep deprivation, sleepiness necessarily divides the attention of each soldier. In addition to fighting the enemy, the soldier is devoting some part of his personal resources to fighting sleepiness, and his motivation to perform is weakened by his conflicting motivation to sleep. Reductions in motivation and mood can have deleterious effects on virtually any task.

## 5 SUSOPS: The Impact of Continuous Land Combat With No Opportunity for Sleep on Soldier and Unit Performance

A variety of studies (both laboratory and field) indicate that after 48-72 hours without sleep soldiers become militarily ineffective. This is especially true of those with command and control responsibilities. Military effectiveness (both personal and unit) depends upon the ability to think clearly, accurately and quickly; upon initiative and motivation; and upon physical strength and endurance. As the period without sleep increases, thinking slows down and becomes confused, lapses (microsleeps) occur, and speed is sacrificed to maintain accuracy. The decline is more rapid with continuous work than with intermittent work. Mood, motivation, initiative, planning, and preventive maintenance (both personal and of equipment) decline. In contrast to cognitive performance, physical strength and endurance are relatively unaffected by lack of sleep and can be restored by simple rest. However, sleep is required to restore cognitive performance. The militarily relevant studies are described in some detail below.

### 5.1 WRAIR 72 Hour Sleep Deprivation Study

A 72 hour laboratory-based total sleep deprivation study was conducted at the Walter Reed Army Institute of Research (WRAIR) (Thorne et al., 1983; Babkoff et al., 1985). Subjects were required to perform a variety of cognitive tasks for at least 30 minutes out of every hour, for 72 consecutive hours. The tasks, ranging from simple to complex, included letter search, addition, logical reasoning, memory, serial addition and subtraction, pattern recognition, complex verbal processing, and vigilance. A throughput measure (the number of correct responses per unit time; effectively the product of speed and accuracy) was used to measure output of work. Also measured were affect and activation (motivation and initiative). Performance on all cognitive tasks deteriorated at the same rate and closely paralleled the decline in mood, motivation, and initiative. Performance on the cognitive tasks declined 25% for every 24 hours of semi-continuous work without sleep. As the subjects became more tired, the cognitive testing which initially took only 30 minutes out of each hour took longer and longer to complete so that by the end of the 72 hours the subjects were working continuously. Superimposed upon the linear decline in cognitive performance was a cyclic variation correlated with circadian fluctuations of body temperature.

### 5.2 USARIEM Artillery-Fire Direction Center Study

A study of sustained operations in Artillery Fire Direction Center (FDC) teams was conducted by the United States Army Research Institute in Environmental Medicine (USARIEM) (Banderet et al., 1981). In this study, FDC teams from the 82nd Airborne Division participated in a realistic laboratory simulation of FDC operations, including unplanned targets, pre-planned targets and concurrent fire missions -- often with superimposed calls for pre-planned fire. The simulation was designed with assistance from the U.S. Army Field Artillery School and created battle using 1:50,000 scale maps following current U.S. Army doctrine for light infantry with armored cavalry advancing against a well-equipped screening force.

Degradation of performance was evident within the first 24-48 hours. No team lasted beyond 48 hours, all teams having elected to withdraw from the study by this time. Teams made more errors as time passed but generally remained militarily effective until the time of their withdrawal. Of particular interest was the type of error that occurred. Performance of individual self-initiated activities (e.g., working out pre-planned fire missions, revising preplanned data on the basis of new information, and keeping up the situation map) deteriorated most. Early in the simulation, pre-planned targets were decoded and calculated upon receipt, causing no disruption of activities when called for during concurrent unplanned fire missions. However, later in the simulation, during a concurrent unplanned fire mission with both charts operating, the call for a pre-planned target (in effect requiring a third chart), produced disorganization and delay. After 36 hours, much of the pre-planned target processing was never completed even for priority targets. In general, planning activities deteriorated markedly. Similarly, early in the simulation the situation maps were well maintained by the Fire Direction Officer (FDO), allowing him to be aware of the tactical situation. Toward the end of the simulation, situation maps were not kept up and targets became simply grid coordinates. Appreciation for the tactical situation (nature and value of the target) was lost.

It should be noted that leadership and FDC cohesion clearly made a difference in performance of the teams. Those teams in which leadership and cohesion were good functioned better and persevered in the simulation longer.

### 5.3 HumRRO ENDURE Tank Crew Studies

The Human Resources Research Organization (HumRRO) conducted a field study (ENDURE II) of selected tank crew activities during 48 hours of sleep deprivation (Ainsworth & Bishop, 1971). Twenty B-man tank crews did four successive repetitions of a It-hour tactical armor problem, including offensive, defensive and retrograde movements for a 48-hour SUSOP. (Although the authors do not report it, we presume the tank used was an M60, but it is possible that it may have been an M48). Time and performance accuracy were measured at specified points along a 35 mile problem course for tank crew radio telephone procedures, obstacle course driving, detection and identification of targets, returning fire to machine gun attacks enroute, performance on dynamic gunnery exercises, and routine operator-level tank maintenance. Ten 4-man crews serving as a control group repeated the 12-hour exercise on four separate days but with 24-hour rest breaks between trials.

Tank crews were able to perform the communication, driving, surveillance, gunnery and maintenance tasks without serious performance decrements during the 48-hour period without sleep. Specifically, over time, some control group communication measures showed slower response times; the experimental group showed slightly slower slalom driving task performance; and both groups improved in traversing a minefield. Whereas the control group's passive surveillance performance showed a slight improvement, the experimental group's degraded slightly in that it not only took them longer to detect targets but they made more errors of omission. As for moving surveillance, the control group improved, while the experimental group showed an initial decrement and then gradually improved as the study progressed. The groups did not differ when firing the tank main gun at stationery targets, but did take slightly longer to engage targets with artificial illumination at night. Both groups exhibited a slight improvement over time in firing machine guns on the move and in firing from a fixed position at moving targets. Sleep loss had no effect, but night visibility did, on performance of routine tank maintenance tasks.

The authors concluded that activities demanding a protracted high level of alertness or complex perceptual-motor activity, such as the moving surveillance and some driving tasks, are the most sensitive to the adverse effects of loss of sleep, and that tank crew performance was not significantly affected by circadian periodicity. This field experiment indicates tank crews can be expected to perform quite acceptably for a 48 hour stretch without sleep, but it is likely they will experience some degradation in surveillance activities, and in general will slow down their overall performance of tasks.

### 5.4 APRE Early Call and Reiated Studies

A series of field and laboratory studies of continuous operations have been conducted by the Army Personnel Research Establishment (APRE) of the Ministry of Defence of the United Kingdom.

In Early Call I, three platoons of light infantry (from the Parachute Regiment) participated in a field study of continuous infantry operations (Haslam et al., 1977; Haslam, 1985b). One platoon was allowed no sleep, one platoon was allowed 1.5 hours sleep, and one platoon was allowed 3 hours of sleep per night. The exercise was organized into a series of controlled retrograde movements with the three platoons digging-in, defending and patrolling, then moving to a new position and digging-in again. Experienced military officers continuously evaluated the military effectiveness of the platoons. In addition, the men were given periodic cognitive tests and tests of strength and endurance.

The results were clear. The platoon allowed no sleep was judged to be militarily ineffective after 3 nights without sleep. The platoon sleeping 1.5 hours per night was judged to be militarily ineffective after 6 days. The platoon sleeping 3 hours per night remained militarily effective for the entire 9 days of the exercise. Performance on cognitive tests paralleled the decline in military effectiveness for the 0 and 1.5 hour sleep platoons. The effects of sleep deprivation were primarily mental rather than physical; mental ability and mood deteriorated but physical parameters did not. Thus, in contrast to overall military effectiveness and cognitive performance, physical strength and endurance remained relatively unaffected. In all platoons, sooner or later depending upon the amount of sleep obtained, self-care (e.g. changing socks, keeping dry and eating) and planning (e.g. planning for patrols) deteriorated.

It is worth noting that the leader of the platoon allowed 1.5 hours of sleep per night was an experienced NCO, who had seen extensive action in Malaysia against communist guerillas. His leadership reduced voluntary withdrawals from the 1.5 hour sleep platoon and as a result over half of the platoon finished the 6 day exercise. However, as excellent as his leadership was, his platoon failed to perform as well as the indifferently-led 3-hour sleep platoon. Thus; it can be concluded that while under equivalent sleep deprivation conditions, a well-led unit may outperform an indifferently led one, superior leadership cannot overcome large quantitative differences in the amount of sleep obtained or lost.

In Early Call 11, soldiers were deprived of sleep for 90 hours (3.75 days of continuous activity), and then allowed 4 hours sleep each night for the next 6 days (Haslam, 1978). The purpose of this trial was to assess the effect of brief sleep on performance after a period of prolonged sleep deprivation. The soldiers in Early Call II showed initial decrements in vigilance, cognitive performance and mood after 24 hours without sleep, as did the totally sleep deprived soldiers in Early Call I. Marked decrements in cognitive performance were evident after 72 hours (falling to 35% of control values) and at that point they were judged to be militarily ineffective. The introduction of 4-hour blocks of sleep had a beneficial effect upon mood and performance. After the first 4-hour block of sleep, performance improved to 60% of control values and after the third Q-hour block of sleep, performance improved to 80% of control values. For the remaining 3 days of the trial performance remained above 80% of control values. The exception to this overall positive effect was the performance on the cognitive tests initiated immediately after awakening. Performance immediately upon awakening remained low even after several nights in which 4 hours of sleep were obtained. These performance decrements were undoubtedly the effects of sleep inertia.

In subsequent studies (Haslam, 1982, 1985a) the utility of obtaining 4 hours of sleep within each 24 hour period for restoring and sustaining performance was confirmed. Data also indicated that 4 hours of sleep divided into 4 one-hour blocks was as restorative as 4 hours of continuous sleep. Further, even after 3 days without sleep, the anticipation of a 2-hour nap produced a substantial improvement in performance.

### 5.5 DCIEM Continuous Work Study

A series of Laboratory studies have been conducted by the Defence and Civil Institute of Environmental Medicine (DCIEM) of Canada. In these studies subjects were required to do continuous work for 54 hours (Angus & Heslegrave, 1985). The work simulated the message traffic and information processing typical of a brigade headquarters. Using this experimental setting of continuous work with embedded testing, the authors found larger decrements in performance sooner than had been found in studies employing intermittent testing. They found performance dropping to 70% of baseline after 24 hours of continuous work and falling to 40% of baseline after 48 hours of continuous work. Of interest is the stepwise shape of this decline. Performance remained relatively stable and near baseline for the first 18 hours, declined over the next 6 hours to 70% of baseline, then remained stable at 70% for the next 18 hours, then declined over the next 6 hours to 40% of baseline, and again remained stable at 40% after that. Declines in mood and motivation and increases in subjective reports of sleepiness paralleled the decline in performance. The stepwise decline in performance over successive nights without sleep occurred in association with the normal circadian trough in performance (0300-0600). This indicates that the circadian trough serves to "harvest" the performance deficits accruing from total sleep deprivation. Various “fixes” were tried (e.g. brief periods of rest or exercise, higher levels of pre-study fitness) but these did not materially affect the rate or degree of degradation in performance.

### 5.6 USAARL Studies of Pilot Fatigue

In the first of two U.S. Army Aeromedical Research Laboratory (USAARL) studies of pilot performance during extended flight operations, six aviators flew a UH-1 utility helicopter for 11 & 1/2 hours per day on each of five to-hour work days with 3.5 hours of sleep per night (Kimball & Anderson, 1975; Lees et al., 1979). Pilots flew each of 32 different maneuvers once per hour during the flight portions of their workday. In a second study, pilot-copilot crews flew 14 instrument helicopter simulator hours per 20-hour workday for 5 days, sleeping about 4 hours each night (Krueger, Armstrong & Cisco, 1985).

These studies required numerous 1 and 2-hour periods of continuous precision psychomotor control, compensatory tracking performance, decision making (e.g. the complex judgments required in day and night helicopter flight), navigation, take-offs and landings and the performance of a variety of emergency procedures. . Contrary to predictions by certified Army instructor pilots and several experienced flight surgeons, all twelve pilots completed the five-day studies without incident.

Even with intensive pre-training, pilots improved their performance during the first two to three days of the testing (a psychomotor skill development practice effect associated with doing something so repeatedly). Generally, all the pilots flew acceptably well into the third, and in most cases into the fourth and fifth days; all flight missions were successfully completed. The psychomotor portion of the testing did not degrade to unacceptable levels of flight performance; but by about the fourth day of the test pilots appeared to adopt a more passive flight control strategy by making less frequent but larger cyclic control inputs (responding to obvious need for control change rather than "actively controlling" the helicopter as they did when they were fresh and more alert). More importantly, by the fourth day in both studies, pilots at the controls made occasional errors of omission (e.g. forgetting to make safety or communication checks, or neglecting to make a needed turn at familiar spots on a well learned route) and simulator copilots occasionally fell asleep in their less active role as navigator. Pilot fatigue ratings increased, mood degraded and they exhibited irritability by the middle of the fourth day of the extended work schedule.

These studies indicate that with just 3.5 to 4 hours sleep per night, well trained highly skilled soldiers can successfully control and maneuver complex man-machine systems for 12-14 hours a day for at least 5 days.

### 5.7 ARI Model Study

Estimates of performance effectiveness were derived by the U.S. Army Research Institute (ARI) from a 5-day simulated engagement which studied the effects of fatigue, diurnal rhythm, light level and psychological stress on the performance of critical military tasks for duty positions in various types of units. Overall performance of the the squad leader and the platoon leader of mechanized infantry and armor units, respectively, showed the effects of sleep deprivation. Additionally, when performance was looked at as a function of type of combat activity, those activities which were estimated to deteriorate the most due to fatigue were the ones with the most embedded cognitive components (e.g. acquiring and tracking targets would decrement more than firing a main gun and loading). These results are commensurate with other studies.

### 5.8 Insights on the Effects of SUSOPS on Performance

The studies described above indicate that soldiers and units can remain militarily effective for 2-3 days without sleep. Cognitive abilities degrade more rapidly than physical strength and endurance and thus are the weak link in the chain of human performance in SUSOPS. With continuous work, degradation in cognitive performance can be seen as early as 18 hours into a SUSOP. These decrements in cognitive performance take the form of decline in output of useful work per unit time (throughput) and generally subjects sacrifice speed for accuracy as the time spent working continuously increases. The decline in performance in continuous work without sleep is at least 25% for every 24 hours of operation, with the drop in performance occurring in stepwise fashion in the early morning (0300-0600). Initiative and motivation decline in parallel to cognitive performance. Thus pre-planning, preventive maintenance and self-care are impaired.

The differences in susceptibility to effects of sleep deprivation are related to task-ability considerations; that is, those duty positions which comprise critical tasks requiring the use of cognitive skills will degrade more, and more rapidly, than those having more of a physical component (e.g. loader in a tank). Well-practiced, routine motor tasks would be freer from decrements than tasks requiring encoding/decoding, reasoning, concentration and vigilance skills. Thus loading a magazine or marching would be more resistant than map reading.

Expecting soldiers and military units to maintain acceptable levels of intense effort during continuous or sustained operations has very important performance and behavioral implications. Soldiers who work continuously for long periods of time can in aggregate produce a great deal; but as the work shift extends, they also get tired, begin to slow down, miss important signals, make mistakes, are more likely to become involved in accidents, judge things differently, change the way they do or do not do things, become irritable, and sometimes fall asleep on duty. Understanding what to expect in such situations can help take advantage of the best soldiers have to offer and also to plan effective countermeasures to anticipated degradations of performance.

Generally, if a person works for 14-16 hours, rather than the 8-10 of a normal duty day, we expect him to produce a greater quantity of work. Our own experiences tell us that. But, we also sense that at some point during that longer work stint the quantity of effort per unit time, and the quality of what we do are no longer as good. This seems especially true if we maintain such a schedule for many days in succession. If a person is expected to work 18-24, or even 32, 48 or 72 hours with few breaks and no rest or sleep, we expect performance to be markedly affected. Studies show that we can expect a noticeable deterioration in performance on monotonous tasks like vigilance, or on any newly learned task after 18 hours or so; a deterioration in ability to register and understand information anytime after 24 hours; generally a 75% degradation of performance on most tasks after about 72 hours; and usually, we can predict much lower performance between 0300 and 0600 hours each day.

We are likely to have different expectations of people asked to perform simple vigilance tasks (e.g. being on guard duty) or to shoot a rifle, or to align tank gun sights, or to fly a helicopter at nap-of-the-earth at night, or to watch a radar scope in air traffic control or air defense, or to perform arithmetic calculations and plot coordinates on a map for artillery fires, or perform maintenance on a tank, prepare and deliver food, or ultimately, in the case of command and control personnel, to devise and execute the battle plan.

These findings suggest that command and control functions will be particularly impaired in a SUSOP. Since excellence in command and control is crucial to effectiveness in maneuver warfare, and since command and control functions are very similar qualitatively (if different in scale) from the level of the corps down to the level of the tank and infantry squad, SUSOPS will degrade performance at all levels.

### 6 CONOPS: The Impact of Continuous Land Combat With Opportunity for Brief or Fragmented Sleep on Soldier and Unit Performance

The exigencies of continuous operations during modern conventional war are likely to dictate that the soldier's typical total sleep time (normally 6-8 hours of sleep each day) will be reduced. As with total sleep loss, the most pronounced and predictable effect of partial sleep loss is increased sleepiness. In general, the greater the reduction in sleep time each night, the greater the sleep debt and subsequent sleepiness. There are, however, wide individual differences in the amount of sleep required each night. Some individuals require less than 3.5 hours (Meddis, Pearson, & Langford, 1973; Jones & Oswald, 1968) while others require 10-12 hours of sleep each night (Hauri, 1982).

**However,** the vast majority of adults require 6-8 hours of sleep each night to maintain adequate, normal levels of daytime arousal. Normal adults are capable of reducing their total sleep times by as much as 1-2.5 hours below baseline for several months without affecting performance on most tasks, but chronic fatigue (with its attendant loss of motivation and initiative) is the price that is paid (Friedman, Globus, Huntley, Mullaney, Naitoh, & Johnson, 1977). Chronic restriction of sleep length to less than 4.5 hours each night is not possible -- this is the lower limit of sleep length plasticity for most individuals, and failure to obtain at least 4-4.5 hours of sleep each night results in the rapid deterioration of mood, motivation, and performance on even the simplest of tasks.

It is important to note that even on restricted sleep schedules which allow more than 4.5 hours of sleep per night, there is a cumulative sleep debt manifested by gradually- increasing daytime sleepiness which may be tolerated for several days or even weeks, but that sleep debt is never satisfied until recovery sleep is obtained. In other words, under sleep restricted conditions, sleep debt can continue to accrue albeit at a slower rate than under total sleep loss conditions (see Figure 1).

In summary, (a) sleep restriction regimens which allow more than 4.0-4.5 hours per night can be tolerated for extended periods without rapid deterioration in performance levels, however, sleep debt continues to accrue and is never reversed on these sleep schedules; (b) when less than 4.0-4.5 hours of sleep is allowed each night, performance decrements are rapid and severe. This level of sleep restriction represents a physiological limit beyond which further reductions in total sleep time are not possible for most people.

### 6.1 Adaptation to Restricted Sleep

There is no objective evidence of adaptation to restricted sleep schedules, though subjectively, some adaptation may occur (Carskadon & Dement, 1979; 1981). T'hat is, although sleep debt continues to accumulate on a regimen of restricted sleep, subjective estimates of sleepiness may start to level off after several days of restricted sleep. This increases the potential dangers associated with sleep loss because it suggests that the soldier's ability to accurately estimate his own degree of impairment declines with continued sleep loss.

There is no evidence that prior experience with sleep loss in any way inoculates individuals against the deleterious effects of sleep loss on performance in subsequent sleep deprivation situations. In fact, evidence indicates that performance actually deteriorates across sleep deprivation sessions (Webb & levy, 1984; Wilkinson, 196 1), most likely because of decreased motivation levels concomitnt with reduced "novelty" of the sleep loss situation or diminished interest in the challenges incurred in sleep loss situations. It is not likely that soldiers would suffer from reduced levels of motivation in actual combat situations, so prior experience with sleep loss should not have deleterious effects on soldiers' combat effectiveness. However, these findings suggest that training soldiers under sleep loss conditions is not likely to be effective in improving performance under subsequent sleep loss conditions. Soldiers who participate in exercises involving the stress of sleep loss will not acquire skills or coping strategies which will allow them to better withstand the effects of sleep loss in the future. The advantage of conducting training exercises under conditions of sleep loss is that it allows assessment of each individual's performance under these conditions and indicates where training and preparedness may be deficient. Ability on tasks which a soldier can perform "passably" during normal alertness might be severely compromised during the stress of sleep loss.

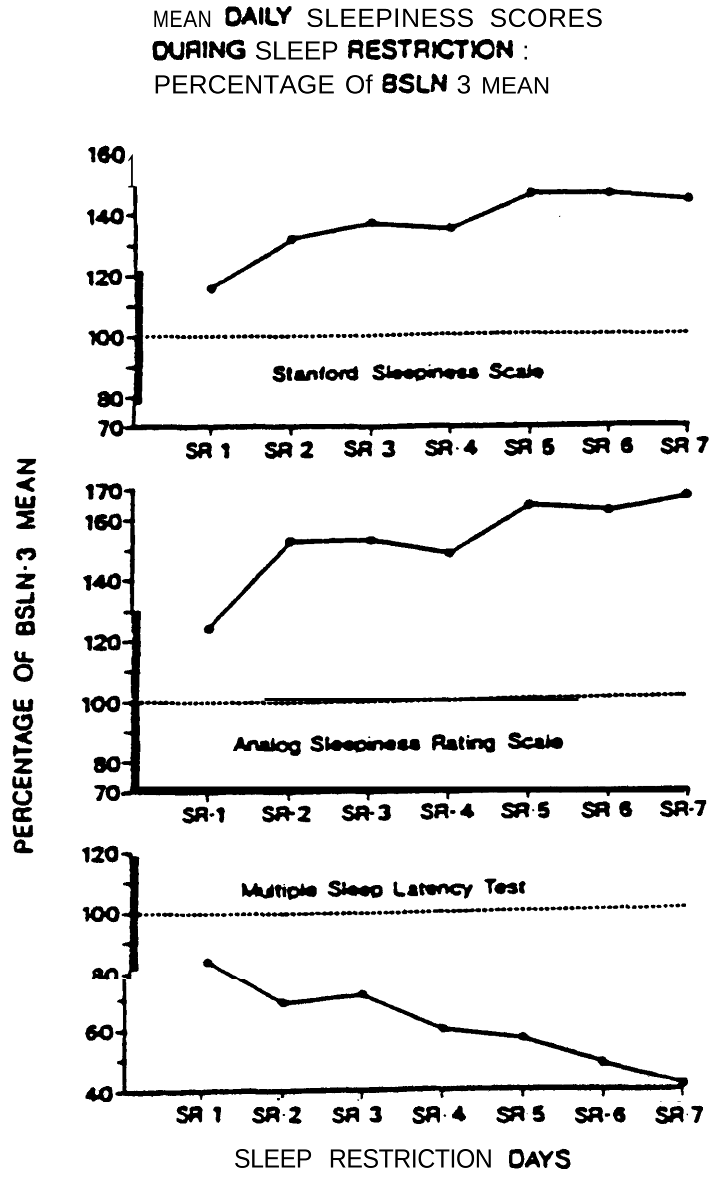

Figure 1. Sleepiness measures for the 7 sleep restriction days are displayed as percentages of the BSLN-3 day mean scores. The SSS scores increased significantly above (sleepier) baseline on the first sleep restriction day and reached a plateau after SR-4. A similar finding was seen-for the analog sleepiness rating, which differed from BSLN-3 on the second SR day and reached a plateau after SR-4. Multiple sleep latency test scores were significantly reduced on SR-2 and showed further reductions on each of the sleep restriction days. From Carskadon and Dement ( 198 1).

Training soldiers to the point where they can perform their tasks with relative ease under conditions of normal alertness will help them maintain performance levels during subsequent sleep loss conditions.

### 6.2 Effects of Fragmented Sleep

During those few and precious opportunities for sleep, it is likely that the modern soldier involved in continuous combat operations will be attempting to sleep in environments which are noisy and dangerous. In addition, it is possible that the soldier will be repeatedly awakened and required to perform various tasks as the need arises. Therefore, in addition to reduced total sleep time, the soldier is likely to experience the added effects of sleep fragmentation (defined as repeated arousals or full awakenings from sleep). The recuperative value of sleep is dependent not only upon the total amount of sleep, but also upon the continuity of that sleep (Stepanski, Lamphere, Badia, Zorick, & Roth, 1984). The higher the rate of fragmentation, the lower the recuperative value of the sleep even when total sleep times are held constant. Roehrs, Levine, Stepanski, Clark, Wittig and Roth (1986) showed that sleep which is fragmented at rates greater than once every 5 min has severely compromised recuperative value. The smallest time unit in which the recuperative value of sleep is realized is not known. However, maximal recuperative value is obtained from sleep which is minimally fragmented.

To some extent prior sleep loss will help prevent arousals to external stimuli during subsequent sleep (Balkin & Badia, 1985), and therefore help protect the soldier from being disturbed by environmental events that would normally induce arousals. That is, those soldiers who are excessively sleepy before they fall asleep will require greater intensities of environmental stimulation to arouse or awaken them from that sleep. However, the number of arousals is more important than the degree of arousals in determining the recuperative value of sleep (Stepanski et al. 1984). Therefore, even if a particular stimulus that would typically awaken a soldier for 30 sec now only results in 2-sec "speeding" in the sleeping EEC, the recuperative value of that sleep would still be compromised to the same extent because the continuity of the sleep would be compromised equally by both events.

Therefore, (a) Sleep fragmentation reduces the recuperative value of sleep. To maximize its beneficial (recuperative) value, sleep should occur in environments which are as safe and free from external noises as possible, and awakenings or arousals should be avoided or as widely spaced as possible. (b) Prior sleep loss will reduce the arousability of the sleeping soldier and to some extent protect his sleep from fragmentation by environmental noises. However, mild arousals are just as devastating to sleep continuity as full awakenings, and the apparent ability of a sleepy soldier to sleep in loud, noisy environments can be deceptive. Mild arousals caused by environmental stimuli may be detectable only with EEG tracings. Therefore, a 4-hour nap in a quiet environment can be expected to yield more recuperative value than a 4-hour nap in a noisy environment.

### 6.3 Effect of Sleep Timing

As shown in Figure 2, alertness varies with time of day with a trough in alertness occurring in the early morning (0300-0600) and a peak in alertness in the early evening (1600-1900). Under conditions of mild sleep loss (of less than 7.5 hours but more than 4.5 hours of sleep obtained each night) this circadian rhythm remains evident for several days (e.g., Akerstedt & Gillberg, 1981) but with severe or continuous sleep loss, alertness levels remain lowered at all times of the day.

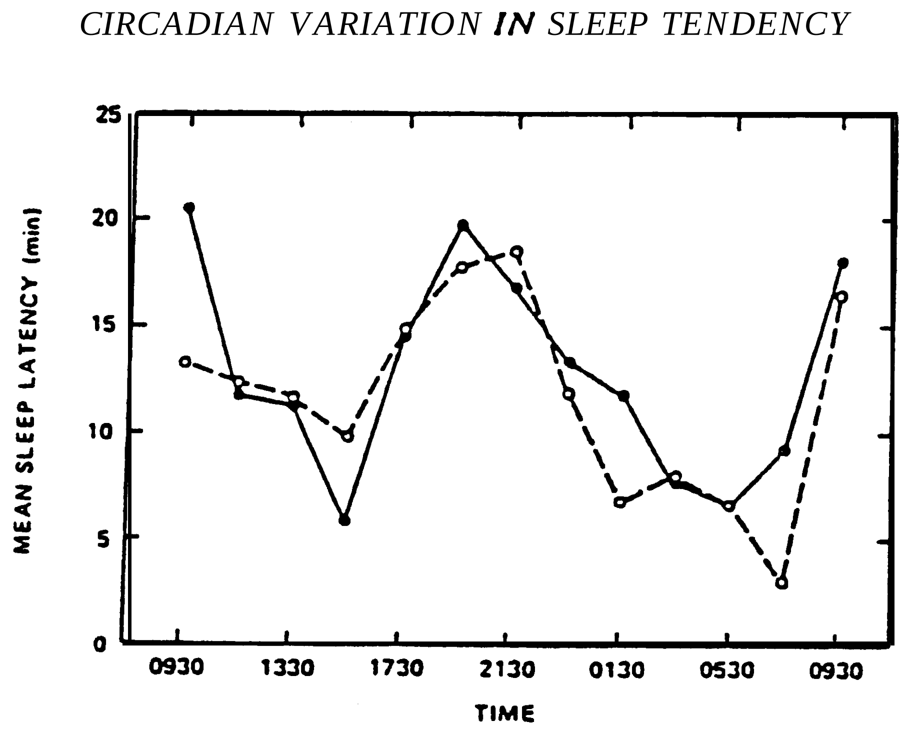

Figure 2. Mean’ sleep latency in minutes for young (open circiles, n=8) and old (filled circles, n=10) subjects as a function of time of day. Nocturnal sleep period was from approximately 2330 to 0700 hours. (From Richardson et al., 1982)

Haslam et al.'s (1977) Early Call I study demonstrated that mood, ability to “survive” the 9-day exercise, and observer rated military effectiveness depended on the amount of sleep obtained in each 24 hour period. However, the placement of sleep within the circadian cycle also determines the recuperative value of that sleep. For example, Gillberg (1984) compared the effectiveness of 1-hour naps occurring at 2100 and 0430 in reversing the deleterious effects of sleep loss on a visual reaction time task, sleepiness ratings, and sleep latency tests. He found that naps at both times were effective in reversing the effects of sleepiness, but the 0430 nap (which is when a circadian trough in alertness is typically seen) had more recuperative value than the 2100 nap (which is when a peak in alertness occurs).

In addition to restoring performance levels following sleep Loss, naps can also provide a prophylactic effect against subsequent sleep loss. Nicholson, Pascoe, Roehrs, Roth, Spencer, Stone and Zorick (1985) found that 4-hour naps in the early evening prior to all-night sleep deprivation, or in the morning following all-night sleep deprivation, had beneficial effects on daytime performance. Though the sleep at these times was Less efficient than normal (i.e., it contained more wake and stage 1 sleep than normal) performance was improved by naps at both times. Dinges, Orne, and Orne (1985) extended these findings by showing that naps taken early in the sleep loss period (before significant sleep debt has accumulated) are more effective than naps taken later in the

. sleep loss period for preventing performance decrements, regardless of whether those naps are obtained at the peak or the trough of the circadian cycle of alertness.

Therefore, (a) Sleep occurring at any point in the circadian cycle will have some recuperative value, but (b) the most recuperative value will be gleaned from sleep periods occurring during the troughs in the typical circadian rhythm of alertness. (c) Naps taken earlier in the sleep loss period are more effective at preventing performance decrements than naps taken late in the sleep loss period, regardless of the time of day that these early naps occur. Therefore, for 'preventative napping" time-of-day is unimportant, but as sleep debt accrues, the time at which the "recovery nap" is taken becomes more relevant, with greater benefits realized from naps taken during the circadian trough in alertness.

### 6.4 Importance of Sleep Stage

By convention, sleep has been divided into five stages: 1, 2, 3, 4, and REM (rapid eye movement sleep) based on salient changes in the electroenceohalogram (EEG), electromyogram (EMG), and electrooculogram (EOG) that occur periodically throughout the nighttime sleep period (Rechtschaffen & Kales, 1968). In studies using selective sleep stage deprivation procedures it has been repeatedly demonstrated that the various sleep stages do not differ with respect to their recuperative value (Agnew, Webb, & Williams, 1967; Johnson, Naitoh, Moses, & Lubin, 1974; Lubin, Moses, Johnson, & Naitoh, 1974). The one exception is stage 1 sleep, which is actually a stage of transition between wakefulness and sleep, and has been shown to have' virtually no recuperative value (Stepanski et al., 1984).

Sleep inertia effects are performance decrements which are evident immediately upon awakening, and which persist for 15-30 minutes after awakening from normal sleep (Lubin, Hord, Tracy, & Johnson, 1976). Sleep inertia effects are evident for a wide variety of tasks (for a review see Dinges, Orne, & Orne, 1985). Measures of cognitive performance are particularly sensitive to sleep inertia effects (Akerstedt & Gillberg, 1979; Bonnet, 1983) but physical performance is also impaired immediately upon awakening from sleep (Jeanneret & Webb, 1963). For reaction time tasks, sleep inertia effects are more pronounced when the sleep stage from which the subject is awakened is stage 3 or 4 (these stages, collectively referred to as slow wave sleep (SWS) predominately occur during the first few hours of nighttime sleep). For cognitive tasks, the amount of stage 3 or 4 obtained within the sleep period is positively related to the amount of impairment seen immediately upon awakening, regardless of which sleep stage was present at the time of awakening (Dinges, Orne, Evans, & Orne, 1981).

Following recovery sleep (i.e., sleep subsequent to sleep deprivation) sleep inertia effects are more pronounced and can actually result in performance levels which are the same as (Naitoh, 1981) or lower than (Fort & Mills, 1972; Rosa, Bonnet, & Warm, 1983) performance levels of subjects who are not allowed to obtain any recovery sleep . Short sleep periods (naps) obtained during continuous operations (and therefore during a period of sleep loss) are likely to contain large amounts of stage 3/4 sleep regardless of when those naps occur since this is the stage of sleep that typically rebounds first (Agnew et al., 1964). Under the sleep loss conditions of continuous operations, naps which occur during the circadian troughs in alertness (0300-0600) produce more profound sleep inertia effects (Dinges et al., 1985). This produces a dilemma, since (as described above) naps which occur at the circadian troughs in alertness also have the most recuperative value. Therefore, if given the opportunity to chose the soldiers' sleep times, consideration should be given to the likelihood that the soldier will have to awaken and perform cognitive/physical/skilled tasks on very short notice. This should be weighed against the advantages that sleeping during the circadian trough in alertness affords, i.e., more recuperative value per unit of time spent asleep.

In summary, (a) Except for stage 1 sleep, ail sleep stages appear to possess equal recuperative value. (b) However, sleep inertia effects are more pronounced upon awakening from stages 3 and 4. (c) Sleep inertia effects are also more pronounced upon awakening from naps which occur during the circadian trough in alertness.

### 6.5 Effects of Circadian Rhythms

In well rested individuals circadian oscillations in body temperature are associated with a 10% variation in performance over the course of 24 hours, with a tendency to low values in the early morning. With increasing sleep deprivation, the same oscillations in body temperature are associated with a 20-40% variation in performance, with a peak in the early afternoon and a trough in the early morning (Bugge et al., 1979).

### 6.6 Effects of Age

The evidence suggests that the degree to which sleep loss impairs performance on a variety of tasks (e.g., cognitive and vigilance tasks) increases with age (Webb & Levy, 1982). Although it is also known that the amount of SWS obtained also decreases with advancing age, the implication that this may indicate an increased resistance to sleep inertia effects has not been tested.

### 6.7 Effects of Prior Brief or Fragmented Sleep on Subsequent Performance During SUSOPS

Partial prior sleep deprivation diminishes reserves for coping with a subsequent SUSOP. In following a demanding schedule of continuous work coupled with restricted sleep (e.g. a continuous cycle of 4 hours of work followed by 2 hours of rest) a soldier will use up his performance reserve and be less resilient in the face of the demands of emergency conditions such as those imposed by a prolonged (e.g. 24-48 hour) SUSOP (Alluisi, 1969). In SUSOPS in general, the cumulative effect of workload may lead to unpredictable and catastrophic human failure (O'Donnell & Eggemeier, 1983). In long range deployments such as from CONUS to Central Europe or Southwest Asia, soldiers are likely to suffer partial sleep deprivation during the 2-3 days of preparation prior to deployment, and thus may arrive in theater with diminished resiliency and suffer more than expected degradation in combat effectiveness if initial combat takes the form of a SUSOP.

### 6.8 Effects of Chemical Protective Clothing (MOPP Gear]

The battlefield of the next war may include the use of chemical munitions. Just as soldiers must be prepared to fight under other than ideal conditions, such as at night or in the rain, they must be able to operate in a chemically contaminated environment. One important means of protection against the use of chemical agents is the use of chemical protective clothing, consisting of an overgarment, mask with hood, overboots, and gloves. The military categorizes various degrees of wearing such apparel as Military Oriented Protective Posture (MOPP) and thus the clothing is commonly referred to as MOPP gear. This protection may have disadvantages if endurance is limited and performance on military tasks is decremented due to the heat-containing and bulky nature of the suit. For example, the following representative activities are difficult to perform (to varying degrees) in MOPP gear: eating, sleeping, elimination of bodily wastes, communication, tasks involving manual dexterity, use of tactile sense, rifle firing, and maintenance of weapons and vehicles. An equally important consideration is the endurance capability in the suit, especially in a hot environment; CONOPS could be compromised if individual endurance is limited.

A recent U.S. Army research program called $P^2NBC^2$ included field studies of the ability of combined arms crews (tanks, howitzers, and infantry fighting vehicles) *to* perform and endure while in MOPP gear under various temperature and battle-realistic scenarios. General findings include: (1) Accuracy in the performance of military tasks is maintained at the expense of speed; for example, round-firing accuracy of howitzer crews in the suit was equal to that of a control crew, but time to fire the first round of a fire mission, as well as inter-round latencies within missions, were increased. (2) Hot and/or humid environmental conditions limit endurance; for example, tank crews, operating under a variety of conditions including "buttoned-up" tanks, lasted 3.3 to 16.7 hours. Howitzer crews, working under extreme heat conditions, remained operational for 2-4 hours. (3) Doctrinal measures which influence endurance include short rest breaks and suit changes every 6 hours, food, and a 6-hour sleep period; these conditions allowed infantry fighting vehicle crews to last approximately 60 hours, equal to their time spent in a control condition. When the rest breaks, food, and MOPP gear changes, but not the sleep periods were removed from the scenario, other infantry fighting vehicle crews lasted from 31.4 to 37.9 hours. Habituation and training in MOPP gear appear to be important doctrinal strategies.

### 6.9 The Nature of Optimum Alertness in CONOPS

The average young adult sleeps 7.5 hours a night. If he sleeps less, he then is more likely to be less alert during the subsequent day and has a tendency to nap, particularly in the late afternoon. Alertness can be measured by the Sleep Latency Test. In this test, the subject is told to take off his shoes, lie down on a bed in a dark, quiet room and to try to sleep. The subject has EEG and EMG electrodes on. The sleep latency is the interval from the time he lies down to the time he falls asleep (enters Stage I sleep by EEG/EMG criteria). He is immediately awakened and thus in actuality sleeps no more than 30 to 60 seconds. This test can be repeated at 2-hour intervals to constitute a Multiple Sleep Latency Test (Carskadon & Dement, 1979,1981).

The Multiple Sleep Latency Test can be applied to objectively measure alertness. The average young adult having slept 7.5 hours the night before will have a sleep latency of 10-12 minutes. If he has slept less, especially over the previous several days, his latency will be shorter, generally in the 7-8 minute range. If he has been deprived of all sleep for one or two nights, his sleep latency will be 1-2 minutes. If he is sleep deprived for more than two nights his sleep latency will be a minute or less. Thus three or more nights without sleep produces maximum drowsiness (minimum alertness). Similarly, partial sleep deprivation over a longer period (e.g. sleep restricted to 5 hours a night for 7 days) will lead to maximum drowsiness (i.e. a sleep latency of less than 1 minute). Thus sleep debt is cumulative and eventually results in maximum drowsiness and minimum alertness. Drowsiness impairs initiative and motivation and is associated with slowed thinking and lapses in attention. In the Multiple Sleep Latency Test the subject is left in the dark, quiet room until he falls asleep or until 20 minutes have elapsed. If he has not fallen asleep in 20 minutes he is said to be maximally alert. The young adult who sleeps 9 hours and 45 minutes a night for one or two nights will not fall asleep during the Multiple Sleep Latency Test and is by this criterion maximally alert.

The ends of the spectrum of alertness are well defined. Maximum alertness is a sleep latency of greater than 20 minutes; minimum alertness is a sleep latency of less than 1 minute. Optimum alertness is somewhere in between and depends on the task at hand. Most young adults voluntarily restrict their sleep to 7.5 hours a night, substantially less than the 9.75 hours necessary to sustain maximum **alertness.** Thus they are to a degree always drowsy during the day and on the Sleep Latency Test will fall asleep in 10-12 minutes.. Young adults restrict their sleep to less than that required for maximum alertness presumably because they are able to accomplish more in aggregate being up and about for two hours more each day even if mildly drowsy than by being awake for two hours less each day albeit maximally alert.

### 6.10 Insights on the Effects of CONOPS on Performance

The above studies implicitly or explicitly indicate that within definable limits increasing the length of time awake **and** engaged in continuous work increases the aggregate output of work. In maneuver warfare, this quantitative increase in output can lead to qualitative differences in battle outcome. However, if these definable limits are exceeded then the point of diminishing returns is reached and passed **and** aggregate output declines, with the potential for catastrophic failure. These definable limits are, relative to the spectrum of war duration, relatively narrow. For SUSOPS, the limits are between 2 and 3 days. For CONOPS with minimal sleep (i.e. less than 3 hours in 24 hours) the limit is **several** days to a week. For CONOPS with moderate sleep to completely adequate (i.e. 4 or more hours sleep in each 24 hours) the limits are on the order of 2+ weeks depending on the actual amounts of sleep obtained. Such limits are likely to apply to all levels of command and control, but generally to be narrower for the older soldier.

## 7 Recommendations and Conclusions

CONOPS for the U.S. Army is continuous land combat with opportunity for brief or fragmented sleep interspersed with periods of SUSOPS when no sleep is possible. CONOPS can be a war winner if a doctrine for managing sleep and alertness is developed and implemented. This doctrine should in part be based upon the following insights gleaned from studies of continuous **and** sustained operations. Cognitive performance is more sensitive to the effects of brief, fragmented or no sleep than physical strength and endurance. So those elements of military operations involving cognitive abilities (e.g. command and control at ail levels) will be more affected. Cognitive abilities are the weak link in human performance in CONOPS. Six to eight hours sleep each night will maintain cognitive performance indefinitely. Three to four hours of sleep each night will maintain cognitive performance for 5-6 days. Less than 3 hours **sleep** each night will lead to rapid declines in cognitive performance and hence military effectiveness. The break point between sustaining performance with varying degrees of decrement and degrading performance with varying rapidity to ineffectiveness appears to **be** in the vicinity of 4.5 hours sleep each night. Cognitive performance begins to show decrements after a mere 18 hours of continuous work. Soldiers can remain militarily effective for only 2-3 days with little or no sleep. Decrements in cognitive performance **take** the form of decline in useful work per unit of time. Generally, speed of work slows in order to preserve accuracy. The decline in performance in continuous work without sleep is roughly 25% for every 24 **hours** of operation. The decline occurs in a stepwise fashion with the bulk of the drop during the circadian trough (0300-0600). Mood, morale, initiative **and** motivation decline in parallel to the decline in cognitive performance. In practical terms, planning, preventive maintenance, **and** self-care are particularly impaired.

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# EFFECTS OF CONTINUOUS OPERATIONS (CONOPS) ON SOLDIER AND UNIT PERFORMANCE

## CHAPTER II:

## STRATEGIES FOR SUSTAINING THE SOLDIER IN CONOPS

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**Phase** II Report Submitted to
the **TRADOC** Study Advisory Group on Continuous Operations (CONOPS)

JOINT **WRAIR/ARI** REPORT

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# 1 Summary of Phase I

As a part of the overall TRADOC Continuous Operations (CONOPS) Study, members of the Waiter Reed Army Institute of Research (WRAIR) and the Army Research Institute (ARI) for the Behavioral and Social Sciences reviewed the scientific and technical literature to determine what previous studies tell us about soldier/unit performance in CONOPS (Belenky et. al., WRAIR/ARI CONOPS Phase I Report, October 1986). This report for Phase II of the CONOPS study presents general human factors principles to be applied in planning, preparation and conduct of Sustained and Continuous Military Operations and some previews of research planning underway to enhance our CONOPS posture. A summary of the Phase I report is presented first.

## 1.1 Definitions (U.S. Army Field Manual 22-9)

1.1.1 Continuous Operations (CONOPS) are defined as continuous combat with opportunities for steep, though these opportunities may be brief and scattered through the day and night.

1.1.2 Sustained Operations (SUSOPS) are defined as continuous combat with no opportunity for sleep.

1.1.3 Within any CONOPS there will likely be periods of SUSOPS; and during CONOPS, for some personnel (e.g. those involved in command, control, communication and intelligence ($C^3I$), sleep will be more severely restricted than for others.

## 1.2 Review of Research on Performance in CONOPS

Performance degrades as a result of cumulative sleep deprivation and fatigue in CONOPS and SUSOPS. Mental performance degrades more rapidly than physical performance. Initiative, the integrating of information, planning and plan execution are the aspects of mental performance that degrade most rapidly. With complete sleep deprivation (SUSOPS), alertness and performance decline rapidly, with. mental performance declining in spsed and accuracy approximately 50%, and latency to fall asleep (when permitted to do so) declining to less than one minute after two days total sleep deprivation. With partial sleep deprivation (CONOPS), alertness and performance decline more gradually, but after 5-7 days of partial sleep deprivation (e.g. sleep limited to 4-5 hours each night) alertness and performance decline to the same low levels as those seen following two days of total sleep deprivation.

## 1.3 Implications of the Research Literature for Strategies of Sustaining the Soldier in CONOPS/SUSOPS

The U.S. Army is developing and applying a doctrine for managing sleep and alertness in CONOPS. The current Training and Doctrine Command (TRADOC) Study Advisory Group (SAG) on CONOPS is part of this development. Researchers, tacticians and doctrine developers combine what is already known from laboratory and field studies of CONOPS with findings from ongoing and newly scheduled studies whose goal is to develop new behavioral and pharmacological techniques for managing sleep and alertness in CONOPS. This process in the U.S. Army is proceeding in parallel with similar developmental efforts in ‘other armies, and in the U.S. Navy and Air Force. In the near future this doctrine will:

1.3.1 Identify those positions in which personnel are most likely to suffer sleep deprivation in CONOPS and SUSOPS and adapt adequate manning doctrine, over-learning and cross-training to reduce the impact of continuous battle upon these personnel.

1.3.2 Optimize the timing and duration of naps in CONOPS in order to make the most of sleep opportunities.

1.3.3 Field drugs to facilitate and improve the efficiency of brief sleep in CONOPS.

1.3.4 Field drugs to maintain normal alertness when for 2-3 days, sleep is not possible (as in SUSOPS), and to reduce the need for sleep and maintain normal alertness when for days or weeks only limited sleep is possible (as in CONOPS).

## 2 Strategies for Sustaining Soldiers in CONOPS - Phase II

### 2.1 Human Factors Principles for CONOPS

Human factors principles for planning, preparation and conduct of CONOPS/SUSOPS were derived from careful interpretation of the voluminous literature on biological, behavioral and performance aspects of work/rest activities, sleep deprivation, sleep management and extended military operations studies (e.g. those found in Krueger, Cardenales-Ortiz & Loveless, 1985, Englund & Krueger, 1985 and Krueger & Englund, 1985), and from consultation with our counterparts in the U.S. Navy, the U.S. Air Force, the Canadian and British Armed Forces (especially Naitoh et. al. 1986, Woodward & Nelson, 1974, APRE, 1986). To all of them we owe a debt of gratitude, for the principles outlined here are a result of their work.

The principles listed here in executive summary form include considerations for use in staffing military units for CONOPS, for training and preparation before CONOPS, for work/rest scheduling and sleep management during CONOPS. Brief descriptions are presented of ongoing sleep management research programs, efforts to lighten the soldier’s load and implementation of concepts of good physical fitness and nutrition as they pertain to CONOPS.

#### 2.1.1 Staffing/Organizational Principles

Armies planning to fight CONOPS must organize and staff their organization/units (e.g. for the U.S. Army - their TOEs: Tables of Organization and Equipment) in preparation for CONOPS. Some units should be taliored specifically for such combat operations.

Units should be staffed with sufficient personnel to provide some redundancy and to allow soldiers to work in shifts in select organizational elements (e.g. communications and command-control personnel).

Units should increase staffing in areas known to have shortfalls for CONOPS (e.g. support platoons, transportation in logistics elements, communication elements, etc.).

Reserve platoons should be judiciously re-created for select applications (e.g. like the old armor security squad).

Where possible, tasks should be modified to minimize effects of sleep loss (e.g. design a vigilance task so the operator must occasionally look away to do something else).

### 21.2 Training and Preparation for CONOPS

Leaders must train themselves to organize and supervise their units for the particular idiosyncrasies of CONOPS.

Generally, the higher the state of training prior to sleep loss, the longer performance deterioration can be staved off (but it is still difficult to go beyond 2-3 days without sleep). Thus, units should be highly trained before SUSOPS.

Individuals should be trained on complex tasks to degree of “over-learning,” the point at which responses become almost automatic and therefore resistant to stressful, fatiguing conditions.

Personnel should be cross-trained to take over other crew members’ tasks; individual rotation gives some members a rest.

Unit physical conditioning programs should be conducted for strength and physical stamina.

Soldiers ought to be in good physical shape, but, overall physical fitness is not sufficient. Soldiers should train select muscle groups to do frequently repeated physically demanding tasks (e.g. a light infantryman should train with a loaded pack on his back for extended periods of time).

"Train as you plan to fight.” Physical fitness for military tasks means that we should train as we plan to fight. Thus, load bearing marches should be part of an infantry training program.

CONOPS requirements go beyond physical endurance. They generally involve much cognitive work and mental stress. Therefore, units should consider the unique aspects of CONOPS in the conduct of their stress management programs. (See U.S. Army Field Manual 26-2).

There are large individual differences in tolerance to sleep loss. Individual soldiers must know how well they tolerate working without sleep. Some may be overwhelmed by loss of one night of sleep; others may take considerable sleep loss in stride.

Units should train under conditions of continuous and sustained operations so all personnel will recognize effects of sleep loss, their own responses to it, as well as those of others.

Leaders should use constructive, purposeful, combat-relevant training to build morale. Morale, motivation, cohesion and leadership generally sustain soldiers in combat and bolster performance, and help considerably in CONOPS.

Commanders should develop and promulgate a work/rest schedule and sleep discipline plan; and then use it.

Consideration should be given to identifying and selecting personnel who prefer and are able to adapt to different shiftwork schedules and then honoring such preferences (e.g. owls work at night and larks during the day).

Commanders should consider the merits of the concept of appointing a Second in Command (2IC) for SUSOPS so that the battle can be conducted without interruption while the commander gets rest.

Commanders should identify those places where reliance is on the performance of a few individuals **and** try to lessen such dependence. Back-up personnel capability is essential.

### 2.1.3 Reducing Performance Impairment Risks During CONOPS/SUSOPS

Soldiers should get a 12-hour period of “off duty time” (for rest and sleep and as free of duties as possible) immediately preceding a prolonged work (SUSOPS) episode. Although one cannot **store** up sleep, this will delay **the onset** of performance degradation.

Units should use the work/rest and sleep discipline plan. It is the field commanders’ and NCOs' responsibility to insure unit members comply with sleep management recommendations - in pre-deployment, deployment and combat phases. Set the example!

Work/rest plans should recognize the influence of known circadian factors. Expect performance lulls from 0300-0600 and 16304800 hrs. These lulls will be more easily noticed on continuous, monotonous tasks such as CRT vigilance. Additionally, cognizance over other circadian factors is also important, (e.g. assignment of personnel to rapidly rotating shift changes desynchronizes bodily rhythms and . brings about performance degradations faster).

Soldiers should take periodic breaks or rests from tasks; sometimes mild physical exercise or recreation will help. Rotate duties of individuals between visual, mental and physical tasks if possible. This can relieve **some** effects of fatigue and visual strain, and increase alertness; such relief will be moderate however and is **not** to be overrated.

When performance begins to degrade in a unit, find time for soldiers to nap, change routines, or rotate **jobs** if they are cross trained.

Crewmembers cross-trained on relatively routine jobs should rotate **tasks to reduce** performance deterioration (**e.g. tank** crew members rotate **jobs** periodically; seated sentries rotate with those walking the perimeter).

Performance on complex tasks involving decision making benefits from crew rotation only if personnel are well-practiced **and** expert in shifting functions. Crew rotation on complex tasks is advisable only when members are highly trained to shift functions.

Let the most sleep loss affected soldiers do tasks that can be accomplished at a pace set by the worker, not by the job. Sleep loss has less impact on self-paced jobs.

Allow more time for execution of tasks (i.e. task rate) because as soldiers become tired, performance will be slower - the "friction" of CONOPS!

Communication - Take extra care to make communication (messages and orders) clear and simple. They should be written when possible. After about 36 hours of sleep deprivation (SUSOPS) there is a marked deterioration in ability to register and understand information. Repeating back orders to insure they were understood is a useful technique, but memory lapses that follow significant sleep loss may be detrimental. Encourage everyone to write down work to be done or messages received, and have others check what has been written for clarity and legibility;

After about 24-36 hours without sleep, decisions, calculations, etc. should be cross-checked by a 2nd person for accuracy and completeness. Mix rested with unrested soldiers as CONOPS continues. Since it is unlikely two members of a unit will become sleepy or make the same mistake at exactly the same time, teaming up two or more persons to do a job is a useful concept in SUSOPS.

Special consideration should be given to personnel responsible for tasks more adversely affected by sleep loss (e.g. those undertaking surveillance and/or command/control functions).

Mental stimulation, increased incentive, interest or morale can, within limits, often raise the level of mental alertness, and improve performance.

Mild physical activity (e.g. walking around) can temporarily alleviate fatigue from sleep loss. Exercise, noise and cold can give temporary help; however, they increase the physical cost and lead eventually to greater fatigue.

The lightening-the-soldier%-load concept is a workable, important doctrine for the light infantry. Minimized loads, based on combat planning factors (e.g. METT-T: mission, enemy forces, terrain, troops available and time) allow for movement and maneuverability, and conserve energy for engagement with the enemy.

To improve CONOPS capability, water and meal consumption discipline must be instituted to ensure proper hydration and caloric intake.

Attention to personal logistics (e.g. timing of hot meals, provision of coffee or other caffeine containing drinks) can help maintain morale.

Personal hygiene (e.g. changing socks, uniforms, cleaning up etc.) can he!p maintain morale as well as health and in a preventive medicine way, help stave off psychological stress and medical casualties.

Stimulant drugs can attenuate decline in mental & physical performance in SUSOPS and CONOPS; but benefits with currently used drugs are limited because, use of currently available drugs to counteract several days of total sleep loss leads to rebound fatigue when they are discontinued; and while restoring alertness and motivation, these currently available drugs can impair judgment.

Research is underway to identify new stimulant drugs that can maintain normal alertness and performance in the face of 2-3 days of complete sleep deprivation (SUSOPS), and in the face of days or weeks of partial sleep deprivation (CONOPS), without impairing judgment while the drug is in use and without rebound fatigue when the drug is discontinued.

### 2.1.4 Sleep scheduling

Normally, soldiers should get 6-8 hours continuous sleep time per 24 hour period. Soldiers should be able to sustain performance under these conditions indefinitely.

Performance degradation can be averted by preventing or reducing sleep debt. This requires using a properly established work/rest/sleep schedule. Some of the rest period must be used for sleep. The only really effective remedy for sleep loss is sleep. Naps are beneficial and should be taken as frequently as possible.

As a minimum, there should be at least 4-5 hrs sleep per 24 hours, preferably in a single unbroken period. Four + hours of sleep in each 24 hr day is likely to maintain adequate performance over a week or more, but by that time, for some soldiers, sufficient sleep debt will have accrued to make them as fatigued as if they had gone for 2 days without sleep. This precaution is particularly pertinent to command and control personnel.

A small amount of sleep relative to that lost is very beneficial. For example, 4 hours of sleep after 90 hours of wakefulness markedly improves performance and mood. For full recovery, 12 hours uninterrupted sleep should be allowed after 48 to 72 hours without sleep.

Soldiers should be encouraged to take naps during CONOPS. Some of the rest period(s)) must be used for sleep because only sleep *can* prevent sleep debt from increasing.

Generally, the Longer a nap, the greater the improvement in performance and the less sleep inertia (groggy slow responses) upon awakening. Naps are generally more restorative if taken between 0300-0600 and 1600-1800 (during the circadian lulls), however there is also greater sleep inertia upon awakening from naps during these times.

Since opportunities for naps in CONOPS come at unpredictable times, an opportunity for a nap should be taken regardless of the time of the day. Soldiers should be told *to* take naps when they safely can.

A key factor in sleep management is to avoid accumulation of daily sleep deficit. If personnel are able to sleep only 2 or less hours one day, then this should be made up by sleeping for more than 5 hours the next day.

If necessary, sleep can be taken in short periods of 10-30 minutes. This method is less recuperative than long blocks of sleep; so the longest periods feasible should be allotted. Apply the basic rule of sleeping at least 4-5 hours per 24 hour period.

Sleep-inducing drugs may be useful to induce brief, restful sleep during lulls or as part of duty rotation in CONOPS. They may also be useful during long range deployments by air.

Research is underway to identify effective short-acting sleep-inducing drugs that would ensure a brief restful nap during CONOPS, while reducing sleep inertia, and leaving no untoward residual drug effects (e.g. headache or hangover) upon awakening.

Research is also underway to identify short-acting sleep-inducing drugs for use in long range deployments by air.

### 2.1.5 Recovery Sleep Concepts

After 36-48 hours of continuous work without sleep, six hours of sleep (or less) is generally inadequate to return to normal performance levels. Four or more hours of sleep can raise performance levels from approximately 50% of baseline to about 7596 of previous performance levels.

A combination of 12 hours sleep/rest (about 8-10 of which must be sleep) are required after 36-48 hours acute sleep loss, although subjective fatigue may linger until the third full night of sleep.

24 hours sleep/rest are recommended (about 15 of which are sleep) after 36-48 hours sleep loss under conditions of high workload (12-16 hours per day). This is particularly applicable for those who have high cognitive workloads.

Sleep loss of 72 to 96 hours will require more than one solid night of recovery sleep before performance recovery is complete. Although there are wide individual differences, after 72 hours or more acute sleep loss, 2 to 3 days time off from normal job duties (during which the individual may sleep or rest or carry out light duties at his own pace) are usually required to restore performance to 100% of “normal performance” levels. Where mission requirements dictate, less time off for rest and sleep, 8-16 hrs, may restore individuals to levels of performance between 50-80% of normal performance. This may be acceptable given the tactical situation.

3 to 5 days are required to initiate biological adaptation and return to normal day/night cycle from short stints of working the night shift. Three to four weeks are required for full adaptation of biological rhythms to extended periods of atypical work-rest schedules (as in night shift work).

After enduring a stressful period of sleep loss and having gone to sleep, soldiers 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. Restlessness of some individuals may disrupt attempts of others to get sleep. Soldiers will have to become very cognizant of their fellow team members’ sleep needs and avoid unnecessary awakenings of others. A glaring-lack of such courtesy is apparent in most field exercises. - We are our own worst enemy here.

The performance of individuals just after being awakened from a normal night of sleep typically will be below normal (groggy and slow) for at least 15 minutes until they "wake up”. This is called sleep inertia.

Sleep and rest are not synonymous. Sleep fulfills a biological need that cannot be denied indefinitely. Rest is what a person does when he or she says he is "relaxing" - a change in a pattern of work activity. For the soldier, rest usually means time away from specific military tasks and may include reading mail, eating a meal etc. but, it may also mean doing other light duties away from his regular set of tasks, preferably ones that he can do at his own pace.

When a second combat phase/period is expected to follow shortly, sleep management *after* the first combat is important. This first post-combat sleep period should be allowed to extend either to spontaneous awakening, or for 10 hours (whichever comes first).

The most important point is that one should pre-plan when soldiers are to expect some rest and sleep.

### 2.1.6 Work/Rest Scheduling

A work/rest schedule takes into consideration the nature of the work to be done, its interaction with others doing their work, rest and sleep time, how far away from the work station is the rest or sleeping location, meal provisions, showering facilities, mail call etc., and when and where in the 24 hr day these things occur.

Choose the schedule that gives the greatest amount of contingency time - time that can be used to make up for the inevitable delays that occur because of snafus, errors, and other uncontrollable variables.

Several different work/rest schedules might work for particular situations (e.g. 12 hrs on/12 hrs off duty; rotating 8 hr shifts among 3 teams; 6 hr on/off shifts; work 10 hrs on/off 14 hrs). There are obvious and not-so-obvious advantages and disadvantages to each.

Imposing phase shift rotations (rolling schedules e.g. 8 hr. on/8 off/8 on/8 off) on successive days desynchronizes biological rhythms and is not recommended. It is preferable to begin work shifts about the same time each day. If a rotating schedule is necessary, work periods should occur later during each successive day. That is, a soldier would start work later as opposed to earlier each day.

12 hrs on/ 12 off (12 hrs work per 24 hrs) is attractive for many combat arms applications because individual work shifts ate predictable and such a schedule provides enough time for a normal sleep period of 7-9 hrs and time to do "personal business". It is easy to set up and to maintain. Under conditions of light to moderate physical and/or mental workloads this schedule works quite well.

No matter what the shift arrangement, expect personnel scheduled to work through 0300-0600 hrs, particularly those doing vigilance tasks, to experience performance deficits.

Many military activities seem to lend themselves to 10-12 or even 14 hour work shifts - putting an operation into effect and then completing it.

The potential benefits of staggering and overlapping shifts (e.g. some members of a Tactical Operations Center (TOC) reporting to work on staggered 12-hr shifts) should also be considered. The entire shift does not rotate at the same time, providing some overlap for task transition continuity.

A tabular synopsis of some of the effects of sleep deprivation is presented in Table 1 (APRE, 1986).

## 2.2 Sleep and Alertness in CONOPS

### 2.2.1 Current Directions in Doctrine Development

The development and- application of a doctrine for managing sleep and alertness in CONOPS entails work with respect to nap timing and duration, cross-training, rotation, and manning; the use of short-acting sleep-inducing drugs during long range deployments and CONOPS; the use of drugs to maintain alertness acutely during complete sleep deprivation (SUSOPS) and chronically during partial sleep deprivation (CONOPS); and developing a better understanding of the neurobiology of initiative, motivation, alertness, sleep and fatigue.

### 2.2.2 Naps and Sleep Discipline in CONOPS

Sleep discipline is undergoing re-evaluation in the U.S. Army and in other armies (e.g. British, Canadian, West German, French, and Israeli). Making an analogy to water discipline, in the past, water discipline meant doing with as little water as possible. More recently it has been realized that such an approach leads to dehydration and a decrease in combat effectiveness. Water discipline now means enforcing adequate fluid intake to maintain good hydration. Sleep discipline is undergoing a similar revolution. In the past, sleep discipline meant doing with as little sleep as possible. This ignored data from a variety of field and laboratory studies that performance degrades to unacceptable levels in 48-72 hours without sleep. A new sleep discipline is emerging which entails enforcing adequate sleep management to maintain good cognitive performance. This new sleep discipline will set guidelines, standards and procedures to insure soldiers get sufficient amounts of sleep during CONOPS.

Individual soldiers, particularly those with command and control responsibilities, need 4 or more hours sleep in each 24 hours to sustain combat effectiveness for more than a few days. To maintain combat effectiveness in CONOPS, soldiers must have periodic naps. The longer the nap (i.e. the closer the nap is in length to normal requirements of 6-8 hours sleep in each 24 hours) the greater the likelihood performance will be maintained and the less sleep inertia upon awakening. Naps are more restorative if taken in the temporal vicinity of the normal circadian lows in alertness occurring even in well-rested persons between 0300-0600 and 1600-1800 hrs. However, there is also greater sleep inertia initially upon awakening when naps are taken at this time. In any case, since opportunities for naps in CONOPS will come at unpredictable times, an opportunity for a nap should be taken regardless of the time of day. The cognitive per-

## Table 1: APRE Summary

## EFFECTS OF SLEEP DEPRIVATION

### Effects on Mental Processes

Lack of concentration
Lapses of attention
Reduced vigilance
Slowing of action
impaired short-term memory

Loss of insight
Misinterpretation
Visual illusions
Disorientation

### Mood Effects

Fatigue
Depression
Irritability
Loss of interest in surroundings and events
Increasingly dominating desire to sleep

### Tasks More Adversely Affected

Sustained
Unstimulating
Work paced
Surveillance
Inadequately learned
High workload
Complex decision making

### Countermeasures

Rest periods
Short naps
Shorter work periods
Rotation of duties
High state of training
Realistic training
Mental stimulation
Cross-checking
Clear and simple orders
Written instructions

UK's Army Personnel Research Establishment, 1986; Army Code 71375 formance of older soldiers is more impaired by sleep deprivation and older soldiers generally require longer or more frequent naps for the same restoration of function.

Similar principles can be applied to tank or armored personnel carrier and' infantry fighting vehicle crews and to other small group organizations such as battalion tactical operation centers.. In CONOPS, a crew may not have the opportunity to withdraw from action as a unit, but can increase endurance by using the procedures of crew rotation when the tactical situation allows. For example, a day can be divided into 4- or 6-hour shifts in which heavy workload or critical tasks are distributed over individuals. During any given shift, some soldiers have the opportunity for rest or performing light miscellaneous details whereas others are engaged in heavier work or cognitively demanding tasks. Certain principles can be invoked in scheduling duty positions or individuals at a given time. Graber, Rollier and Salter (1986) suggested a infantry fighting vehicle (mechanized armor forces) team schedule that has the company commander resting during the first night shift (say 2000-0200) and awake during the 0200-0800 period on the assumption that the complexity of the cognitive demands will be greater than during the earlier shift. Additionally, platoon leaders and platoon sergeants would not be on the same work/rest schedules. A reasonable schedule for an artillery howitzer crew would partial out responsibility for ammunition carrying duties over several work shifts (or, task load could be shared within shifts).

Field studies are being conducted to develop and refine sleep discipline doctrine. Non-invasive, non-intrusive, solid state, wear-and-forget sleep/activity monitors are being used in studies of sleep and activity in field training exercises and force development tests to identify those personnel positions in combat units most likely to be deprived of sleep. The studies will lead to recommendations regarding cross-training, manning, sleep discipline and other doctrinal SOPs, as well as to objective tests of the effectiveness of these recommendations.

### 2.2.3 Sleep-inducing Drugs for Use in Long Range Deployments and CONOPS

An area for specific consideration in the development of sleep discipline doctrine is the use of short-acting sleep inducing drugs for use in long range aerial deployment and in CONOPS. Flight times during long range deployments by air are generally long enough to permit an extended nap. Soldiers are often too anxious, too preoccupied with the upcoming mission, or paradoxically, too tired to sleep. Thus, a short-acting sleep-inducing drug that would ensure a restful nap, with no untoward effects (e.g. decrements in performance or increased sleep inertia) upon awakening, would be very useful.

Laboratory experiments underway are designed to study short-acting sleep inducing drugs that might ensure restful sleep during long range deployments and during lulls in CONOPS. In long range deployments by air, a simple short-acting sleep-inducing drug may be adequate as the duration of the flight is generally longer than the duration of action of the drug and it is unlikely soldiers will need to be fully alert during the trip.

In CONOPS, either an ultra short-acting sleep-inducing drug, or alternatively a sleep-inducing/reawakening drug combination, is needed because soldiers who have taken the drug may have to return rapidly to full alertness if the battle situation changes. In addition, there may be sleep-inducing drugs that not only promote brief efficient sleep, but minimize sleep inertia upon awakening.

Initial studies of sleep-inducing drugs for use in Long range deployments were completed in 1986, and a recommendation for fielding a first generation drug for this purpose will be made in 1987, Further studies to refine the recommendation for long range deployments and to investigate the use of sleep-inducing drugs in CONOPS are underway.

### 2.2.4 Alertness Sustaining Drugs for Use in CONOPS

In SUSOPS there will be no possibility for sleep. In CONOPS, sleep may be brief and fragmented, amounting to "restricted sleep" (e.g. 4-5 hours in each 24 hours). SUSOPS may last for several days. CONOPS may last for days, weeks, or months. Thus, in SUSOPS there is need for a drug that will maintain normal alertness (and hence performance) in the face of 2-3 days of complete sleep deprivation. In CONOPS there is a need for a drug that will reduce the need for sleep so that normal alertness can be maintained for days, weeks and even months in the face of restricted sleep (e.g. 4-5 hours in each 24 hours).

Laboratory studies of drugs for possible use in maintaining normal alertness acutely during SUSOPS and chronically in CONOPS are currently underway.

### 22.5 Tech Base Studies on the Neurobiology of Alertness, Sleep and Fatigue

Despite enormous progress in neurobiology over the last century, we still do not understand the neurobiological (i.e. neurophysiological and neurochemical) basis of the decline in performance produced by fatigue, or how performance is restored by sleep; nor do we know the mechanisms that initiate or maintain sleep. Studies of human psychology indicate the first functions affected by sleep deprivation are initiative and motivation. However, initiative and motivation are not well understood at the level of neurobiology (i.e. at the level of brain events). Studies are underway to delineate the neurobiology of initiative, motivation, alertness, sleep and fatigue. Through these studies, we hope to develop knowledge regarding the neurobiological changes that occur with fatigue and in this way develop new means of reversing or attenuating these changes.

## 2.3 Lightening the Soldier's Load

The foot soldier in an extended engagement may likely find the weight of the equipment he must carry is an important determinant to his endurance. His energy is better spent maneuvering and fighting, not in carrying unrealistic loads. A U.S. Army Battlefield Development Plan, 1985, states: "Close combat light forces lack the ability to carry all of the equipment needed to fight and survive on the battlefield. New systems are added to the soldier's load without consideration of how they will be carried."

The U.S. Army Infantry Board's suggested load carrying standards for a fighting load is 48 pounds, and for an approach marching-load, 72 pounds. Soldier loads typically exceed these recommended figures. The estimated average individual loads in a Light Infantry Division (LID) company operating under a low intensity conflict, in a temperate climate scenario were 69 pounds for combat load and 104 pounds for marching-load (DRC, 1956; figures based on a soldier load model of the Army Development and Employment Agency, 1986). When a LID company was asked to prepare for a low-intensity, 48-hour operation in which each soldier would carry 2 gallons of water, 4 grenades, and 6 meals the average load was even higher, at 145 pounds (DRC, 1986). Determining performance costs of carrying heavy loads is important because the constant presence of the load may add to one's fatigue, physical discomfort and declining morale, even to the extent soldiers may be exhausted by the time contact is made with the enemy.

To enable troops to sustain maximum fighting effectiveness over the course of a lengthy engagement, a concept called Lightening the Soldier's Load has been advocated by the U.S. Army Development and Employment Agency (ADEA, 1986). The focus of this effort is on determining what clothing, weapons, ammunition, food, water and other items are needed to move and fight effectively as a function of METT-T, and how they should be transported. Thus research in this area involves much more than traditional issues of portability (that is, consideration of weight/bulk ratios, arrangement of load, development of lighter equipment, ease of movement, and comfort).

An additional important concept is that of mission-specific requirements by units: a determination is made as to what equipment actually needs to be carried by the soldier and which needs only to be in close proximity. The distinction between what to bring and what to have nearby represents a fine line, in that light infantry are expected to have a 48-72 hour operational capability before re-supply. Extra weight not only hampers mobility and maneuverability, but wears one out in the process. Yet one does- not want to be without necessary equipment.

TABLE 2: Overview of Soldier Load Echelonment Concept

| Echelon | Method of Transport | Principal Items | Transport Responsibility |
|---|---|---|---|
| Combat, Light Fighting | Load bearing vest, clothing | Primary weapons and equipment, MRE, water, ammunition | Soldier |
| Combat, Assault | Assault pack | Ammunition, water | Soldier-Company |
| Combat, Approach March | Rucksack | Ammunition, MRE sleeping bag, batteries | Soldier<br>Company |
| Sustainment | A bag | Threat specific equipment (e.g., chemical, anti-armor | Battalion |
| Contingency | B bag, C box | Extra clothing cold weather parka) | Division-Corps |

Source: Dynamics Research Corp, 1986

The heart of ADEA's proposal is the echelonment concept advocating a mission-oriented approach to soldier load. Load type is dependent on mission. The three main echelons, types of general equipment, and transport responsibility are outlined in Table 2. According to this doctrinal strategy, soldiers would carry all or part of a combat load depending on the specific phase of an operation. The load-bearing equipment is to be designed such that "pack shedding" the rucksack is possible while leaving the assault pack intact. Sustainment loads would be transported by small 4-wheel drive all-terrain vehicles; contingency loads by high-mobility, cross-country trailers. Thus, the idea is to cache or "stockpile" on the battlefield what at a given time are mission non-essential items. These items would then be re-supplied to the troops via load-carrying vehicles.

Tailoring the load based on METT-T is designed to direct transport energy for movement and maneuverability to conserve the soldiers' strength and energy for contact with the enemy. Thus, important variables to consider for given load types include distance to be traveled, rate of movement, time allowed for travel, march/rest schedules, type of terrain, anticipated length and physical demands of mission, and environmental characteristics.

### 2.4 Nutrition

In 1982 the US Army Medical Research and Development Command sponsored a Committee on Military Nutrition Research (under the auspices of the National Research Council) established to provide guidance on issues and research relevant to "nutritional factors that may critically influence the physical and mental performance of military personnel under all environmental extremes" (NRC, 1983). Proceedings on efforts of the Committee (NRC, 1986) summarize the Army's continuing interest and active involvement in research that pertains to the interrelationships of nutritional status, physical activity, work capacity, and work productivity. Army agencies involved include the USA Research Institute of Environmental Medicine and the Natick Research and Development Center.

Inadequate nutrition in combat can manifest itself not only in degradation of performance but also in reduced resistance to disease and ultimately prolonged recuperation from wounds and illnesses. In relation to sustained operations, reduced caloric input can have a negative effect on muscle glycogen levels, especially when coupled with continuous or at least frequent physical activity. Muscle glycogen levels are closely related to exertion and ultimately to the onset of exhaustion in certain types of physical activity. If the soldier is too busy, too stressed or too tired to eat adequate amounts of rations during CONOPS, his carbohydrate intake will be reduced. Sub-optimal carbohydrate intakes during CONOPS preclude the normal cycle of work (muscle glycogen depletion) and eat/rest (muscle glycogen repletion). This reduced caloric input may lead to both physical and mental fatigue and degraded performance (Askew, 1956).

Personnel subsisting solely on the U.S. Army's light weight, dehydrated meal-ready-to-eat (MREs) have been known to lose weight over just a few weeks in field tests (Schnakenberg, 1985). Additionally, there is some indication from aviation accident reports that Army pilots in accidents deemed to involve aviator fatigue had irregular eating schedules or missed one or more meals prior to the accidents (Krueger & Jones, 1978). In various field tests approximating continuous operations, meals are frequently delivered very late or missed altogether, prompting soldiers to allege their leaders show little concern for the welfare of the troops (e.g. Morgan et al., 1985). The relationships between eating regularly, diet, nutrition and performance are not at all clear, but it appears reasonable that eating regularly is quite important in CONOPS/SUSOPS; and providing hot meals at assigned times or when the workload has been sustained can be a real morale booster.

Another consideration is the effect of inadequate fluid intake. The excitement, stress and general rapid pace of events associated with preparing to go to the field can cause the soldier to “forget” to drink and thus enter the early part of a field scenario sub-optimally hydrated. Dehydration may result, especially if the early scenario calls for assault of a position, rapid air/land deployment to an objective or other demanding SUSOPS scenarios. The relative lack of moisture in the MREs and other packets contributes to the developing dehydration. Soldiers experiencing dehydration tend to “lose their appetite” and reduce food intake. Reduced food intake and dehydration present a “double edged sword" diminishing performance capabilities (Askew, 1986).

Leadership must emphasize scheduled drinking regimens to insure soldiers are properly hydrated going into battle. Given the availability of food and water, once into sustained operations, leadership and self discipline will play key roles in maintaining nutritional levels commensurate with the physical activity and stress of battle. The motivational benefit alone of providing food (particularly provision of a hot meal) to tired, hungry soldiers may be an important factor in a successful SUSOPS.

As pertains to the light infantry, current and developmental food packets take into consideration the weight/volume needs of the foot soldier. Whereas MREs provide 1,200 kilocalories per meal or 3,600 kilocalories per day, the weight (1 pound per meal) and volume make portability of multimeals a concern. The Food Pack Assault, planned as a replacement for the Long Range Patrol ration, has a better weight/volume ratio and provides 1,550 kilocalories per day. This ration has been tested and approved for use over 10 continuous days. The developmental Ration Light Weight provides 2,000 kilocalories per day and is supposed to sustain a soldier for 30 days with no more than IO per cent loss of body weight. Anticipated fielding is during 1988. Although the latter food packets provide less caloric input than MREs, the improved carrying capability represents an important tradeoff.

### 2.5 Physical Fitness for Military Tasks

Meeting fitness standards as defined by U.S. Army Physical Readiness Test criteria does not necessarily indicate soldiers are fit to perform mission specific military tasks for prolonged periods of time. A conference sponsored by the Army Physical Fitness Research Institute listed as its main concern the physical requirements of conducting SUSOPS. A study coordinated by the institute (Drews, 1984) put soldiers through a S-day simulated light infantry scenario (4 hours sleep per night). The offensive and defensive operations necessitated nearly continuous movement on foot. The average carrying load was 42 pounds. As rated by ‘on-site evaluators, soldiers showed some difficulty in carrying their packs over the 5-day exercise, which included a 10 kilometer road march. The study group recommendation invokes the principle “train as one plans to fight;” that is, to include progressive load bearing marches as part of the light infantry training program. By increasing distance and Load, aerobic and specific muscle (legs & back) buildup should result in endurance and strength levels allowing load bearing for distance.

### 2.6 Cross-Training

Tasks may be characterized by their importance, difficulty, time to complete, frequency of occurrence, and susceptibility to degradation (Kopstein, Siegel & Wilson, 1979). Cross-training is important not only for redundancy on critical tasks if a given soldier is disabled, but also to allow for crew rest rotations. Redundancy can additionally serve to ensure accuracy of performance well into a SUSOPS on, say, critical but vulnerable cognitive-type tasks (e.g., calculating map grid locations) by having two individuals perform the same task or having one check the other (via shift overlap, one of the two presumably would be rested). Cross checking on decisions, calculations, etc. for accuracy and completeness is especially necessary after about 24-36 hours without sleep.

### 2.7 Over-Learning

Over-learning is the process of continuing to train and practice beyond the point where incremental gains in speed and accuracy become negligible. The point of such over-learning is to make responses so automatic they will easily be performed even under very stressful conditions. This form of training has been of traditional importance to the military. The classification of tasks as to their susceptibility to fatigue effects indicates automatic response sequences such as those developed in well-learned tasks are resistant to fatigue and the performance degradations that do occur take the form of errors rather than increased response latency (Wilkinson,' 1964). There is substantial evidence from research on fatigue, sleep deprivation and performance that over-learning provides resistance to performance degradations due to sleep deficit (Morgan, Coates, Brown & Alluisi, 1973).

In summary, "extended training beyond initial mastery (over training) assures extremely high reliability, automaticity, and rapidity of performance. It is a very powerful management tool for counteracting the debilitating effects of fatigue, disrupted diurnal rhythms, stress, etc. on performance" (Kopstein et al., 1979).

## 3 Summary and Conclusions

A number of initiatives can be taken immediately to improve resiliency of soldiers and their units in CONOPS. Immediate initiatives include 1) staffing units specifically for CONOPS missions, 2) designing and implementing unit sleep discipline plans, ensuring at least 4 hours sleep each night for command and control personnel during CONOPS, 3) lightening the soldiers mental and physical load, especially during combat, 4) providing adequate nutrition tailored to the demands of SUSOPS and CONOPS, 5) insuring high levels of relevant physical fitness, 6) cross-training crewmembers to do the jobs of others, and 7) over-training, particularly on cognitively demanding or monotonous tasks.

Other initiatives (both behavioral and psychopharmacological) currently under investigation that could be available for implementation within the next 2-3 years include 1) more refined analyses of which personnel suffer the greatest sleep deprivation in command and control groups (e.g. battalion TOCs) allowing more accurate tailoring of sleep discipline to combat operations; 2) recommendations for short-acting, sleep-inducing drugs to promote brief, restful sleep in long-range deployments and CONOPS; and 3) recommendations of drugs to sustain normal alertness in the face of no sleep in

SUSOPS and to maintain- normal alertness in the face of restricted sleep in CONOPS. Further, research into the neurobiology of initiative, motivation, alertness, fatigue and sleep is underway and will during the next decade, no doubt provide novel means (both behavioral and pharmacological) to sustain soldier alertness and unit performance during SUSOPS and CONOPS.

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