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Human Performance in Continuous/Sustained Operations and the Demands of Extended Work/Rest Schedules:

An Annotated Bibliography
Volume II

By

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A society intent upon maintaining high productivity levels 24 hours per day, and on providing a variety of services around the clock, produced occupations and circumstances requiring prolonged, continuous work periods. The performance of workers under conditions of sustained or continuous work has become an important topic in industrial psychology, and in particular, in the military services. There are some traditional jobs, circumstances, and even some new occupations that involve prolonged, sustained work periods without rest, in which individual workers continue beyond the normal 8-to-10 hour work day. In many of these sustained work situations, the termination point for a shift is unknown. Such activities usually require prolonging physical stamina and sustaining high levels of organizational and cognitive effectiveness. These continuous operations are of two types: First, there are extended operations, jobs, or tasks that proceed continuously with only a short break or breaks, but that operate within a typical shift system for lengthy periods, longer than a normal duty day. The worker knows he or she will be relieved or able to rest. Second, (continued on reverse)

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there are sustained operations, planned or unplanned, goal-oriented, nonstop continuous performance/operations without allowance for rest or sleep, in which the worker is expected to keep going as long as he or she can. Both have very important worker performance and behavioral implications.

Available research data on these topics are scattered through diverse printed sources, many of them difficult to locate. This second volume of the annotated bibliography lists 182 references containing research data, conceptual position papers, and different methodological approaches to studying human performance in continuous/sustained operations and extended work/rest schedules. The time covered in the references is from 1940 to 1989 with a concentration on references printed between 1985 and 1989. Volume I, listing 399 references, was published separately in 1985 at the Walter Reed Army Institute of Research. This Volume No. II also includes a cross subject index for the combined 582 references of both volumes.

Introduction

We compiled this second volume of the annotated bibliography on human performance in continuous/sustained operations and the demands of extended work/rest schedules as an updated source document for our research colleagues. Also, it should be of interest to the many military decision makers presently concerned with these topics. As indicated in Volume I, we began with a primary interest in the psychological literature that might apply to the performance of military personnel engaged in continuous work for sustained periods of time -- durations that exceed a "normal duty day" -- long enough to involve some individual sleep deprivation.

We did not include references to industrial shift work schedules, sleep deprivation, sleep discipline, circadian and biological rhythms, jet lag, exercise physiology, vigilance or fatigue per se. However, since all of these are involved to some degree in any study of sustained work, many references contain elements of these topics. We also included select cross references to these topics. We included multidisciplinary articles that described different methodological approaches to studying the psychological, physiological, biochemical, and ergonomic factors relating to sustained work as well.

To us, all of the articles and reports should in some way be of interest to those who do research on sustained performance or continuous operations. Some of them can be categorized as reviews, or conceptual descriptions of problem areas. Some offer alternative methodological approaches. Many offer fairly complete data, while others offer only sketchy or incomplete data. For the sake of completeness, and because the ideas advocated in some papers and reports listed here may spur more good research on the topic, we included them all.

The assembly of this second volume of the bibliography highlights research issues raised by members of the U.S. Department of Defense-sponsored Human Factors Engineering's international Technical Group on Sustained and Continuous Operations. One of us, Gerald P. Krueger, while at the Walter Reed Army Institute of Research in Washington, D.C., was the chairman of this group from 1985 to mid-1988.

The first volume of this annotated bibliography, printed in June 1985, covered articles and reports printed during the period from 1940 to 1985. The time covered in this second volume generally is June of 1985 until June 1989, but also contains several references earlier than 1985.

The references cited were obtained from diverse and widely scattered sources. We searched the U.S. Defense Technical Information Center (DTIC), and the National Technical Information Service (NTIS), the open psychological and biomedical literature journals and the file drawers of numerous research colleagues for appropriate references. References cited are almost exclusively those available in the printed English language. We included foreign language reports only if we had an English translation of at least the abstract. For example, we included reference to a few reports available only in French because Suzanne M. Barnes translated the abstracts for those documents into English.

We did not include references containing a security classification of U.S. "confidential" or above. We included some citations without abstracts when the distribution of that abstract was restricted or limited and listed them as such.

We listed acquisition numbers (AD numbers) for many documents available from the Defense Technical Information Center (DTIC). Interested readers should determine their own status for accessibility to these reports by checking with the DTIC and the Defense Logistics Agency at Cameron Station, Alexandria, Virginia 22304-6145.

Many of the abstracts come directly from the articles as published. We slightly modified a few of those. We wrote abstracts for some papers where none were provided by the authors.

In this second volume, we also included a subject index to all citations listed in both Volumes I and II. Citations numbered 1 through 399 appear in Volume I: Krueger, G.P., Cardenales-Ortiz, L., and Loveless, C.A. (1985). **Human performance in continuous/sustained operations and the demands of extended work/rest schedules: An annotated bibliography.** Washington, DC: Walter Reed Army Institute of Research (WRAIR Technical Report No. BB-85-1), DTIC No. AD-A155-619. Citations numbered 400 or above appear in this volume.

Users of this bibliography are encouraged to submit copies of additional applicable references to the Biomedical Applications Research Division of the U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama 36362-5292, for consideration in research and subsequent publications related to these topics.

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400. Adame, M. A. 1985. **TRASANA analysis in support of the management of sleep and stress in continuous operations (MOSSICO) study.** White Sands Missile Range, NM: U.S. Army Training and Doctrine Command Systems Analysis Activity. (U.S. Army Soldier Support Center Letter Report No. TRASANA-LR-29-85) {DTIC No. AD-B099-127L}. Distribution of this document limited to U. S. Department of Defense only.

401. Anderson, R. M., and Bremer, D. A. 1987. Sleep duration at home and sleepiness on the job in rotating twelve-hour shift workers. **Human factors.** 29(4): 477-481.

The relation between sleeping patterns at home and sleepiness ratings on the job was examined for 29 shift workers. The workers' 12-hour shift schedule was an 8-day cycle, with two day shifts followed by two night shifts and 96 hours off. The workers were categorized as early-onset or late-onset sleepers and as long or short sleepers, based on their sleeping patterns on a nonworking day. No significant differences were found between early-onset and late-onset sleepers in reported sleepiness on the job. The reported sleepiness on the job of short sleepers was significantly less than that of long sleepers on both day and night shifts. This difference was explained in terms of a hypothesized effect of long sleeping on circadian rhythms. Social factors appeared to explain the shorter sleeping periods of some workers.

402. Angus, R. G., Heslegrave, R. J., and Myles, W. S. 1985. Effects of prolonged sleep deprivation, with and without chronic physical exercise, on mood and performance. **Psychophysiology.** 22(3): 276-282.

The effects of physical exercise and sleep deprivation on mood and cognitive performance were studied in 12 healthy young male volunteers deprived of sleep on two occasions. During the first 60-hour period without sleep, half of the subjects walked on a treadmill at 25-30 percent of their maximum aerobic capacity (exercise condition) for 1 out of every 3 hours while the remaining 6 subjects remained physically inactive (no exercise condition) during that same hour. Eight weeks later the same 12 subjects underwent an identical sleep-deprivation protocol except that those who were previously inactive exercised, while those who previously exercised remained inactive. Throughout the sleep deprivation periods, subjects in both conditions completed subjective assessments of fatigue, sleepiness, and mood every 3 hours, performed an auditory vigilance task every 6 hours, and completed a cognitive test battery every 12 hours. The results revealed clear decrements in mood and performance as a function of sleep loss. However, with the exception of somewhat more long reaction times in the exercise condition, exercise neither increased nor decreased the impairment induced by sleep deprivation.

403. Angus, R. G., Redmond, D. P., Englund, C. E., and Heslegrave, R. J. 1985. The measurement of fatigue and sleep during sustained operations in a chemical environment. Annex M to **Canadian CHACE II final report: Casualty handling assessment in a chemical environment.** Ottawa, Canada: Canadian National Defence Headquarters. (The distribution of the overall report is Canadian restricted).

CHACE II was a realistic evaluation of a Canadian field medical unit's personnel, equipment, and doctrine for operation in a chemical environment. To assess fatigue levels of soldiers dressed in chemical protective clothing, researchers used subjective self-report questionnaires and more objective activity measures to estimate the amount of sleep obtained. The aim of the study was to determine the effects of sustained working conditions in a chemical environment on sleep discipline (i.e., unusual work/rest/sleep patterns and sleep loss). The sustained operations portion of the trials lasted 68 hours. Results of fatigue, sleepiness and mood scales, and sleep indications from activity monitors are presented.

404. Babkoff, H., Genser, S. G., Sing, H. C., Thorne, D. R., and Hegge, F. W. 1985. The effects of progressive sleep loss on a lexical decision task: Response lapses and response accuracy. **Behavior research methods, instruments and computers.** 17(6): 614-622.

A lexical decision task was used in a paradigm testing the effects of sleep loss and fatigue on performance during a 72-hour period of sleep deprivation. The data were partitioned into categories of response lapses, response accuracy, and the signal detection measures of discriminability (d') and (β). Response lapses increased as a function of sleep loss and were fitted best by a composite equation with a minor linear component and a minor rhythmic component. Response accuracy decreased as a function of sleep loss, with the rate of decrease being greater for nonwords than for words. Although d' was higher for right visual field (RVF), it decreased for both fields almost linearly as a function of sleep deprivation. The rate of decrease for RVF stimulation was greater than for left visual field (LVF) stimulation.

405. Babkoff, H., Mikulincer, M., Caspy, T., Carasso, R., and Sing, H. 1989. The implication of sleep loss for circadian performance accuracy. **Work and stress.** 3(1): 3-14.

The effect of sleep loss on circadian performance rhythms is discussed. Data are presented which indicate that the maxima and minima of the circadian component of performance curves are delayed by 2 to 4 hours as a result of sleep deprivation. The consequences of such a change are discussed.

406. Babkoff, H., Mikulincer, M., Caspy, T., Kempinski, D., and Sing, H. 1988. The topology of performance curves during 72 hours of sleep loss: A memory and search task. **The quarterly journal of experimental psychology.** 40A(4): 737-756.

Three levels of working memory load of a visual search (memory and search) task were tested in a 72-hour sleep deprivation paradigm. General performance and accuracy decrease over time with monotonous and rhythmic components. The signal detection discriminability index, d', decreases monotonically with rhythmic variations. The index of response bias, β, shows no monotonic trend, but significant circadian rhythmicity. The extent of the monotonic and rhythmic changes in accuracy and in d' is directly related to the level of working memory load. The amplitude of the circadian component of accuracy and d' is enhanced for the higher levels of working memory load. The implication of potentiated circadian rhythmicity as a function of cumulative sleep loss is discussed.

407. Babkoff, H., Thorne, D. R., Sing, H. C., Genser, S. G., and Hegge, F. W. 1985. Dynamic changes in work/rest duty cycles in a study of sleep deprivation. **Behavior research methods, instruments, and computers.** 17(6): 604-613.

The effects of moderate workload and 72 hours of sleep deprivation were studied using a modified continuous-performance paradigm. Ten subjects were tested hourly on a number of perceptual and cognitive tasks designed to require approximately 30 minutes to complete, with the remainder of each hour free. As sleep deprivation continued, the average time on task increased at an accelerating rate. The rate of increase differed among tasks, with longer tasks showing greater absolute and relative increases than shorter ones. Such increases confound sleep deprivation and workload effects. This paper compares the advantages and disadvantages of several experimental paradigms; describes details of test design; and discusses methodological problems associated with separating the interactions of sleep deprivation, workload, and circadian variation with performance.

408. Baird, J. A., Coles, P. K., Nicholson, A. N. 1983. Human factors and air operations in the South Atlantic campaign: Discussion paper. **Journal of the royal society of medicine. 76**: 933-937.

The 1982 British air operation to support the South Atlantic campaign (Falkland Islands conflict) necessitated frequent extensively long flights between the UK, Ascension Island, and the Falklands. This posed problems for the aircrews, in particular disturbances of sleep inevitable in maintaining a continuous long-range operation. Medical staffs provided advice on human factors for the aircrew and ground personnel as well as considerations of crew tasks in flight, duration and frequency of flights, unusual patterns of work and rest, rest facilities. The operations posed two problems: Flights of very long duration and intensive rates of work. Flying rates were extended far beyond previous experience, so from the early stages of the campaign, hypnotics were used -- particularly as the rest periods occurred at various times of the day and night, and because several weeks of disturbed sleep were envisaged.

The use of hypnotics in such a critical situation required a drug which was effective at any time of the day or night without a residual effect on awakening after 6 hours sleep. Also, it required facility to use the drug repeatedly at intervals of about 24 hours without accumulation, a drug which is absorbed rapidly and in which plasma concentration fell below that of the minimum effective concentration for impaired performance before awakening. The benzodiazepine, temazepam, a metabolite of diazepam which has no long-acting metabolite and which is rapidly eliminated, was the useful hypnotic used widely to good avail.

During the campaign, the flying rate reached 150 hours per month for Hercules transport crews, sometimes involving six long-range flights with durations of up to 28 hours. Such flights usually extended over two nights with augmented crews. Other crews were flying up to 19 hours in a single flight, and over a 3-month period some accumulated over 360 flying hours. Problems with such flight schedules, conduct of air-to-air refueling, carrier operations, flying helicopter crews up to 10 hours per day etc. are all briefly described in the article.

409. Bartlett, F. C. 1943. Fatigue following highly skilled work. **Proceedings of the royal society (B)**, 147-257.

If the character and causation of fatigue following highly skilled work are to be understood, the first need is for the discovery of more relevant and experimentally controlled facts. Unfortunately, almost all the investigators who attempt to study fatigue of this type have adopted methods taken over with very slight change from those which have proved valuable in the study of simple muscular fatigue. They have chosen elementary operations usually considered to require some "mental" effort -- such as easy calculations, word or color recognition and naming and the like -- have repeated these operations over and over again for long periods, and have tried to express the resulting fatigue in terms of the diminution in quantity or quantity of the work done. The skill fatigue of daily life is not set up under such conditions. Routine repetition of simple actions is not a characteristic of any highly skilled work, and least of all of work having a strong "mental" component. The operations involved here are marked by complex, coordinated and accurately timed activities. The stimuli in response to which these activities are set up are neither simple nor do they usually fall into an order of fixed succession. They have the character of a field, or a pattern, which has become very highly organized, and may retain its identity in spite of a great diversity of internal arrangement.

It is possible to develop fully controlled experimental situations in which these realistic considerations have full play. When this is done the picture which emerges of fatigue following highly skilled work has certain strongly marked characters.

In such fatigue, the "standards" accepted and followed by the central nervous system unwittingly deteriorate. The operator tends to think he is doing better work, because errors treated as significant all the time get wider and wider limits. Until a stage of great fatigue is reached, it is far more likely that the right actions will be performed at the wrong times than that the wrong actions will be performed. If accurate timing is insisted upon, gross mistakes of action may appear. The stimulus field splits up. Its pattern character alters. It becomes a collection of unconnected signals for action, with some of these predominant over all the others. Particularly, stimuli in the margin of the pattern, not closely organized with the central field, are ignored, "forgotten," and serious lapses of specific reactions occur. There is a marked change in the effect of certain "distracting," or additional stimuli. Sensations of bodily origin, in particular, become more pressing and insistent and affect the performance in ways peculiar to the tired operator. Side by side with all these changes go constant subjective symptoms. Verbal reports about any circumstances connected with known failure of performance become increasingly inaccurate, and errors are regularly projected upon objective conditions, or attributed to the interference of other people. There is a tremendous growth of irritability.

An attempt is made to discuss the light thrown by this picture upon the relation of high-level central nervous functions to simpler neuromuscular mechanisms.

410. Beatty, J., Ahern, S., and Katz, R. 1976. Sleep deprivation and the vigilance of anesthesiologists during simulated surgery. In: Mackie, R., ed. **Vigilance: Theory, operational performance, and physiological correlates**. New York: Plenum Press.

The effects of sleep deprivation on performance of anesthesiologists was studied using a simulation of surgical patient monitoring functions and the analytic procedures of signal detection theory. The multichannel simulation was tested first on 36 undergraduate volunteers. The resulting receiver-operating characteristics were highly asymmetric. Observer sensitivity varied significantly as a function of the processing parameter, observation time. In a second experiment, the simulation was used to assess monitoring efficiency of anesthesiologists under rested conditions and after mild sleep deprivation. The monitoring performance of four of six anesthesiologists tested was degraded by sleep deprivation. No differences were observed. However, systematic deficits in complex cognitive processing were present. The role of simulation in studying factors affecting performance in highly specialized, professional occupational groups is discussed.

411. Belenky, G. L. 1979. Unusual visual experiences reported by subjects in the British army study of sustained operations, Exercise Early Call. **Military medicine. 144**: 695-6.

In a British Army field study of sustained operations 9 per cent of the 66 men participating reported unusual visual experiences. These reports were obtained during interviews conducted throughout the course of the study. All the unusual experiences occurred under conditions of severe sleep loss, after 3 or more days of sustained operations. Those which occurred during night-time watch-keeping duties, where the men were socially isolated and had relatively little sensory stimulation, appeared to confuse the men and to disrupt their performance. These latter visual phenomena resembled those reported in studies of sensory deprivation and in anecdotal accounts of prolonged isolation. This suggests that reducing social isolation and increasing sensory stimulation would improve performance during sustained operations.

412. Belenky, G. L., Krueger, G. P., Balkin, T., Headley, D. B., and Solick, R. E. 1987. **Effects of continuous operations (CONOPS) on soldier and unit performance: Review of the literature and strategies for sustaining the soldier in CONOPS.** Washington, DC: Walter Reed Army Institute of Research. (Joint WRAIR/ARI Report No. WRAIR-BB-87-1) {DTIC No. AD-A191-458}. Also in: Dewulf, G.A., ed. 1987. **Continuous operations (CONOPS) final report.** Fort Leavenworth, KS: Headquarters, U.S. Army Training and Doctrine Command and U.S. Army Combined Arms Center. (ACN 073194) {DTIC No. AD-B111-424L. Distribution of Dewulf report limited to U.S. Government agencies only.}.

Two chapters were submitted in a special study of Army conduct of continuous operations. The first chapter 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: Adaption to restricted sleep, effects of fragmented sleep, sleep timing, importance of sleep stages, circadian rhythms, effects of age, wearing chemical protective clothing, and 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 the topics:

Training and preparation for CONOPS; 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.

413. Belk, D. D., and Workman, K. F. 1987. **Resiliency analysis of selected armor and infantry units in continuous operations.** White Sands Missile Range, NM: U.S. Army Training and Doctrine Analysis Command. (TRAC-WSMR-Technical Report No. 23-87) {DTIC No. AD-B114-670L}. Distribution of abstract and document limited to U.S. Department of Defense only.

414. Berkhout, J. 1970. **Simulated time-zone shifts and performance ability: Behavioral, electroencephalographic and endocrine effects of transient alterations in environmental phase.** Paper presented at the NATO Advisory Group for Aerospace Research and Development meeting: Rest and activity cycles for the maintenance of efficiency of personnel concerned with military flight operations, pp. 6:1 - 6:9. (NATO AGARD No. CP-74-70) {DTIC No. AD-717-265}.

Three subjects were maintained on an experimental sleep-activity time-line which simulated a flight assignment crossing 10 time-zones eastbound and return within 72 hours. The subjects were required to operate an automobile and an array of electronic equipment during the simulated flights. Sleep periods were assigned during the simulated local night, involving a 10-hour translation of normal habits, and occasioning two 12-hour epochs of sleep deprivation. Including baseline and recovery periods, the subjects were studied continuously for 9 days.

Mental calculating ability, motor coordination, and auditory perceptual actuality were determined several times per day throughout this period. Electroencephalograms were recorded during all assigned sleep periods and during the administration of behavioral tests. All urine produced during the experiment was collected, and volume, osmolarity, creatinine, and 17-OHC levels were determined as a function of time-of-day.

EEG recordings provided useful monitoring of the subjects' transient arousal status, and permitted the resolution of observed behavioral deficits into sleep-induced, stress induced, and idiopathic classes. Urine chemistry determinations provided measures of circadian physiological fluctuations and their distortions following sleep-activity dislocations, and provided independent estimates of endocrine stress and energy expenditure.

Behavioral capability was observed to depend on several factors, including baseline circadian phase, time-since-waking (an approximation of local circadian phase), endocrine stress, and subjective fatigue. Conclusions are drawn concerning the optimum scheduling of crew assignments on extensive trans-meridian flights.

415. Bills, A. G. 1931. Blocking: A new principle of mental fatigue. **American journal of psychology. 43:** 230-245.

The phenomena investigated in a series of experiments is that of "blocking" in mental work. The study uncovered a principle of mental fatigue. The term "block" refers to those periods, experienced by mental workers when they seem unable to respond, and cannot, even by an effort, continue until a short time has elapsed. Blocking has been frequently observed by students of mental work, but has not heretofore been systemically studied to determine: (a) What laws govern the occurrence of these blocks; (b) what factors determine their frequency; (c) the relation of blocking to fatigue and the decrement; (d) its relation to the principle of refractory phase; and (e) the relation of blocking to the occurrence of errors, and to the amount of previous practice in the task.

Several considerations make an understanding of the phenomenon of blocking important. (1) It has been suggested that the failure to find large and rapid decrement in mental work, such as is found in muscular work, is due to the fact that the subject gets frequent short rests which give sufficient opportunity for recovery from accumulated fatigue, and thus cover up or stave off decrement. (2) The fact of a more or less rhythmic fluctuation in the degree and direction of attention has long been recognized on the subjective side, and it is reasonable to suppose that some corresponding form of fluctuation in performance level would be found as soon as a sufficiently refined technique should be devised for investigating it. (3) A consideration of refractory period in nerve operations, especially the findings pointing to the existence of a cumulative refractory period, of greater length than the simple phase, suggest that a corresponding recurrent gap in the mental activity ought to occur. (4) Granted the existence of such recurrent periods of lowered mental functioning, it would be natural to expect they would have an important bearing on the occurrence of errors, and would yield important information about the cause of errors.

416. Bloom, W. 1970. Shift work and the sleep-wakefulness cycle. **Psychology and industry**. **32**: 315-323.

The requirements of technology and product demand dictate that certain industries operate for more than 8 hours a day. Indeed, some plants are in operation on a round-the-clock basis requiring men to work at different hours of the day and night. This article discusses the effect of shift work on workers' productivity and attitudes and offers suggestions for improving the shift-work arrangement.

417. Blum, M. L. 1956. Fatigue and other phenomena. In: **Industrial psychology and its social foundations.** New York: Harper and Row.

This textbook chapter covers such topics as: Definitions of fatigue, both physical and psychological, describes laboratory and industrial studies of fatigue, and outlines various psychological tests used to study it. It also describes classical work and worker fatigue as it relates to monotony and boredom, mental fatigue, attitudinal variables etc. A discussion of the relationship between an employee's hours of work and his production, notions of an optimum, and even an ultimate work week also are presented.

418. Bodrov, V. A. 1988. Flight crew fatigue problems: Concepts, causes signs, and classification. **Fiziologiya Chelovek.** 14(5): 835-843. (In Russian).

The researcher draws on the data of the literature and an analysis of the results of experimental research he performed with colleagues on the problem of fatigue to define the concepts of "fatigue" and "over fatigue" in a flight crew, the causes and signs of development of the conditions, and a classification of the conditions. Here "fatigue" is taken to represent the functional conditions that develop as a result of an intensive or lengthy stint of work (both in the air and on the ground) and that manifests itself as a temporary disturbance in the condition of a number of the body's functions and a lower efficiency and poor quality of job performance. "Overfatigue" is defined as a pathological functional condition of the body that results from repeated lengthy, intensive work stints and accumulating fatigue, is accompanied by substantial disturbance of the condition of a number of functions of the body and a reduction in efficiency and quality of performance, and is normalized only with treatment and use of medical and psychophysiological means of rehabilitation. The principle cause of fatigue and over fatigue is an intensive or long work schedule. Adverse flight conditions, mental stress, or too much physical and mental labor before a flight can accelerate the development of fatigue; factors that predispose a crewmember to fatigue include not getting proper rest and relaxation, lengthy intervals between flights, illness, lack of exercise, harmful habits, poor occupational training, and adverse physiochemical or sociopsychological environmental conditions. Signs of fatigue or overfatigue may be occupational or physical. The former involves efficiency and job performance. Physical signs include a turn for the worse in one's health or an inability to sleep. A feeling of tiredness in fatigue may worsen to a feeling of apathy, constant headaches, vertigo, loss of appetite, nausea, or even vomiting, chest pains, a quickened heartbeat, and nightmares. The researcher classifies fatigue as compensated, acute, or chronic, sometimes worsening to overfatigue. References 51: 46 Russian, 5 western.

419. Borowsky, M. S., and Wall, R. 1983. Naval aviation mishaps and fatigue. **Aviation, space, and environmental medicine.** 54(6): 535-538.

Naval aircraft mishap data were analyzed to determine if statistical relationships among variables generally associated with fatigue and mishap liability exist. Pilots in mishaps were divided into two groups: Those who were involved causally and those who were not. The results demonstrated that fighter and helicopter pilots who had worked at least 10 hours in the previous 24 were significantly more likely to fall in the causally involved group. However, variables related to sleep, continuous duty, missions performed, and hours flown in the immediate past showed no significant relationships with mishap liability. However, analysis of mishap rates as a function of time of departure indicated that rates tended to be lowest for flights originating between 0900 and 1800, a result that possibly supports the hypothesis that "circadian desynchronization" contributes to mishaps.

420. Boutelier, C., Maurice, E., Lefievre, C., and Guerin, G. 1983. **Thermal constraints in a helicopter during long duration flights under extreme climatic conditions.** (Contraintes thermiques en helicoptere au cours des vols de longue duree en ambiances climatiques extreme). Paper presented at the NATO Advisory Group for Aerospace Research and Development meeting: Sustained Intensive Air Operations, pp. 25:1 - 25:7. (NATO AGARD Report No. CP-338) {DTIC No. AD-A139-324}. (In French).

The physiological and psychophysiological effects of extreme climatic conditions on helicopter crews were observed and analyzed. It is concluded that the operational effiency of flight crews can be obtained by adopting four measures: 1) Preliminary acclimatization of the crews; 2) limitation of hours of flight with a possibility for rest between flights in a climatized environment; 3) improvement of the comfort and ergonomics of the pilot station; and 4) improvement from partial to total individual acclimatization.

421. Brecht, J. M., and Hedley, D. 1985. Psychological and physiological effects of NBC and extended operations on combined arms crews. In: Mangelsdorff, A.D., King, J.M., and O'Brien, D.E., eds. **Fifth users' workshop on combat stress**, pp. 152-174. Fort Sam Houston, TX: U.S. Army Health Services Command. {DTIC No. AD-A170-784}.

Three studies were conducted to address questions on the psychological and physiological effects of wearing the chemical defense ensemble, particularly at military oriented protective posture (MOPP) level 4, in continuous operations. The first test was a sustained operations scenario at Fort Knox with M60 and M1A1 tank crews. The second test, also a sustained operations scenario, was at Fort Sill with M109 howitzer crews. The final test was a continuous operations scenario conducted at Fort Benning with Bradley infantry fighting vehicle and M113 armored personnel carrier crews. It has become evident from the test results that the chemical defense ensemble combined with heat severely limits endurance. A field circular with information for tactical commanders on "how to fight" has been generated from the information garnered in the studies.

422. Brictson, C. A. 1977. Methods to assess pilot workload and other temporal indicators of pilot performance effectiveness. **AGARD conference preprint no. 217.** Paper presented at the Aerospace Medical Panel Specialists meeting, Studies on pilot workload, Cologne, Federal Republic of Germany.

A systematic approach to define, measure, and describe how certain pilot-related variables influence carrier landing performance during sustained operations is outlined briefly. Previous exploratory research on the interrelations between psychophysiological variables, pilot experience and performance is described. Pilot work activity, mood, and sleep are identified as indicators of a pilot's temporal state of readiness. A field study design and techniques to measure and describe temporal readiness during prolonged flight operations are provided to demonstrate the methodology in an operational environment. Potential applications of the research are discussed along with the future role of temporal, psychological, and other moderator variables in estimating pilot flight status.

423. Brictson, C. A., and Young, P. 1980. **Measures of Navy pilot workload, sleep, and performance in stressful environments.** La Jolla, CA: Dunlap and Associates, Inc. (Office of Naval Research Final Report Contract No. N00014-77-C-0066) {DTIC Report No. AD-A087-131}.

Measures of Navy pilot workload, sleep, and landing performance collected under two stressful environments -- carrier deployment and carrier landing qualification -- are analyzed and described. The study was conducted to demonstrate the application and utility of data collection techniques in operational environments and to describe the typical workload and sleep activity of Navy pilots. Attack pilots and landing signal officers averaged 12-hour workdays at sea and supplemented their sleep by short naps during flying periods. Landing performance for attack aviators was remarkably high with boarding rates at night averaging 93 percent for the entire deployment. Performance decrement was noted both day and night only after extensive in-port periods of flight inactivity. Recommendations and summary are discussed.

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424. Chiles, W. D. 1955. **Experimental studies of prolonged wakefulness.** Wright-Patterson Air Force Base, OH: U.S. Air Force Wright Air Development Center, Air Research and Development Command. (WADC Technical Report 55-395) {DTIC No. AD-100-698}.

Two experiments considered the effects of prolonged wakefulness and fatigue on performance of psychomotor and psychological tasks. The first involved four subjects sitting individually in an aircraft cockpit for 56 hours. During this time, measures of reaction time and alertness were taken, and, at the end of the experiment, two of the subjects flew instrument landing system passes in a Link trainer. The reaction time and alertness measures reflected considerable variability in the attentiveness of the subjects. Performance in the Link trainer was judged to be within limits of acceptability.

The second experiment involved assessment of the effects of 30 hours of wakefulness with continuous work (painting a barracks) on the performance of 15 subjects on a psychological and a psychomotor task. In addition, the effects of two different drugs, d-amphetamine sulphate and cortisone, were compared with those of a placebo. The psychological test involved the summing of rows of figures, and the psychomotor test involved arm-hand steadiness. Each of these tests distinguished, to some extent, the two drug groups from the placebo group. It was concluded that the two drugs improve performance on the addition test, whereas they tend to decrease arm-hand steadiness as a function of time.

425. Clark, B., and Graybiel, A. 1961. Human performance during adaptation to stress in the Pensacola slow rotation room. **Aerospace medicine. 32**(2): 93-106.

This report presents the results of tests to determine any changes in the performance of subjects on a variety of tasks during a 2-day period of constant rotation. Some of the tests selected were of such a nature as to impose a stress by requiring the subject to move his head to produce random, bizarre patterns of stimulation to the semicircular canals. All of the tests were designed to give gross measures of the subject's ability to function under prolonged constant rotation rather than to get minute changes in performance. The findings are concerned with the function of the psychophysiological mechanisms involved, but they also apply directly to man exposed to slow rotation in orbiting satellites, radar domes, and the like. They also apply directly to motion sickness of all types insofar as the semicircular canals contribute to the symptomatology.

426. Colligan, M. J., and Tepas, D. 1986. The stress of hours at work. **American industrial hygiene association journal. 47**(11): 686-695.

Many human physiological and psychological functions follow a 24-hour cycle which is related to, but not necessarily controlled by, the diurnal activity pattern. This is true of literally hundreds of processes as diverse as respiration rate, urine excretion, cell mitosis, blood pressure, adrenal hormone production, enzyme activity, and reaction time. These independent functions form a complex network of phase relationships to the activity cycle and to each other. The relationship between diurnal activity and body temperature is more parallel than casual, however, if the activity cycle is disturbed or altered in some way the body temperature rhythms remain relatively unchanged and the two cycles become dyssynchronous. While body temperature may be influenced by the activity cycle, it is not controlled or regulated by it, and changes or inversions in the activity cycle do not readily and automatically produce similar phase shifts in other circadian functions. This has important implications for shiftwork which requires that the individual alter his customary diurnal activity pattern to comply with a work schedule. This may potentially disrupt the phase relationship between each of the individual circadian functions and the activity cycle, as well as the interrelationships between the cycles themselves. A brief review of the current findings regarding shiftwork as it affects individual safety is followed by a discussion of some strategies proposed to facilitate worker adjustment to shiftwork. Finally, some preliminary findings with respect to worker acceptance of alternate work schedules, specifically the extended or 12-hour workday, are examined.

427. Colquhoun, W. P., ed. 1971. **Biological rhythms and human performance**. New York: Academic Press.

This book illustrates some of the ways in which characteristic human rhythms influence behavior through their effects on the functioning of the nervous system. Particular emphasis is laid on measurement of actual performance rather than on feelings or mood, because emotional changes are more difficult to quantify than perceptual motor and cognitive functions. A major section of the book is devoted to the diurnal cycle. There is a review of the literature of the effects of the diurnal rhythm on mental efficiency, and an account of some research dealing with the question of individual differences in diurnal performance rhythms and their relation to personality and physiological factors. Two chapters demonstrate the wide range of time-scales over which biological rhythms influence performance. The final chapter "Industrial Work Rhythms" tackles the problems of measuring and accounting for the fluctuations in production which often occur on the actual shop floor from hour-to-hour or day-to-day.

428. Colquhoun, W. P. 1982. Sleep and performance. In: Webb, W. B., ed. **Biological rhythms, sleep, and performance**. New York: John Wiley and Sons.

This chapter considers performance as it relates to the time period in which it occurs. Early work describing diurnal changes influencing "mental efficiency" and the relationships between temperature and performance are reviewed. The complex issue of repeated measures and the resultant compounding of "learning" and "motivational" effects are noted. A systematic analysis of recent research, emphasizing the task specific nature of the performance/time relationship, provides evidence of clear cut variations linking performance level and time of day. The impact of the modifying factors of motivation and personality are considered. The chapter discusses conceptual and explanatory issues raised by data relative to "arousal" and "fatigue" and the methodological problems of measuring performance "efficiency." The effects of various task dimensions and strategy changes relating to these issues are also explored.

429. Colquhoun, W. P. 1985. Hours of work at sea: Watchkeeping schedules, circadian rhythms and efficiency. **Ergonomics**. 28(4): 637-653.

This review is concerned with the hours of work of personnel engaged in watchkeeping duties on board ocean-going vessels sailing between distant ports. Existing research findings are considered in the context of the degree of adjustment shown by physiological and performance rhythms to the various watchkeeping systems in use on different types of ships. The findings are discussed in relation to a proposed program of research aimed at determining the optimal system for maintaining efficiency in crews operating the modern, fully automated vessels coming into service in the 1980s.

430. Cook, M. R., Cohen, H., and Orne, M. T. 1972. **Recovery from fatigue.** Fort Detrick, MD: U.S. Army Medical Research and Development Command. (Institute of the Pennsylvania Hospital Annual Report No. 55, Contract No. DADA 17-71-C-1120) {DTIC No. AD-A117-379}.

To study the effectiveness of daytime sleep (napping) in alleviating the subjective and objective consequences of fatigue, partially sleep-deprived subjects volunteered to take naps in a controlled laboratory setting. EEG and EOG records were obtained as well as a behavioral performance measures, reaction time measures, and subjective depth of sleep reports. Subjects carried out a serial subtraction task (a) before going to sleep, (b) immediately on being aroused from sleep, and (c) some time later after the electrodes had been removed and they felt fully aroused. In general, when subjects were aroused from napping, there was an initial impairment of functioning. Further, some trends in the data suggest that naps were effective in improving final performance. Significantly greater performance decrement was associated with sudden arousal from delta sleep than from REM sleep. Short periods of sleep which did not include significant amounts of delta sleep caused little or no decrement in performance. Further research is in progress studying the physiological characteristics of naps and their effects on the subjective recovery from fatigue among individuals who habitually take naps versus those who do not.

431. Cook, M. R., Evans, F. J., Cohen, H., and Orne, M. T. 1973. **Recovery from fatigue.** Fort Detrick, MD: U.S. Army Medical Research and Development Command. (Institute of the Pennsylvania Hospital Annual Report No. 58, Contract No. 17-71-C-1120) {DTIC No. AD-A117-380}.

Three studies are reported on: (1) A factor analytic investigation of questionnaire data to help establish the attributes of individuals who habitually nap as opposed to others who do not. (2) A study over eight sessions comparing the physiological napping behavior of habitual nappers versus individuals who do not normally nap. (3) A study currently in progress evaluating the effect of napping on performance in partially sleep-deprived individuals. Previous observations about the deleterious effects of naps involving delta sleep on performance immediately on awakening were again observed. One of the more striking findings is that nappers seem to perceive descending stage I sleep as more like being awake while nonnappers describe it as sleep. Further, it would appear that daytime napping serves appetitive functions in addition to facilitating recovery from fatigue in nonsleep-deprived habitual nappers. The likelihood that there are functional differences in napping behavior between nappers and nonnappers is discussed.

432. Cox, T., and Krueger, G. P. 1989. Editorial: Stress and sustained performance. **Work and stress.** 3(1): 1-2.

An editorial introducing nine technical articles in a special journal issue on the topic of stress and sustained performance. Authors indicate many industries must run high cost plants continuously, many services are now provided round-the-clock and other work situations require prolonged periods of continuous working coupled with demands of high performance. Sometimes these work needs can be met adequately by the use of traditional shiftwork systems, but sometimes they cannot and employees then may be faced with the challenge of long hours of work inevitably married to the problems of sleep loss. The articles in this edition of **Work and stress** highlight research issues raised by members of the U.S. Department of Defense-sponsored Human Factors Engineering Technical Group on Sustained and Continuous Operations.

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433. Darsch, G. A. 1986. **REDLEG --- Physiological and psychological effects of nuclear, biological, and chemical and extended operations on crews (P2NBC2) command post vehicle life support exercise.** Natick, MA: U.S. Army Natick Research, Development, and Engineering Center. (Natick Technical Report No. TR-86-049L) {DTIC No. AD-B110-649}. Distribution of document limited to U.S. Department of Defense.

434. Davis, D. R., Shackleton, V. J., and Parasuraman. 1983. Monotony and boredom. In: Hockey, G. R., ed. **Stress and fatigue in human performance.** New York: Wiley and Sons.

Boredom is an individual's emotional response to an environment perceived to be monotonous. This chapter examines the effects of monotony and boredom on the performance of industrial and laboratory tasks. It surveys definitions of monotony and boredom and proceeds to a review of industrial studies of boredom and output, varied and unvaried work, music, output, and job attitudes and correlates of susceptibility to boredom. Laboratory investigations of monotony and boredom then are considered, including studies of vigilance, individual and group differences in boredom, and performance and psychophysiological correlates of the experience of boredom. The chapter concludes with a brief assessment of ways in which boredom might be alleviated.

435. Deese, J. 1955. Some problems in the theory of vigilance. **Psychological review. 62**: 359-368.

A paper concerned with current specifications of the concept of vigilance. Much of this paper consists of a discussion of two alternative hypotheses about the exact nature of the stimulus events sufficient for the control of vigilance, the reinforcement hypothesis and the expectancy hypothesis, with a main emphasis upon excitory properties. There is a brief section on inhibitory properties showing the advantages resulting from minimizing the importance of an inhibitory construct. The data reported here come from studies of simulated radar watching on a PPI-type cathode ray tube.

436. Defense Research Group 1986. Physical fitness as it pertains to sustained military operations. In: **Panel on the defense applications of human and bio-medical sciences, research study group on physical fitness, final report**, pp. 50-70. (NATO Document No. AC/243-D1092, AC/243 [Panel VIII]D/125).

Sustained physical performance is limited by many physiological factors, including but not limited to; sleep deprivation, circadian rhythms, and the environment. Ergogenic aids can affect positively sustained physical performance. Some examples of these are: Carbohydrate loading, blood doping, used primarily in competition, and caffeine. Physical fitness possibly, in turn, can have an impact on sustained cognitive performance. The physical work rate that can be maintained nearly continuously is clearly related to physical fitness. One can infer the protective effects of increased aerobic fitness on decrements in cognitive performance, but there remains a need for studies with more direct evaluation.

437. DeJohn, C. A., Murdoch, D. M., Parker, J. B., and Banta, G. R. 1986. Effects of sustained flight operations on naval aircrews. **Aviation, space, and environmental medicine. 57**(5): 497. (Abstract).

Fatigue is frequently cited as a contributing factor in aircraft mishaps. Sustained flight operations may have physiological and psychological effects that can be determined by measuring urinary metabolites, subjective mood, and subjective fatigue of the aircrews. This study evaluated the effects of sustained flight operations on subjects exposed to extended over water flights. The subjects were 10 men, ages 21-33 years, all members of the same flight crew. The crew was observed at an overseas deployment site for 14 days. Nine of the 14 days were no-fly days and resting data were taken. Antisubmarine warfare (ASW) missions were flown on 4 days and in-flight urine, subjective mood, and subjective fatigue data were collected on four of the five missions. Total flight time for in-flight data collection was 32.6 hours. Sodium, potassium, and negative mood showed increases with flight time, while sodium-potassium ratio and urea showed decreases with flight time, none of which were statistically significant. Positive mood decreased and subjective fatigue increased with flight time, both significantly. Changes occurred in urinary metabolites, subjective mood, and subjective fatigue with sustained flight operations; however, only positive mood and subjective fatigue showed any statistically significant change.

438. DeWulf, G. A., ed. 1987. **Continuous operations (CONOPS) study, final report.** Fort Leavenworth, KS: U.S. Army Training and Doctrine Command Combined Arms Center. (Final Report No. Z01707) {DTIC No. AD-B111-424L}. Distribution of document limited to U.S. Government agencies only.

439. Dinges, D. F., and Powell, J. W. 1985. Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations. **Behavior research methods, instruments, and computers.** 17(6): 652-655.

There is a need for brief, portable performance measures that are free of practice effects, but that reliably show the impact of sleep loss on performance during sustained work. Reaction time (RT) tasks hold considerable promise in meeting this need, if the extensive number of responses they typically yield can be processed in ways that quickly provide the essential analyses. While testing the utility of a portable visual RT task during a sustained, quasi-continuous work schedule of 54 hours, a microcomputer software system was developed to input, edit, transform, analyze, and reduce data from the RT portable audiotapes, for each 10-minute trial on the task. With relatively minor modifications, the software system can be used on a minimally configured microcomputer system that supports BASIC. The software is flexible and capable of retrieving distorted data, and it generates a variety of dependent variables reflecting intratrial optimum response capacity, lapsing, and response slowing.

440. Dinges, D. F., and Whitehouse, W. G. 1985. A dual-probe recognition memory task for use during sustained operations. **Behavior research methods, instruments, and computers.** 17(6): 656-658.

Although memory has been shown to be greatly affected by sleep loss, there is an absence of data on the effect of sustained work on recognition memory. This is unfortunate because recognition, unlike free recall, can be analyzed to separate effects on memory sensitivity from effects on report bias. Based upon work with single-probe recognition memory tasks, a dual-probe recognition task was developed for practical use in sustained work paradigms. The task requires 20 minutes to complete and yields an array of performance variables that can be used to conduct signal detection analyses, to assess serial-position effects, and to evaluate speed-accuracy functions.

441. Dinges, D. F., Whitehouse, W. G., Orne, E. C., and Orne, M. T. 1988. The benefits of a nap during prolonged work and wakefulness. **Work and stress. 2**: 139-153.

Prolonged work scenarios with demands for sustained performance are increasingly common. Because loss inevitably compromises functioning in such situations, napping has been proposed as a countermeasure. The optimal timing of the nap relative to its benefits for performance and mood is not known. To address this issue, 41 healthy adults were permitted a 2-hour nap at one of five times during a 56-hour period of intermittent work, with no other sleep. Naps were placed 12 hours apart, near the circadian peak (P) or trough (T) and were preceded by 6(P), 30(P), 42(T), or 54(P) hours of wakefulness. Work test bouts occurred every few hours and consisted of a variety of psychomotor and cognitive tasks as well as mood scales completed at the beginning, middle, and end of each bout. A total of 8 performance and 24 mood parameters were derived from the bouts and compared between groups at all test points prior to and following the naps. An estimate of the extent to which each nap condition differed from the control 54(P) condition was derived by totalling the proportion of test points that yielded statistically significant results relative to the total number of tests conducted both before and after naps.

Although all performance and most mood parameters displayed a circadian-modulated deterioration as the protocol progressed, a nap appeared to attenuate the extent of this change in all performance parameters, but not in mood parameters. Overall, the timing of the nap across days and within the circadian cycle was irrelevant to its effect on performance, suggesting it diminished the intrusion of sleepiness into behavioral functioning, even though subjects were phenomenally unaware of this benefit.

442. Donnell, J. M. 1969. Performance decrement as a function of total sleep loss and task duration. **Perceptual and motor skills. 29**: 711-714.

To determine the effect of task duration and its sensitivity to total sleep loss, measures of speed and accuracy on the Wilkinson addition test were obtained from 11 Navy enlisted men for 4 baseline days and 2 days without sleep. The number of additions attempted decreased significantly from the baseline level after 10 minutes of testing on the first deprivation day and after 6 minutes on the second day. Fifty minutes of testing were required to detect a significant decrease in accuracy from baseline on the first deprivation day, while 10 minutes were required the second day.

443. Draper, E. S., and Lombardi, J. J. 1986. **Combined arms in a nuclear/chemical environment (CANE) force development testing and experimentation (FDTE). Summary evaluation report, phase I.** Fort McClellan, AL: U.S. Army Chemical School. {DTIC No. AD-B101-686}. Distribution of abstract and document limited to U.S. Government agencies and their contractors only

444. Drory, A. 1985. Effects of rest and secondary task on simulated truck-driving task performance. **Human factors. 27**(2): 201-207.

A study examined the effects of extra task stimulation and extra rest on performance and fatigue of long haul truck drivers engaged in a simulated driving task. Sixty male subjects, randomly selected from the population of truck drivers in a large mining company, operated a driving simulator for a period of 7 hours. A 2 x 3 experimental design was employed including two levels of rest conditions and three levels of secondary-task manipulations. The results show that performance and perceived fatigue were significantly higher when a secondary task involving voice communication was added to the basic driving task, but an added vigilance task had less effect. An extra 30-minute rest period in the middle of the experimental session significantly alleviated the reported experience of fatigue, but did not affect performance. The results are discussed in terms of their relevance to actual industrial driving tasks.

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445. Ellis, S. L., Elliot M., Johnson, M. A., Pimental, N. A., Rauch, T. M., and Smith, H. R. 1986. **Concept evaluation of M1E1 NBC 72-hour test.** Fort Knox, KY: U.S. Army Armor and Engineer Board. (TRADOC TRMS Report No. 4-CEP195) {DTIC No. AD-B100-557L}. Distribution of document limited to U.S. Government agencies.

446. Englund, C. E. 1985. The stresses and strains of sustained operations as a function of time-of-day. In: Mangelsdorff, A.D., King, J.M., and O'Brien, D.E., eds. **Fifth users' workshop on combat stress**, pp. 183-197. Fort Sam Houston, TX: U.S. Army Health Services Command. {DTIC No. AD-A170-784}.

This summary reports the findings of a series of continuous work studies simulating an extended reconnaissance patrol. The focus was upon task performance with physical demands and sleep loss. Eleven pairs of Marines (one exercising and one nonexercising) experienced one 12-hour and two 20-hour continuous work episodes (CWE). The 20-hour CWEs were separated by 5 hours which included a 3-hour nap from 0400-0700. Each hour of CWE was split into 2 half-hour sessions. During the first half-hour, subjects performed alphanumeric (A-N) visual vigilance tasks. The exercising member of each pair spent this first 30 minutes also walking on a treadmill in full combat gear at 31 percent VO2 heart rate for a total distance of approximately 114 kilometers. The nonexercising subject performed the A-N task sitting quietly at a video terminal. During the second half-hour, all subjects completed mood and fatigue scales, measured oral temperature, blood pressure, and grip strength, and performed a simple reaction time task. Also during this second half-hour, both subjects performed selected combinations of tasks, such as rapid alternating response, logical reasoning, word memory, four-choice serial reaction time, reading, rifle assembly, naval anti-air warfare task and educational testing service visual memory. Continuous heart rate measurements were obtained for both subjects while performing the A-N task. During sleep periods, electroencephalograph, electrocardiograph, and electrooculograph recordings were obtained. Treadmill walking did not accentuate or attenuate sleep-loss effects on performance, but increased physical complaints. Sleep loss alone degraded visual vigilance and memory. Visual vigilance for nonexercising subjects degraded sooner on the second day CW than it did for those exercising. Combat start time made a critical difference in maintaining performance effectiveness, positive mood, and less fatigue. All variables showed significant circadian rhythms during the first continuous work episode except negative mood for the exercise group. Sleep deprivation and continuous work seem to decrease rhythm strength, and in most cases, decrease rhythm amplitude.

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447. Fine, B. J., and Kobrick, J. L. 1985. **Effect of heat and chemical protective clothing on cognitive performance.** Natick, MA: U.S. Army Research Institute of Environmental Medicine. {DTIC No. AD-A162-001}.

This study examined the effects of heat on the sustained cognitive performance of sedentary soldiers clad in chemical protective clothing. Twenty males trained for 2 weeks on selected military tasks. Then, they performed the tasks for 7-hour periods on 4 successive days in hot (32.8^{o} C., 61 percent rh) and normal (21.1^{o} C, 35 percent rh) conditions, with and without protective clothing. After 4-5 hours in the heat wearing protective clothing, the cognitive performance of the group began to deteriorate markedly. By the end of 7 hours of heat, increases in group error on investigator-paced tasks ranged from 17 percent to 23 percent over control conditions. Virtually all of the decrements were due to increases in errors of omission. The productivity of the group on a self-paced task (map plotting) diminished by approximately 40 percent from control conditions after 6 hours in the heat in protective clothing; accuracy of plotting was not markedly affected.

448. Folkard, S. 1983. Diurnal Variation. In: Hockey, G. R., ed. **Stress and fatigue in human performance.** New York: Wiley and Sons.

Measures of human performance efficiency show more or less predictable variations over the day and night. These "diurnal" variations are thought to reflect the underlying 24-hour, or "circadian" rhythms now known to exist in most physiological parameters. In particular, it had been suggested in the past that there was a pronounced parallelism between variations in certain simple types of performance over the day, and those in body temperature. This parallelism gave rise to the arousal theory of time-of-day effects that assumed diurnal variations in performance to reflect an underlying circadian rhythm in basal arousal level.

This parallelism between changes in performance over the day and those in temperature is, however, now known to hold for only a limited range of tasks and individuals performing such tasks. The precise nature of the task demands, and, in particular, the memory load involved in performing the task, has been shown to exert a large influence on the trend in performance over the day. In addition, even for simple, nonmemory loaded tasks, the parallelism between temperature and performance has been shown to depend on the nature of the individual performing the task.

These findings, together with those on the interaction of time of day with other arousal manipulations, and the trends in other physiological measures of arousal over the day, suggest a re-examination of the arousal theory of time-of-day effects is necessary. Nevertheless, it is undoubtedly the case that such effects exist, that they are relatively unavoidable, and that they have important practical, as well as theoretical, implications for the study of human performance efficiency.

449. Folkard, S. and Monk, T. H., eds. 1985. **Hours of work: Temporal factors in work-scheduling.** New York: John Wiley and Sons.

In an era of ever-increasing shift-work and more flexible work schedules, what does the growing research in chronobiology have to offer in making the structure of the working day more pleasant, productive, safe, and cost-effective? Experts in several disciplines address the ways human physiological and psychological processes interact and vary over time, and the implications of these changes for human performance and work scheduling. Initial chapters discuss 24-hour (circadian) rhythms and sleep, noncircadian rhythms such as the menstrual cycle, and nonrhythmic time variations. The second half of the book is practically oriented, offering articles on normal and abnormal work hours, shiftwork, and jet lag.

450. Fourcade, J., Buget, A., Bugat, R., and Raphel, C. 1983. **Variations in states of alertness during continuous operations at the control post level.** (Variations des etats de vigilance au cours d'operations continues au niveau d'un poste de commandement). Paper presented at the NATO Advisory Group for Aerospace Research and Development meeting: Sustained Intensive Air Operations, pp. 10:1 - 10:15. (NATO AGARD Report No. CP-338) {DTIC No. AD-A139-324}.

The evolution of certain mental and decision making capacities of control post personnel was observed and two officers were chosen as representative of the group for neurophysiological studies of sleep and wakefulness as well as psychological and psychoergonomic evaluation. Urinalyses also were performed. Hypnograms from the neurophysiology of sleep tests show a difference in sleep deprivation for the two subjects because of the hours worked and the degree of comfort during sleep. Occipital and temporal deprivation obtained by EEG is plotted and results of the urinalysis are discussed. It is concluded that persons responsible for cognitive and decision making tasks at a control post must have a nearly normal amount of sleep.

451. Fourcade, J., and Raphel, C. 1983. **Psycho-ergonomic problems presented by the prolonged wearing of gas masks.** (Problemes psycho-ergonomiques poses par le port prolongue de masques a gaz.) Paper presented at the NATO Advisory Group for Aerospace Research and Development meeting: Sustained Intensive Air Operations, pp. 18:1 - 18:13. (NATO AGARD Report No. CP-338) {DTIC No. AD-A139-324}. (In French).

The adaptation of man to the gas mask and the constraints that wearing this protective device continuously from 16 to 48 hours imposes on his living and working was investigated in 34 subjects over a 2-year period without simulating a toxic chemical environment. The relation of the mask wearer with his environment, with other mask wearers, with the mask itself, and with nourishment were investigated. Results discussed cover the effects of the mask on visual tasks, sensorimotor adjustment (writing, walking, driving, use of instruments, etc.), verbal communications, and the making of medical examinations. The opinions of the subjects on their affective and mental states are examined including individual dynamics, sociability, the tendency for isolation, annoyance with the mask during work, manifestations of pain, sleeping conditions, and general comfort. Liquid feeding, caloric intake, and gastric system disturbances also are covered.

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452. Gander, P. H., and Graeber, R. C. 1987. Sleep in pilots flying short-haul commercial schedules. **Ergonomics.** 30(9): 1365-1377.

To observe the effects of commercial short-haul flight operations on sleep, 74 pilot volunteers were monitored before, during, and after 3- or 4-day duty schedules. Subjects kept daily logs of going to bed, falling asleep, waking up and getting out of bed, and of the number of nocturnal awakenings and the duration of sleep (not including time in bed but awake). They also rated the quality of each night's sleep. Heart rate and the activity of the nondominant wrist were recorded every 2 minutes throughout the study, using portable physiological monitors. Average heart rate and wrist activity during sleep were used as physiological indicators of sleep quality. Pilots fell asleep later and woke up earlier on trip nights. The timing and duration of sleep were correlated strongly with the timing and duration time available for sleep, i.e., the time between duty days. In particular, early duty report times necessitated early arousals. On the other hand, sleep quality was related most consistently to the number of segments flown in the preceding duty day rather than the duration of the duty day. Sleep generally was better after days with more flight segments, unless long duty days encroached on the time available for sleep. There was evidence of recuperation after a trip, when the duration of sleep was longest, the time taken to fall asleep was shortest, sleep ratings were highest and napping was most common. These studies indicate that pilots flying scheduled short-haul commercial duties do experience sleep restriction. Evidence from other laboratory and field studies suggests sleep restriction may have detrimental effects on subsequent daytime sleepiness, performance, and mood.

453. Gerd, M. A. 1975. Man's capacity for work under a special regime in an isolation chamber. **Voprosy Psikhologii.** May-June (no. 3): 123-128. (In Russian).

A study of the adaption of three subjects isolated within a small chamber in a submarine to an 18-hour sleep-wakefulness cycle with equal time (6 hours) scheduled for sleep, work, and other activities, over an interval of 20 cycles (360 hours, or 15 days). Adjustment to the 18-hour schedule is reported to have occurred after 11 to 12 cycles (198 to 216 hours, or 8 to 9 days), as indicated by the return of "deep and quiet sleep" and the absence of sleepiness during waking hours. However, work-performance levels remained below pre-experimental control values, possibly because of subjective factors that influenced the subjects to work at less than their best.

454. Gibbs, C. B., Leonardo, R., and Rowlands, G. F. 1968. **The effects of psychological stress upon decision processes and the speed and precision of tracking movements: A study of the effects of sleep deprivation and disturbance.** Ottawa, Canada: National Research Council of Canada. {DTIC No. AD-B951-634. Distribution limited to DTIC users only}.

455. Glumm, M. M. 1988. **Physiological and psychological effects of the NBC environment and sustained operations on systems in combat (P2NBC2):** Tank systems climate-controlled trials (Iron Man). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (USAHEL Technical Memorandum 9-88). Distribution of document limited to U.S. Government.

The primary objectives of the investigation were to observe operations of the M1 tank system under NBC conditions for up to 72 continuous hours and to observe the effects of modifications in equipment and procedures on crew performance and endurance. A total of 48 armor crewmen (12 crews) participated in the study. In each of six study iterations the performance and endurance of two crews were measured during a simulated tactical scenario under one of five test conditions: Baseline, training/doctrine, hardware, combined, and a modified combined condition. Data also were collected on each crewman's symptoms, physical discomforts, and mood changes. During the investigation, the percentage of targets engaged decreased and time to engage these targets increased. The greatest number of withdrawals from the study and the greatest degradation in performance occurred between 6 and 11 hours into the test. Lower symptom intensities appeared to be reported by crewmen who participated in the hardware solutions. The most common complaints among crew members during the study were heat discomfort, sweating, nausea, not enough air to breathe, and headaches.

456. Graber, J. G., Rollier, R. L., and Salter, J. A. 1986. **Continuous operations SOP for BIFV units.** Fort Benning, GA: U.S. Army Research Institute for the Behavioral and Social Sciences Field Unit. (USARI Research Note 86-60) {DTIC No. AD-A169-191}.

Based upon the analysis of the threat and the emerging role of the Bradley in combined arms operations, it is apparent there is a clear need for increased Bradley infantry fighting vehicle (BIFV) unit awareness of the combat-relevant aspects of continuous operations. This need must be met by providing small unit leaders with appropriate tools to survive and fight under conditions of prolonged operations. One of these tools is a continuous operations (CONOPS) annex to company tactical standard operating procedure. This SOP provides guidance for establishing a routine work/rest schedule that units can use immediately to improve sleep discipline. Placing guidelines for the conduct of continuous operations in the hands of leaders at company/platoon/squad levels will increase awareness of the issue and provide a tool for evaluating unit implementation of continuous operations procedures during unit ARTEPS.

457. Graeber, R. C. 1986. Sleep and fatigue in operating flight crews. In: Lee, G.E., ed. **Proceedings of the tenth symposium: Psychology in the Department of Defense**, pp. 399-402. Colorado Springs, CO: U.S. Air Force Academy, Department of Behavioral Sciences and Leadership.

The effects of flight duty on aircrew sleep and fatigue were examined in commercial and military crews flying short- and long-haul routes. Sleep duration and quality are affected adversely in short-haul operations despite mostly day and evening flights crossing a maximum of one time zone. These effects are reflected in subjective mood and fatigue changes during the trip. Sleep disturbances are prevalent more in international long-haul crews due to circadian desynchronization. Polysomnographic recordings coupled with daytime multiple sleep latency tests confirmed that greater disruption of sleep-wake patterns occurs after eastward than after westward flights. Factors such as age, personality, and exercise are important determinants of the extent of these effects in individual crew members.

458. Graham, C., Cook, M. R., and Cohen, H. D. 1982. **Task validation for studies on fragmented sleep and cognitive efficiency under stress.** Kansas City, MO: Midwest Research Institute. (U.S. Army Medical Research and Development Command Final Report Contract No. DAMD17-80-C-0075) {DTIC No. AD-A130-260}.

A computer gaming approach was used to create a new type of automated performance task, the strategic and tactical assessment record (STAR). The task unobtrusively measures multiple cognitive skills and risk-taking behavior under various stress and workload conditions. A training manual and protocol were developed, and performance criteria established. Measurement reliability and performance under different task difficulty levels and crisis conditions were assessed. STAR is shown to be a sensitive task which promises to reliably measure major aspects of human function under a variety of conditions.

459. Graham, C., Cook, M. R., Cohen, H. D., Phelps, J. W., and Gerkovich, M. M. 1985. STAR: A unique embedded performance assessment technique. **Behavior research methods, instruments, and computers. 17**(6): 642-651.

STAR (strategic and tactical assessment record) is a versatile research tool designed to evaluate the effects of sustained performance and other stressors on integrated, complex cognitive functioning. This completely automated task is presented in the form of a highly motivating computer game. However, unlike typical computer games, successful performance of STAR depends on an individual's ability to rapidly and accurately assess risk/benefit ratios in a variety of situations, and on the skilled use of an array of multipurpose control systems. STAR is unique in that approximately 80 performance measures are unobtrusively embedded in the operations required to "play the game"; no obvious performance assessment interferes with task presentation. STAR provides multiple measures of psychomotor function, attention, memory, information processing, decision making, risk-taking behavior, subjective state, errors, and error paths. STAR is described and two preliminary experiments designed to separately evaluate the effects of task difficulty and task stress level on complex performance are summarized.

460. Graybiel, A., Kennedy, R. S., Knoblock, E. C., Guedry, F. E., Mertz, W., McLeod, M. E., Colehour, J. K., Miller, E. F., and Fregly, A. R. 1965. Effects of exposure to a rotating environment (10 RPM) on four aviators for a period of twelve days. **Aerospace medicine. 36**: 733-754.

Four military personnel undergoing flight training were exposed to constant rotation at a speed of 10 RPM for 12 days in the Pensacola slow rotation room. Environmental and working conditions simulated in many respects those which might be found in a rotating orbiting spacecraft. The findings are discussed under three headings: Clinical symptoms, clinical laboratory findings and psychophysiological performance. The experiment demonstrated that countermeasures in addition to adaption are needed if there is immediate exposure to rotational velocities of 10 RPM and that the rotating room is a useful device for further exploration of vestibular and central nervous system mechanisms.

461. Guedry, F. E., Kennedy, R. S., Harris, C. S., and Graybiel, A. 1964. Human performance during two weeks in a room rotating at three RPM. **Aerospace medicine. 35**: 1071-1082.

Four men were tested before, during, and after being rotated at three RPM for 2 weeks in the Pensacola slow rotation room. The men also lived in the room preceding the commencement of the rotation. Tests of intellectual and physiological function were included. The principal finding was that no serious psychological or physiological deficit was detected during 2 weeks of rotation or during the subsequent readaptation to normal environment. The only test showing pronounced deterioration of performance at the beginning of rotation and upon returning to normal environment was the Graybiel-Fregly posture test. This means any task requiring ordinarily difficult locomotion would be disturbed at these critical intervals. Ordinary walking with adequate visual reference was not so obviously affected. Results are discussed in relation to: Problems of rotating space stations, the vestibular system, and experiments involving optically distorted visual information.

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462. Hall, D. A., Townsend, R. E., Knippa, J., and Pruett, R. 1980. **The impact of remote fly-away submersible operations on personnel endurance capabilities**. San Diego, CA: U.S. Naval Health Research Center. (Bureau of Medicine and Surgery Interim Report No. 79-52) {DTIC No. AD-A093-706}.

During open-sea submersible operations, particularly those involving quick reaction rescue missions, the physiological and psychological well-being of the operators and surface support personnel (SSP) becomes of increasing importance in ensuring successful completion of the event. The purpose of this study was to obtain information on stress, fatigue, and work-rest cycles of both submersible operators and surface support crew members during an actual submarine rescue fly-away mission. Six operators and seven SSP were monitored during the conduct of a 6-day trial open-sea submarine rescue evolution using the deep submergence rescue vehicle (DSRV), Mystic. Operators and crew members lived aboard the mother submarine which carried the DSRV from port to the site of the downed submarine and return. Demographic information, psychological measures, performance measures, and environmental data were obtained during predeployment, transit-out, at dive site, and transit-in periods. The overall results suggested that a DSRV mission of the present duration and difficulty can be accomplished without exceeding the capabilities of the crew and support personnel. The trend of the changes, do, however, suggest that missions of longer duration may require scheduling of regular sleep periods for personnel to maintain performance. Additionally, it is felt that monitoring and analysis of demographic, operational, and environmental data should aid in the ongoing assessment of the safety of current and future open-sea evolutions, thus providing guidance to operators in the event that deeper, more time-critical missions occur.

463. Hamelin, P. 1987. Lorry driver's time habits in work and their involvement in traffic accidents. **Ergonomics.** 30(9): 1323-1333.

Using representative samples of drivers operating in freight transportation, the sociological features of lorry drivers, the process of formation of this group, and their work conditions are described. In many ways, they are similar to other blue collar workers.

As "normal" durations and rhythms of work are known, it was possible to calculate the risk exposure to road accident involvement (according to the time at which the drivers are at the wheel and in relation to the amount of work already carried out) and to compare it, using a representative sample of the drivers involved, to the time features of the driver's activities prior to the accident. This demonstrated that risk of involvement in an accident increases with the number of hours carried out, and according to the time at which the drivers are at the wheel (at the end of a normal working day and at night).

However, the relation between the duration of the work periods and the accident risk is not the same for different types of drivers. Younger drivers, and those in the Transportation Branch, are exposed to a higher global risk level, but apparently find various "resources" to fight fatigue for the most dangerous threshold periods. Thus, it is necessary to take account of physiological mechanisms on the one hand, and acquisition modes of "know-how" which may compensate for fatigue, on the other.

464. Hamilton, P., Wilkinson, R. T., and Edwards, R. S. 1972. A study of four days partial sleep deprivation. In: Colquhoun, W.P., ed. **Aspects of human efficiency: Diurnal rhythm and loss of sleep.** London: English Universities Press.

This chapter details a study performed to assess the effects of cumulative partial sleep loss over a period of 4 days. The tests used are sensitive to change in performance efficiency thereby making it possible to assess the effects of various lengths of sleep deprivation periods. These tests enable researchers to use the sleep deprived state as a tool in the study of general problems such as effects on motivation on performance and the nature of the inverted U curve relating arousal and efficiency. The implication of the findings for both general theories of human information processing and for hypotheses concerning the effects of sleep deprivation are discussed.

465. Hancock, P. A. 1981. Heat stress impairment of mental performance: A revision of tolerance limits. **Aviation, space, and environmental medicine. 52**(3): 177-180.

A time-related, heat stress tolerance curve for unimpaired mental performance was constructed from a summary of 15 studies. The tolerance limits, more properly described as the lower limits for heat impaired mental performance, were subsequently adopted by the National Institute for Occupational Safety and Health as the recommended standard of tolerance times for sedentary work in heat stress. Although Ramsey and Morrissey reported a series of isodecrement curves which indicate mental performance impairment in heat may not be a simple function, a reappraisal of the upper limit for nonimpairment has not yet been advanced. The present review reevaluates results of early studies, apparently supportive of Wing's position, and proposes an alternate interpretation. Further, analysis of more recent data suggests a mental performance impairment/heat stress relationship closely related to human thermophysiological tolerance limits.

466. Harris, W. 1976. Fatigue, circadian rhythm, and truck accidents. In: Mackie, R., ed. **Vigilance: Theory, operational performance, and physiological correlates.** New York: Plenum Press.

Most truck accidents occur because of driver error, and many likely are the result of failures in vigilance performance. The truck driving task requires the driver to maintain a continual vigil if he is to perform successfully. Truck drivers often drive for long hours and at all times of the day and night, conditions that expose them to the effects of fatigue and circadian rhythms. Fatigue and circadian effects on vigilance performance are well established. The purpose of the analyses reported here was to see if such effects were present in truck accidents which seemed to be the result of failures in vigilance performance.

Interstate truck accident data provided by the Bureau of Motor Carrier Safety of the U.S. Department of Transportation were analyzed for three groups of drivers: Dozing drivers, those who had had single vehicle accidents, and those who had crashed into the rear of other vehicles. The effect of fatigue was confirmed for each of the groups: Fewer accidents than expected occurred early in trips and more than expected later in trips; about twice as many accidents occurred during the second half of trips than during the first half, irrespective of trip duration. The circadian effect was observed for dozing drivers, about twice as many of whose accidents occurred between midnight and 0800 hours than in the other 16 hours of the day, and for single vehicle accident drivers, about half of whose accidents occurred in the early morning hours. The circadian effect was not as marked for drivers having accidents involving a second vehicle, likely because of variations by time-of-day in the number of vehicles on the road. There is some evidence of a combined effect of fatigue and circadian rhythm on the relative likelihood of occurrence of accidents.

467. Harsh, J., and Badia, P. 1989. Auditory evoked potentials as a function of sleep deprivation. **Work and stress.** 3(1): 79-91.

Event-related brain potentials (ERPs) were studied in subjects deprived of sleep over a 48-hour test period to assess the effects of different durations of continuous wakefulness on ERP components and to determine whether changes in the ERP components were related to the changes in performance. Forty subjects were randomly assigned to either an experimental (sleep deprived) group (n=30) or a control (not sleep deprived) group (n=10). For the experimental subjects, ERP and performance measures were obtained in 4-hour test blocks throughout the 48-hour period. Performance was assessed using the Walter Reed performance assessment battery. The control subjects were tested at the same times except during designated sleep periods. Both performance and evoked potential measures showed systematic changes over the experimental test period in association with sleep deprivation, time of day, and repeated testing. The latency of the N2 component of the evoked potential co-varied with throughput measured on the performance assessment battery across 12 4-hour test blocks of the experiment. These data suggest that ERPs reflect central processes that change across the sleep deprivation period and that ERP measures might be useful in assessment and prediction of performance degradation under adverse conditions such as sleep loss.

468. Hartley, L., and Shirley, E. 1977. Sleep-loss, noise and decisions. **Ergonomics.** 20(5): 481-489.

Twelve subjects were given a visual detection task under three sleep schedules: Normal 8 hours sleep; 4 hours sleep at night and 4 hours sleep in the afternoon. Subjects experienced each sleep condition for 2 nights and 2 days on three successive weekends. Ninety-five dB white noise accompanied some tests. The results, in the form of confidence ratings, were analyzed by means of statistical decision theory. Time on task made cautious performance more cautious, and sleep-loss made it more risky. Noise caused a rise in the risky criterion. There was some evidence that, in combination, noise and sleep-loss had mutually antagonistic effects on discriminability, and cancelled out each other's effects on the cautious criterion placement.

469. Haslam, D.R. 1987. **The effects of sleep loss and an NBC prophylactic drug upon military performance. Exercise Curtain Call.** Farnborough, Hants, England: United Kingdom Ministry of Defence, Royal Aircraft Establishment, Army Personnel Research Establishment. (APRE Technical Report No. 87R008). Report is United Kingdom restricted distribution.

A trial was carried out to examine the effects on performance and mood of a combination of sleep loss and diazepam. Twenty soldiers were divided equally into a drug group and a placebo group; three subjects, however, withdrew from the trial on the first baseline day, leaving nine subjects in the drug group and eight in the placebo group. All subjects were sleep deprived for 89 hours; this period was preceded by 2 baseline measurement days, and followed by 2 recovery measurement days. The baseline and recovery days were preceded by 7 hours sleep. All subjects were told they would receive 5 mg diazepam on three occasions; otherwise, placebos were administered twice a day throughout the trial, using "double blind" procedures.

The trial was a combination of scientific assessment and military activities, which included the preparation of defensive positions, patrolling, and casualty evacuation. Cognitive performance (using both computer-driven and paper-and-pencil tests), visual functioning, and mood were assessed twice daily, and sleepiness was assessed four times a day. A simulated NBC state medium was maintained throughout the trial, going to state black for 1 hour daily.

The 17 subjects who started the sleep deprivation phase finished the trial. Results for all the tests and assessments indicated there was no significant difference between the drug and placebo groups. For both groups combined, there was a significant deterioration in cognitive performance, mood, and sleepiness on sleep-deprivation days compared to baseline and recovery days. The conclusion drawn was that sleep deprived soldiers can, for therapeutic reasons, be administered 5 mg diazepam without sleep-loss effects being dramatically increased.

470. Haslam, D. R. and Abraham, P. 1987. Sleep loss and military performance. In: Belenky, G., ed. **Contemporary studies in combat psychiatry**. Westport, CT: Greenwood Press.

There have been relatively few militarily realistic field experiments to study the effects of sleep deprivation in battle. There was a need to carry out field trials of a longer duration than previously attempted and with as much realism as possible. Exercise Early Call I and II were both 9-day tactical defense exercises carried out with those objectives in mind.

In Early Call I, three platoons of the Parachute Regiment were scheduled either 0 hours, 1 1/2 hours, or 3 hours block sleep in 24 hours. The aims of the experiment were to compare the platoons on a number of measures and to find out for how many days of total sleep loss soldiers are likely to remain fighting. In Early Call II, 10 experienced infantry soldiers were scheduled for 90 hours of no sleep followed by 4 hours block sleep in every 24 hours for the next 6 days. This was an attempt to create a more militarily realistic regime of continuous activity for several days followed by a period of less intense activity during which short periods of rest are possible.

The results of the study show: 1) Soldiers are likely to be militarily ineffective after 48 to 72 hours without sleep; 2) the effects of sleep loss are mainly psychological; mental ability and mood deteriorate, whereas physical fitness does not; 3) tasks requiring cognitive ability, especially sustained attention, are likely to be impaired after sleep loss; 4) simple, well-learned or physical tasks are unlikely to be impaired after sleep loss; and, 5) a small amount of sleep relative to the amount lost has very beneficial effects.

Also studied in these exercises were levels of physical and mental activity, and sleep patterns.

471. Herbert, M. J., and Jaynes, W. E. 1964. Performance decrement in vehicle driving. **Journal of Engineering psychology**. 3: 1-8.

One hundred and eighty subjects were allocated to five groups on the basis of the number of hours the members of each group drove a truck on a fatigue course after an initial test, and prior to a retest on a battery of nine driving tests. The fatigue periods were of 0, 1, 3, 7, or 9 hours duration. After determining the initial equivalency of the groups by an analysis of pretest results, postfatigue test scores were correlated with hours of fatigue driving. All 15 test scores yielded significant part-correlations. Correlations reached a maximum or r=.50. A decrement function presented showed progressive loss in performance through 7 hours of driving.

472. Heslegrave, R. J., and Angus, R. G. 1985. The effects of task duration and work-session location on performance degradation induced by sleep loss and sustained cognitive work. **Behavior research methods, instruments, and computers.** 17(6): 592-603.

Studies attempting to estimate the degree of performance degradation resulting from sleep loss typically use relatively long-duration tasks that are distinctly separate from ongoing activities. Since long-duration tasks are not practical for assessing the performance degradation induced by sleep loss in field settings, this study was designed to examine whether the results of short-duration (1-minute) tasks were markedly different from those of long-duration (10 minutes) tasks with respect to detecting performance changes during a 54-hour period of sleep loss and sustained cognitive work. Performance changes also were examined as a function of the location of tasks within work sessions by comparing performance on 1-minute tasks placed within work sessions with those tasks that immediately followed short rest periods. Results showed short- and long-duration tasks were equally sensitive to sleep loss. Once sleep-deprivation effects began to emerge, performance on short-duration tasks within work sessions showed significantly more impairment than performance on tasks that followed rest breaks. These results suggest task duration is not a critical factor for detecting performance degradation induced during continuous work experiments, but the location of tasks within work sessions is critical for accurately assessing expected performance.

473. Hildebrandt, G., Rohmert, W., and Rutenfranz, J. 1974. 12 and 24 hour rhythms in error frequency of locomotive drivers and the influence of tiredness. **International journal of chronobiology. 2**: 175-180.

Reports a month investigation of the daytime frequency distribution of about 2,000 automatically induced emergency braking incidents caused by "errors of omission" in about 15,000 engine drivers of the German Federal Railways. The curve exhibited two maxima, one at night, the other 12 hours later (in the early afternoon). Furthermore, the authors measured the hourly frequency of a total of about 20,000 acoustical warning signals, which were evoked in the engines by failure to depress the button of a safety device (shutdown override button) within 25 seconds. The daily course of this parameter again showed the two maxima around 0300 and 1500 hours, and this was particularly the case in the variability of the hourly frequency of errors. The individual amplitude of the second maximum of failures exhibited a fairly linear correlation to the duration of the foregoing time of work up to 9 hours. From these findings it is concluded, fatigue is able to evoke a 12-hour period of vigilance functions, superimposed on the normal circadian period.

474. Hockey, G. R. 1986. Changes in operator efficiency as a function of environmental stress, fatigue, and circadian rhythms. In: Boff, K. R., Kaufman, L., and Thomas, J. P., eds. **Handbook of perception and human performance. Volume II: Cognitive process and performance.** New York: John Wiley and Sons.

This chapter is concerned with the issue of human performance as affected by motivation, bodily arousal, emotion, and fatigue. It examined the effects on performance of environmental conditions, fatigue states, and cyclical fluctuations in bodily processes, as well as a number of other factors influencing bodily states. The topics included in this chapter are determined by their relevance to the general state of the individual. This provides the link between noise, anxiety, fatigue, and shift work; all are independent, but all have consequences on the quality of the work of the individual. An important aim is to identify the types and levels of the conditions found in the working environment that give rise to significant changes in performance. It emphasizes that an assessment of stress effects requires information on the overall pattern of performance changes. This chapter addresses the question of why performance changes occur; how these different patterns of operator efficiency under stress are to be interpreted in the context of theories of cognition and skill. Current developments in research are pointed out and some accessible practical hints provided.

475. Holding, D. H. 1983. Fatigue. In: Hockey, G. R., ed. **Stress and fatigue in human performance**. New York: Wiley and Sons.

Fatigue presents a complex problem for research, which can be made more manageable by considering only the effects of prolonged periods of work or duty. Physical fatigue usually is modifiable by incentives, since components and may often be a function of decreased alertness or vigilance, which are thought to depend on arousal and expectancy. Fatigue effects are measured most readily during the actual performance of many tasks, appearing as direct decrements when stimulation is repetitive and showing a variety of the consequences of central deterioration in complex skills. On the other hand, interpolated or subsequent measurements on different tasks have not generally shown any aftereffects of fatigue, for several reasons depending on change, compensation, and inappropriateness. However, methods which permit the subject a choice of responses have indicated changed attitudes towards acceptance of risk and avoidance of effort, for mental and motor fatigue, which are consistent with subjective expressions of tiredness; it is to be expected that other similar components of fatigue can be identified. Fatigue perhaps may be viewed as an increase in neural noise, although developments in arousal theory may eventually provide a better articulated description of the processes responsible for fatigue and other forms of stress.

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476. Johnson, L. C. 1986. Physiological and behavioral responses to the stress of sleep loss. In: Lee, G. E., ed. **Proceedings of the tenth symposium: Psychology in the Department of Defense**, pp. 403-407. Colorado Springs, CO: U.S. Air Force Academy, Department of Behavioral Sciences and Leadership.

Total sleep loss of greater than 60 hours may be expected to produce some physiological, biochemical, performance, behavioral, and mood changes. The degree of change depends upon the individual but, as sleep loss progresses beyond 60 hours, changes eventually will be evident in all areas; however, the behavioral significance of the changes will vary. Total sleep loss of 40-48 hours probably would be the upper limit with loss of 30-36 hours more likely. These amounts of sleep loss can be tolerated without debilitating changes in the physiological system. In most instances, if any effects are noted, they will be evident first by changes in mood. Performance changes will be minimal if the tasks are brief, self-paced, highly motivating, and feedback is given as to adequacy of response. Tasks that require sustained vigilance and attention, use of newly acquired skills, retention of new information, and which necessitate long periods to complete are more likely to show sleep-loss effects. Most of the decrement will occur during periods of brief sleep. These effects are more likely to occur during the early morning hours when body temperature is low. Performance workload should be reduced during hours when sleep would normally occur, regardless of actual time of day.

477. Johnson, L. C., Tepas, D. I., Colquhoun, W. P., and Colligan, M. J., eds. 1981. **The twenty-four hour workday: Proceedings of a symposium on variations in work-sleep schedules.** Washington, DC: U.S. Government Printing Office. (Department of Health and Human Services [National Institute of Occupational Safety and Health] Publication No. 81-127) {DTIC No. AD-A097-589}.

This symposium brought together workers in three areas that in one way or another, are concerned with a common problem: Variations in work-sleep schedules. These three areas are: 1) Shift work; 2) sleep, and particularly that area concerned with sleep loss and the fragmentation of sleep schedules; and 3) biological rhythms. In addition to social and health problems; sleep problems are a major complaint of shift workers. Any variation in work-sleep schedules immediately involves, in a complex fashion, the basic biological rhythms.

478. Jones, D., Kitting, T., Babcock, C., Morabit, J., Haynie, R., and Farrell, T. 1987. **CANE literature research compendium, volume I-indexes, volume II-abstracts.** Monterey, CA: ORI, Inc. U.S. Army Chemical School, Fort McClellan, AL. (ORI Technical Report No. TR-2532A, 2532B, 2532C) {DTIC Nos. AD-B109-015, AD-B109-016}. Distribution of abstract and document limited to U.S. Government agencies and their contractors.

479. Juin, G., and Pineau, P. 1962. Basis, protocol, and results of a medical inquiry on the fatigue of flying crews on Boeing 707 commercial planes (Bases, protocole et resultats d'une enquete medicale sur la fatigue des equipages volant a bord des Boeing 707 commerciaux). **Revue de medicine aeronautique. 2**: 7-10. (In French).

Because of the noticeable increase in fatigue seen and described among commercial aviation crewmembers since the start of intercontinental, four-engine jet service, the authors, together with a team of specialists from the hospitals in Paris, undertook a medical inquiry for the purpose of rendering this abnormal fatigue, in personnel aboard these four-engine jet planes, more objective, more quantitative, into the clinical, biological, physiological, and ophthalmological areas. The authors report on the general results of investigations made on blood pressure. They show the variations in blood pressure recorded on 11 crews of jet aircraft and on 2 crews of conventional aircraft, for a total of 136 subjects. Three hundred sixteen pressure measurements have been taken on jet-propelled planes, 42 on the conventional type. Although for the latter no significant variations are found in an increase in minimum pressure. This assumes particular importance when considered with the biological, biohormonal, and ophthalmological changes also recorded.

The authors also report the results of the ophthalmological studies bearing on the variations in heterophorias during jet flights and comparing them with changes brought about in conventional planes. They point out the condition and variations in strength of convergence and divergence in crewmen of the same aircraft. In addition, they report the results obtained during the same study which deal with the endocrine and metabolic conditions, carried out in jet aircraft as well as in the conventional type.

In conclusion, during these concise analyses, the authors try to formulate a policy as to the supervision of crew personnel and to locate sources of difficulty in commercial jet aircraft. This medical investigation seems to be the only one of its type up until 1962 in commercial aviation.

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480. Kant, G. J., Landman-Roberts, L., Smith, H. R., Cardenales-Oritz, L., and Mougey, E. H. 1985. The effect of sustained field operations on urinary electrolytes and cortisol. **Military medicine. 150**(12): 666-669.

Urinary cortisol and electrolytes were measured in 10 soldiers participating in a sustained operations field exercise. Urine was collected in consecutive 12-hour periods during two 72-hour field trials as well as pretrial, intertrial, and posttrial phases. Urine specific gravity and cortisol excretion increased markedly during both field exercise periods, while urine volume significantly decreased. The increase in cortisol excretion occurred primarily in the 12-hour night collections (1700-0500 hours) and disrupted the normal circadian variation in cortisol excretion.

481. Kant, G. J., and Leu, J. R. 1986. An animal model of sustained operations and continuous performance. In: Lee, G. E., ed. **Proceedings of the tenth symposium: Psychology in the Department of Defense**, pp. 536-540. Colorado Springs, CO: U.S. Air Force Academy, Department of Behavioral Sciences and Leadership.

The animal model described should prove useful for investigating the effects of chronic stress on physiology and behavior and for testing the effects of potential performance enhancers. Rats were housed around the clock in operant boxes; food was earned by bar pressing and intermittent footshock could be avoided or escaped by pulling a chain. Control animals were housed similarly, but presented with a shock trial at approximately 5 minute intervals around the clock for up to 2 weeks. All food lever presses and chain pulls were recorded by a PDP8 computer which collected responses in 1 hour bins.

Control rats demonstrated a marked circadian rhythm in lever pressing for food, while stressed rats decreased overall responding for food and also showed disrupted circadian patterns of eating. Water intake was similar in control and stressed groups. Adrenal weights were increased and thymus weights decreased in stressed as compared to control groups. These changes in organ weight are typical of chronic stress states. Plasma corticosterone, a major rat stress hormone, was elevated in stressed rats after 1 to 7 days in the paradigm, but levels returned to control levels by day 14.

482. Kjellberg, A. 1977. Sleep deprivation and some aspects of performance: Problems of arousal changes. **Waking and sleeping.** 1(1): 139-143.

The aim in three published papers is to provide a theoretical framework within which the performance effects of sleep deprivation (SD) can be interpreted. In this, the first article, the possibility and limitation of interpretations in terms of dearousal are evaluated. An interactional view of the relation between SD and arousal is proposed, implicating that the effect of SD is to potentiate the dearousing effect of situational variables. The habituation of the orienting response is suggested as one possible mediator of this effect. The reported attentional effects of SD are shown to be interpretable within this framework. The effects of motivational factors on the SD effects and the SD effect on motivation are discussed, leading to the conclusion that habituation cannot be the only mediator of the dearousing influence of the situation, and that an analysis in operant terms must be added. Furthermore, the motivational effects of SD demonstrate the limitations of the present arousal analysis of the effects. The implications for future SD research are discussed.

483. Kjellberg, A. 1977. Sleep deprivation and some aspects of performance: Lapses and other attentional effects. **Waking and sleeping.** 1(2): 145-148.

This article is second in a series of three discussing some effects on performance by sleep deprivation. This section deals specifically with the lapse hypotheses and factors influencing lapses after sleep deprivation. Other attentional effects also are discussed. Conclusions are drawn using information presented in all three articles.

484. Kjellberg, A. 1977. Sleep deprivation and some aspects of performance: Motivation, comment, and conclusions. **Waking and sleeping.** 1(3): 133-136.

This is the third article in a series of three discussing the effects of sleep deprivation on performance. It deals with the problems of motivation and performance in connection with sleep deprivation. Included in the review are dearousal effects and motivational factors. The conclusion drawn is based on information found in all three articles.

485. Klein, K., Reinhold, H., Kuklinski, P., and Wegmann, H.-M. 1976. Circadian performance rhythms: Experimental studies in air operations. In: Mackie, R., ed. **Vigilance: Theory, operational performance, and physiological correlates.** New York: Plenum Press.

Aircrews operate round the clock and over many time zones. This implies interference of air operations with circadian oscillation of biological functioning as well as its disruption through shifts of environmental time cues. In this sense, the significance of circadian performance rhythms in air operations is discussed. This is done mainly by presenting results from seven experimental studies in which behavioral and physiological variables were evaluated before and after transmeridian flights.

In general, performance was assessed every second post-flight day in three hourly intervals round the clock. Between midnight and 0900 hours subjects were allowed to sleep but were aroused twice for testing for a period of 45 minutes. In all but one study eight healthy male students in the range of 23 to 28 years of age served as subjects; in one experiment ten pilots participated in flight simulator tests.

The results confirmed the idea that alertness, or the readiness to be mentally active, belongs to these biological properties of the living organism which are subject to circadian variation. This rhythm persists after transmeridian flights and is de- and resynchronized with the environmental time cues similar to other biological cycles. It so happens that a low performance output temporarily occurs in the local daylight phase instead of, as usual, during the dark phase. Results given in the pertinent literature reveal an alternating effect on performance of operationally induced fatigue and the circadian rhythm; this interference is of operational significance. Recommendations are given for flight scheduling considering circadian rhythm effects.

486. Knapik, J., Patton, J., Ginsberg, A., Redmond, D., Rose, M., Tharion, W., Vogel, J., and Drews, F. 1987. **Soldier performance during continuous field artillery operations**. Carlisle Barracks, PA: U.S. Army War College Physical Fitness Research Institute. (AWC Technical Report No. T1-87) {DTIC No. AD-B113-403L}. Distribution of the document limited to U.S. Department of Defense.

487. Kopstein, F., Siegel, A., Conn, J., Caviness, J., Slifer, W., Ozkaptan, H., and Dyer, F. 1985. **Soldier performance in continuous operations**. Wayne, PA: Applied Psychological Services, Inc. (ARI Research Note 85-68) {DTIC No. AD-A160-470}. Also as: **Soldier performance in continuous operations: Administrative manual for a briefing and seminar for command and staff personnel**. (ARI Research Note 85-69) {DTIC No. AD-A160-471}.

If any Army unit is to meet the demands of continuous operations, a systematic human resources conservation program must be planned and implemented. The details of such a program are described. Without such a program, intolerable levels of performance degradation during continuous operations can be projected. Strategies for countering the anticipated degradation during continuous operations include: Leadership training, confidence building, organizing for full communications, behavioral modeling, overtraining and cross-training, developing physical fitness, and development of performance supports. Tactics for countering performance degradation during continuous operations include task rotation, task sharing, use of performance supports, proper management of stress, and appropriate work/rest cycles. The program for integrating these concepts into a unit developmental program includes systematic steps along a time frame. The strategies are set in place during the preparation stage, and these provide the foundation for implementing the tactics during continuous operations.

488. Krueger, G. P. 1986. Applications of laboratory methodologies to the field study of sustained operations. In: Mangelsdorff, A. D., King, J. M., and O'Brien, D. E., eds. **Proceedings of the fifth users' workshop on combat stress**. Fort Sam Houston, TX: U.S. Army Health Services Command, Health Care Studies and Clinical Investigation Activity.

The paper provides a brief description of a laboratory and field applications research program at the Walter Reed Army Institute of Research to study and predict soldier performance as it is affected by workload, various levels of activity, work/rest schedules and amounts of sleep loss during continuous and sustained military operations.

489. Krueger, G. P. 1986. Problems of using sleep research techniques in the field. In: Lee, G. E., ed. **Proceedings of the tenth symposium: Psychology in the Department of Defense.** Colorado Springs, CO: U.S. Air Force Academy Department of Behavioral Sciences and Leadership.

Experiences in adapting laboratory sleep research methodologies to field study of sustained military operations are reviewed. The use of standard cognitive monitoring system and observer data collection methods are described.

490. Krueger, G. P. 1989. Sustained work, fatigue, sleep loss and performance: A review of the issues. **Work and stress**. 3(2): 129-141.

The physiological and psychological stressors associated with sustained work, fatigue, and sleep loss affect worker performance. This review describes findings relating to sustained work stresses commonly found in our advancing technological world. Researchers report decrements is sustained performance as a function of fatigue, especially during and following one or more nights of complete sleep loss, or longer periods of reduced or fragmented sleep. Sleep loss appears to result in reduced reaction time, decreased vigilance, perceptual and cognitive distortions, and changes in effect. Sleep loss and workload interact with circadian rhythms in producing their effects. These interactions are a major source of stress in work situations requiring sustained work in continuous operations and have implications for theoretical models of sustained performance and cognitive functioning.

491. Krueger, G. P., Cardenales-Ortiz, L., and Loveless, C. A. 1985. **Human performance in continuous/sustained operations and the demands of extended work/rest schedules: An annotated bibliography, Volume I.** Washington, DC: Walter Reed Army Institute of Research. (WRAIR Technical Report No. BB-85-1) {DTIC No. AD-A155-619}. Also in American Psychological Association's **Psychological documents. 15**, 27, entry No. 2729.

The advent of a society intent upon maintaining high productivity levels 24 hours per day, and on providing a variety of services around the clock, produced occupations and circumstances requiring prolonged, continuous work periods. The performance of workers under conditions of sustained or continuous work has become an important topic in industrial psychology, and in particular, in the military services. There are some traditional jobs, circumstances, and even some new occupations that involve prolonged, sustained work periods without rest, in which individual workers continue beyond the normal 8-to-10-hour work day. In fact, in many of these sustained work situations, the termination point for a shift is unknown. Such activities usually require prolonging physical stamina and sustaining high levels of organizational and cognitive effectiveness. These continuous operations are of two types: First, there are extended operations, jobs or tasks that proceed continuously with only a short break or breaks, but that operate within a typical shift system for lengthy periods, longer than a normal duty day. The worker knows he or she will be relieved or able to rest. Second, there are sustained operations, planned or unplanned, goal-oriented, nonstop continuous performance/operations without allowance for rest or sleep, in which the worker is expected to keep going as long as he or she can. Both have very important worker performance and behavioral implications.

Available research data on these topics are scattered throughout diverse printed sources, many of them difficult to locate. This annotated bibliography lists 399 references containing research data, conceptual position papers, and different methodological approaches to studying human performance in continuous/sustained operations and extended work/rest schedules. The time frame covered in the references is from 1940 to 1985. Volume II was published separately in 1989, at the U. S. Army Aeromedical Research Laboratory.

492. Krueger, G. P., and Englund C. E. 1985. Introduction to the 2nd special section on: Methodological approaches to the study of sustained work/sustained operations. **Behavior research methods, instruments and computers.** 17(6): 587-591.

This is the second special section of **Behavior research methods, instruments and computers** dedicated to methodological approaches for the study of sustained work-sustained operations. Like those in the first such special section, published in February 1985, several of the articles presented here were developed from a workshop and a symposium held in August 1984, in Toronto, Canada. The workshop on "Sustained operations research" was held at the Canadian Defence and Civil Institute of Environmental Medicine (DCIEM) on August 23, 1984. A symposium on "Sustaining work hours without decrements in productivity" was held on August 25, 1984 at the 92nd annual meeting of the American psychological association (APA).

Many persons who attended the DCIEM workshop and the APA symposium in August 1984 served as the nucleus for the formation of the U. S. Department of Defense human factors engineering technical advisory subgroup on sustained-continuous operations. The remaining articles in this special section developed as a result of the subgroup's formation meeting held in San Antonio, Texas, in May 1985.

493. Krueger, G. P., Headley, D. B., Balkin, T. J., Belenky, G. L., and Solick, R. E. 1987. **Strategies for sustaining soldier and unit performance in continuous operations.** Washington, DC: Walter Reed Army Institute of Research. (WRAIR Technical Report No. NP-87-11) {DTIC No. AD-A189-501}.

This chapter, submitted in a special study of Army conduct of continuous operations (CONOPS), contains a detailed list of human factors principles and recommendations for sustaining performance of soldiers in 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.

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494. Lavie, P. 1982. Ultradian rhythms in human sleep and wakefulness. In: Webb, W. B., ed. **Biological rhythms, sleep, and performance.** New York: John Wiley and Sons.

This chapter reviews the evidence for ultradian rhythms. These include rhythms of ingestion, digestion, excretion, psychophysiological, perceptual and vigilance, and perceptual-motor performance. These, in turn, are considered in relationship to the ultradian of REM or activated sleep rhythm. A multioscillatory concept for these rhythms is proposed and the research and practical implications are noted.

495. Lavie, P., Chillag, N., Epstein, R., Tzischinsky, O., Givon, R., Fuchs, S., and Shahal, B. 1989. Sleep disturbances in shift-workers: A marker for maladaptation syndrome. **Work and stress.** 3(1): 33-40.

This study investigates the associations between sleep disturbances in shift workers and their general adaptation to the shift system. Three hundred and sixteen refinery, and 55 aluminum factory shift-workers participated in this study. In both plants, sleep disturbances were significantly associated with age, with dissatisfaction with working conditions and the quality of domestic life, with increased morbidity and increased high blood pressure. The association between high blood pressure and morbidity and sleep disturbances remained significant after adjusting for age. Shift workers complaining about their sleep also had higher blood pressure values than day workers with sleep disturbances. These findings suggest periodic evaluation of sleep quality in rotating shift workers can provide useful information regarding their general adaptation level to the shift system.

496. Legg, S. J., and Patton, J. 1987. Effects of sustained manual work and partial sleep deprivation on muscular strength and endurance. **European journal of applied physiology. 56**: 64-68.

In a military field artillery trial, the effects of 8 days of sustained manual work and partial sleep loss on isometric right hand grip strength and upper and lower body anaerobic power (using the Wingate test) was investigated in 25 healthy young male soldiers. During the trial, the physical activity of each subject essentially was identical except that an experimental group manually handled a large quantity of artillery shells and charges, while a control group merely simulated manual handling activities and did no lifting or loading of shells. The daily amount of sleep obtained by each group was similar, as were their activity patterns and food and fluid intake. Isometric right hand grip strength for both groups fell progressively during the trial and did not return to pretrial levels during 3 days of recovery. At the end of the 8-day trial, there were statistically significant reductions in the body weight, percent body fat, and upper body mean power of the experimental group, but not in the controls. Lower body peak and mean power were significantly increased at the end of the trial in both the experimental and control groups. Lower body power decrease was increased significantly in the experimental group but not in the controls. The increase in lower body anaerobic power may be associated with the increased level of physical activity during the trial, and that the decrease in upper body anaerobic power may be associated with the combination of unaccustomed arduous manual handling of heavy loads and partial sleep loss since it was only observed in the experimental group.

497. Lisper, B. H-O., Laurell, H., and Stening, G. 1973. Effects of experience of the driver on heart-rate, respiration-rate, and subsidiary reaction time in a three hour continuous driving task. **Ergonomics. 16**(4): 501-506.

From accident statistics a difference was hypothesized between experienced and inexperienced drivers in vulnerability to continuous driving. This difference was used as a basis for a comparison of changes in autonomic measures and reaction time over driving time. The result showed effects of experience on both types of measures. Heart rate pointed to experienced and reaction time pointed to inexperienced drivers as being the most vulnerable to continuous driving. This contradiction was solved with reference to statistical data and validation of the reaction time task. Thus in this study reaction time was preferred to the autonomic measures.

498. Lisper, B. H-O., Laurell, H., and Van Loon, J. 1986. Relation between time to falling asleep behind the wheel on a closed track and changes in subsidiary reaction time during prolonged driving on a motorway. **Ergonomics. 29**(3): 445-453.

Twelve subjects drove on a closed 5-km track until they fell asleep behind the wheel or quit for other reasons. The instances of falling asleep occurred after 7 to 12 hours of driving. Falling asleep could be characterized by nodding of the head, closing of the eyes and the car continuing in its previous course. On none of these occasions did the experimenter have to take over the control of the car and all subjects awoke by themselves. The average duration between three instances of falling asleep was 24 minutes. Two preceding sessions of 3 hours of driving on a motorway with subsidiary reaction time measurements predicted ($r=-0.72$ and -0.17) the endurance on the closed track.

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499. McDonald, N., ed. 1984. **Fatigue, safety and the truck driver.** Philadelphia: Taylor and Francis.

This book is concerned with the conditions which might give rise to fatigue among truck drivers, and the effects of fatigue on driving safety. The author attempts to take stock, in a critical and evaluative manner, of the topic of fatigue and driving safely in the terms of the scientific adequacy and theoretical integration of the accumulated work prior to 1984, as well as the implications of this work for practice. Of particular interest are the topics of fatigue, falling asleep at the wheel and the nature of accidents, accidents and hours worked and time of day, the mental demands of driving, physiological monitoring of drivers, and coverage of practical implications for research.

500. McMurray, R. G., and Brown, C. F. 1984. The effect of sleep loss on high intensity exercise and recovery. **Aviation, space, and environmental medicine. 55**: 1031-5.

The cardiovascular and metabolic responses of five male subjects during submaximal exercise (80 percent VO2 max) were examined after 24 hours of wakefulness. The protocol consisted of two sets of two trials separated by 7-10 days: First, a 20-minute exercise bout, then a normal night's sleep, followed by another 20 minutes of exercise; second, a 20-minute exercise bout, 24 hours of wakefulness, then another 20-minute exercise trial. Exercise ventilation, heart rate, and oxygen uptake were not affected by sleep loss. However, sleep loss caused the recovery ventilation and oxygen uptake to remain higher than normal during the slow phase of recovery. Blood glucose levels were found to be greater during deprived trials compared to controls, but were similar to controls 15 minutes after exercise, Blood lactates were lower at the end of exercise after sleep deprivation and remained lower during the recovery period. Changes in plasma volume were not affected by sleep loss. These results suggest that although sleep loss may not overtly affect acute submaximal exercise performance, it attenuates the recovery process.

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501. Mackie, R., and O'Hanlon, J. 1976. A study of the combined effects of extended driving and heat stress on driver arousal and performance. In: Mackie, R., ed. **Vigilance: Theory, operational performance, and physiological correlates.** New York: Plenum Press.

An experiment was conducted on the highway to identify the effects of hot, humid environments on driver performance, subjective state, and various physiological responses believed to reflect arousal or stress. Each driver drove a standard-sized American passenger car over a 360-mile (600 km) route, once under comfortable conditions and once under heat stress.

Under heat stress, the drivers had a systematically higher heart rate, greater heart rate variability, less energy in the higher frequency EEG bands, and produced fewer 17-hydroxycorticosteriods than they did in the comfortable driving environment. They rated themselves more alert early in the trip when in the hot environment, but significantly less alert near the trip's end; they also rated themselves as notably more fatigued during the second half of the trip when in the hot environment. Finally, their performance was systematically poorer in the hot environment as reflected by a greater number of relatively large steering adjustments, the commission of a greater number of technical errors, and an increasing tendency to inadvertently drift out of the appropriate lane of traffic.

502. Mello, R. P., Vogel, J. A., and Patton III, J. F. 1986. **Assessment of physical activity: Intensity during infantry combat-simulated operations.** Natick, MA: U.S. Army Research Institute of Environmental Medicine. (USARIEM Technical Report No. T4-87) {DTIC No. AD-A180-038}.

This study estimated the intensity of physical activity of infantrymen during a combat-simulated 5-day field operation by means of continuous heart rate (HR) recordings. Subjects were 29 soldiers forming 4 rifle squads. Each squad rotated daily through 4 separate terrain areas, each with its own combat-simulated scenario, performing the same scenario on the first and last day. Sleep was limited to one 5-hour period per night. Physical activity was estimated by taping HR with Oxford Medilog cassette recorders with an electrocardiographic (ECG) channel. Mean daily average HR (excluding sleep and resupply time) decreased from a high of 101 beats/minute (bpm) on day one to a low of 89 bpm on day five. This suggests the progressive development of physical fatigue, as the 5-day operation progressed. A 10 km forced march proved to be the single most demanding event resulting in a mean HR of 128 bpm for 140 minutes.

Other periods of sustained high HR were associated with moving to and from mission objectives. Time at or above 50 percent of maximal HR averaged only 37 minutes per day while HR 75 percent was only 2.5 minutes, both times tending to decrease from day 1 to day 5. The results of this study suggest: 1) Continuous cassette HR recording is a suitable method of monitoring the intensity of physical activity during strenuous field operations; 2) sustained high physical activity is minimal in rifle squads in simulated combat; 3) this activity intensity can adequately be supported by an aerobic capacity (VO_2max) of 50 ml O_2 per kg/min; 4) the highest sustained HR was produced by marches or movements to contact with the "enemy"; and 5) the sleep deprivation and physical fatigue of combat operations cause infantrymen to perform at a slower rate regardless of operational demands as the operation progresses.

503. Minors, D., and Waterhouse, J. 1987. The role of naps in alleviating sleepiness during and irregular sleep-wake schedule. **Ergonomics.** **30**(9): 1261-1273.

Four groups of four subjects were studied in an isolation unit on an irregular schedule of sleep and waking. Sleep periods of 6 hours duration were taken at irregular times during the 9-day protocol; they were arranged such that the waking periods lasted 6, 12, or 18 hours and were also in an irregular sequence. One-hour naps were taken after 6 and 12 hours of waking if the next sleep was not due then. Just before either a nap or a full sleep, subjects assessed their sleepiness and, on rising, they assessed how well sleep had been initiated and maintained. A mathematical model developed enabled the effects upon sleepiness of circadian rhythmicity, of the length of the waking period since the last full sleep (time-since-sleep), and of the subjective value of the previous full sleep or nap to be independently quantified. Results showed there was a tendency for sleepiness to increase, in some cases quite markedly, as the irregular schedule proceeded. There were also effects upon sleepiness due to circadian changes and the amount of time since the last full sleep. These two effects were similar in size and larger than the benefits to be derived from a previous nap or full sleep assessed as having been a good one. Authors conclude 1-hour naps can play a small role in decreasing an individual's sleepiness and suggest possible means by which their subjective value might be increased.

504. Mital, A. 1984. Maximum weights of lift acceptable to male and female industrial workers for extended work shifts. **Ergonomics.** **27**(11): 1115-1126.

This paper reports the development of maximum acceptable weight of lift databases for male and female industrial workers for 12-hour work periods. Using a psychophysical methodology, 37 males and 37 females, experienced in manual lifting, performed various lifting tasks involving four frequencies, three box sizes, and three height levels. The maximum acceptable weight of lift was significantly influenced by the frequency of lift, height of lift, and box size. Box size effects were, however, less profound than frequency, and height effects. The maximum weight, acceptable for 12 hours of lifting, elicited an average heart rate of 90 and 101 beats/minute for males and females, respectively. Males selected weights that, on average, resulted in metabolic energy expenditure rates of 23 percent of their aerobic capacity for 12 hours of lifting. Females required metabolic energy expenditure rates equivalent to 24 percent of their aerobic capacity for lifting acceptable levels of weight for 12 hours.

505. Mitchell, G. W. 1986. **Integrated concept for physiology, psychology, and performance.** Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. (USAARL Report No. LR-86-3-3-2).

This document outlines an attempt to integrate the effects of physiology and psychology on performance and to provide a phenomenological model which results in qualitative advice for the commander on limitations and strategies for success during continuous operations on conventional and integrated (chemical/ biological) battlefields. Heat stress, associated with wearing chemical protective ensembles, is the primary problem addressed by the model. Three hypothetical scenarios are presented.

506. Mitchell, G., Knox, F. S. III, Edwards, R., Schrimsher, R., Siering, G., Stone, L., and Taylor, P. 1986. **Microclimate cooling and the aircrew chemical defense ensemble.** Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. (USAARL Technical Report No. 86-12) {DTIC No. AD-B123-948L}. Distribution of this document limited to U.S. Government agencies only.

507. Monahan, R. H. 1974. **Technical report sustained operations model: Helicopter wargame simulation.** Alexandria, VA: U.S. Defense Logistics Agency. (DRSAV Technical Report No. 76-19) {DTIC Report No. AD-A024-444}.

The sustained operations model (SOM) is an event sequenced Monte Carlo simulation computer program that uses externally generated cost and single mission effectiveness results to examine the effectiveness of a group of attack helicopter (AH) aircraft operating in a combat environment over a sustained period of operations. The single mission effectiveness inputs utilized by SOM are generated by an external program such as GLOBAL or EVADE, complex combat simulation programs that evaluate the outcome of an attack by an AH fire team against enemy ground units that include an air defense capability. The cost factor is represented in the actual use of SOM, where comparisons of alternative AH systems are based on using equal cost force sizes. Additional cost factors also can be applied to end game results such as aircraft losses, ordnance and fuel expenditures, and maintenance demands, to derive comparative operational costs during the period of operations.

508. Monk, T. H., Knauth, P., Folkard, S., and Rutenfranz, J. 1978. Memory based performance measures in studies of shiftwork. **Ergonomics. 21**(10): 819-826.

The phase of the circadian rhythm in performance efficiency on a given task is known to be influenced by the memory load involved. Two experiments were performed to determine whether memory load also influences the rate at which rhythms adapt to the phase-shifts involved in (a) transmeridian flight and (b) a long period of night work. In the first study, high and low memory load versions of a performance test were given to a 25-year-old female subject experiencing a 5-hour eastward change in time zone. Differences were found both in the initial phase of the two versions of the test and in the rate at which this phase adapted to the new time. In the second study, two young male subjects, working 21 consecutive night shifts, were given high and low memory load versions of the performance test, and a calculation test, every 4 hours around the clock. The results were similar to those of the first study; a cosinor analysis revealed that despite periods of arhythmicity there were large differences between the rate of adaption of the phases of the performance rhythms of high and low memory versions of the test, and also between the rhythms of temperature and performance. It is concluded that it is wrong to speak of a single 'performance rhythm,' and that performance tests in shiftwork and jet-lag studies should thus simulate some aspect of the 'real' task under consideration.

509. Montague, W. E., Webber, C. E., and Adams, J. A. 1965. The effects of signal and response complexity on eighteen hours of visual monitoring. **Human factors. 7**: 163-172.

Subjects monitored a complex display composed of three rows of four digital display boxes each containing a constant reference number. A change in the number lasting 6 seconds, was the signal to be detected. Signals occurred for different groups of subjects at rates of either 16 or 64 per hour. Response complexity was varied by having some subjects merely report the change while others evaluated the size of the change. Four groups of 15 subjects received different combinations of rate and complexity. Neither rate nor complexity influenced performance. All groups showed significant vigilance decrement during the session. The magnitude of the decrement was relatively trivial, however, and in substantial agreement with other studies. In complex tasks, man seems to be an adequate monitor over rather extended time periods.

510. Morgan W. E., Jacobson S. G., Wilt, E. J., Krueger, G. P., Thorne, D. R., and Smith, H. R. 1985. **Military police heavy security test: Human factors in continuous and sustained security operations**. Columbia, MD: Morgan Management Systems, Inc. (Technical Report: USAMRDC Contract No. DAMD 17-85-C-5268) {DTIC Report No. AD-B105-099L}. Distribution of document and abstract limited to U.S. Department of Defense and their contractors only.

511. Moses, S. 1987. Gallant victory for an old bird: *Voyager's* round-the-world flight without refueling. **Sports illustrated**. 66(4): 36.

The "last first" in aviation, a nonstop flight around the world was made on the gossamer wings of one of the strangest looking craft ever built. *Voyager*, made of paper, graphite, and resin, was a cross between a glider and a graphite fishing rod. It was piloted by Dick Rutan, a Vietnam war flying ace, and Jeana Yeager. The *Voyager* slammed, bounced, and flapped for some 26,000 tense miles on 9 days and nights.

Late in the first night, Rutan and Yeager were 7,000 feet over the Pacific ocean, on the way to Hawaii,

Hawaii, with a ground speed of 154 mph and the assistance of a 33-knot tailwind. Rutan piloted for the first 36 hours -- once grabbing a 3-hour nap -- as Jeanna monitored the autopilot and other instruments from the off-duty pilot's space, which was 7.5 feet by 2 feet, and only 14 inches high. Equal flying time was not expected as Rutan had neither the frame nor the temperament to endure the turbulence of the copilot's seat for very long. Yeager, however, got little more sleep than he as she performed the flight engineer's duties.

After 58 hours of flying, Rutan had been in the pilot's seat for all but 5 hours. Mission control begged him to give up the controls and get some rest. Tired of being badgered and busy dodging thunderstorms, Rutan finally stopped communicating with mission control. Fears that fatigue had severely affected his judgement swept through mission control. Finally, after 72 hours in the seat, Rutan crawled in the back and slept. Yeager flew through the night, across the mountains and valleys of the Philippines. She watched lightning lash, and stayed as low as possible in order to catch tailwinds and conserve fuel. After 10 days, the *Voyager* landed with about four gallons of fuel left in its main tank. "Just enough to get to Sacramento," said Rutan.

After the flight, both Rutan and Yeager expressed confidence with the way the situation had been handled. Yeager didn't have the flight time under her belt (1,000 hours to Rutan's 4,000 hours) to give her experience to handle the *Voyager* unusual situations. They had been planning on Rutan doing most of the flying, especially in the beginning when the *Voyager* was heaviest with fuel, and most difficult to maneuver.

512. Munro, I., Rauch, T., Tharion, W., Banderet, L., Lussier, A., and Shukitt, B. 1986. **Factors limiting endurance of armor, artillery, and infantry units under simulated NBC condition.** Natick, MA: U.S. Army Research Institute of Environmental Medicine. (USARIEM Presentation Report No. M18-86) {DTIC No. AD-A165-865}.

The war of the future will require 72-hour operations in environments contaminated with nuclear, biological and chemical agents. The 1985 P2NBC2 program assessed soldier endurance and performance under simulated NBC conditions. A total of 175 soldiers were observed during 4 tests differing in design, site, climatic conditions, and performance demands. In all but one of the iterations where the full chemical protective ensemble (MOPP 4) was used without cooling, soldier endurance fell far short of the projected requirement. Psychological data were analyzed to determine which factors were associated with the incidence of casualties.

The findings showed that perceived intensity of symptoms resembling the hyperventilation syndrome was significantly greater in soldiers classified as casualties. Five of these symptoms (painful breathing, difficulty breathing, shortness of breath, headache, and nausea) showed casualty-survivor differences in all tests. Symptom intensity was attributed to two factors. (1) External conditions: Thermal stress exacerbated the five basic symptoms, induced others (tetany and paresthesia), and decreased endurance. Periodic relief from respirator use attenuated these symptoms and enhanced endurance. (2) Individual differences: Significant casualty-survivor differences in anxiety, depression, and cognitive strategy scores indicated perception of hyperventilation symptoms and endurance were related to personality variables. Hyperventilation symptoms could incapacitate the soldier or induce removal of the protective mask under actual chemical attack. These symptoms also could limit soldier effectiveness under other operational conditions.

513. Murphy, M., Knapik, S., and Vogel, J. 1984. **Relationship of anaerobic power capacity of performance during a 5-day sustained combat scenario.** Natick, MA: U.S. Army Research Institute of Environmental Medicine. (USARIEM Technical Report No. T5/84) {DTIC No. AD-A181-444}.

Anaerobic power capacity was assessed on 34 infantrymen before and after a 5-day combat scenario. The objective of this study was to determine the importance of this fitness component with the ability to perform field infantry tasks. Anaerobic performance was assessed for the upper and lower body muscle groups using the Wingate test (WT). To perform the WT, the subject pedals or cranks at maximal RPMs for 30s against a resistance of 75 gm/kg body weight for the lower body and 50 gm/kg body weight for the upper body. A second test, the isokinetic endurance test (IET) was administered to asses anaerobic capacity of the elbow flexor and knee extensor muscles. This test utilized the Cybex dynamometer with which the subject performed

50 consecutive maximal arm or leg contractions (C) at an angular velocity of 180 degrees per second. Peak variables were calculated as the mean of the first 5 seconds for the WT and first 4C for the IET. Mean variables were determined for the 30 seconds of the WT and 20 arm or 25 leg C of the IET as well as all 50 contractions of the IET.

Although different muscle groups were utilized during each procedure, the tests were significantly correlated indicating both describe anaerobic performance. A comparison of pre- to postscores revealed a decrease in mean upper body/elbow flexor performance, but no change in lower body/knee extensor performance. The decrease observed could possibly be attributed to the constant load bearing of 28 kg as well as a lower state of conditioning in these muscle groups. Both upper body peak and mean power WT were significantly correlated with performance rating. In conclusion, upper body muscular endurance as assessed by anaerobic power capacity may play an important role in the ability to sustain infantry tasks over 5 days.

514. Murrell, K. F. H. 1970. The relationship between work and rest pauses. **Psychology and industry.** 33: 324-330.

The problem of fatigue on the job and ways to prevent or minimize it has long been of interest to industrial psychologists. This article discusses physical and mental fatigue, reviews research conducted in Great Britain on the relationship between work and voluntary rest pauses, and presents some conclusions on work-rest scheduling.

515. Myles, W. S., and Romet, T. T. 1986. **Combat engineer effectiveness in sustained operations.** Ontario, Canada: Defense and Civil Institute of Environmental Medicine. (DCIEM Technical Report No. 86-R-27) {DTIC No. AD-B103-768}.

The effect of sleep deprivation and physical fatigue on self-paced work output was determined in two sustained combat engineer operations. In the first (Ripe Snapper), four subjects from the 2nd Combat Engineer Regiment went without sleep for 69 hours. During this period, they performed only four physically demanding tasks, three of them in the last 24 hours. Continuous recordings of the heart rate (HR) indicated that sleep deprivation, in the absence of physical fatigue, had no effect on work intensity and the work/recovery cycle. In the second sustained operation (Longue Journee'), six subjects from the 5th Combat Engineer Regiment carried out a full schedule of physically demanding tasks during a period of sleep deprivation lasting 47 hours. Some of the tasks were repeated at least once so that the effects of sleep loss and physical fatigue could be assessed. For the first 14 hours of Longue Journee', the subjects worked at an average HR of 120 bpm, the equivalent to energy expenditure of 35-40 percent of maximal oxygen uptake in fit young men. In the remainder of the sustained operation, work intensity declined as the subjects worked for shorter periods and took longer rests. Rating scales confirmed these changes coincided with the development of physical fatigue. Since sleep deprivation was without effect in Ripe Snapper, the decline in self-paced work output in Longue Journee' was attributed to physical fatigue.

The results of this study have important implications for those responsible for planning sustained combat engineer operations. Longue Journee' demonstrated that typical combat engineers were able to complete all the tasks assigned to them within the allotted 48 hours. Although times to complete individual tasks increased in the later stages, the goal of operating continuously for 48 hours was achieved. The finding that sleep loss, per se, had no effect on self-paced work output in Ripe Snapper suggests that soldiers who are sleep deprived, not physically fatigued, can be expected to complete physically demanding tasks in the same time as fresh troops. Moreover, troops who receive at least 4 hours of dedicated sleep every night should not be considered immune to the effects of sustained operations. If the 20 waking hours are spent in prolonged fatiguing tasks, self-paced work output may still decline.

516. Myles, W. S., and Romet, T. T. 1987. Self-paced work in sleep deprived subjects. **Ergonomics. 30**(8): 1175-1184.

The effect of sleep deprivation and physical fatigue on self-paced work was determined in two experiments simulating sustained combat engineer operations. In experiment A, four subjects went without sleep for 69 hours. During this period, they performed only four physically demanding tasks, three of them in the last 24 hours. Continuous recordings of heart rate (HR) indicated sleep deprivation, in the absence of physical fatigue, has no effect on work intensity and the period of fatiguing work (HR above 120 beats/minute). In experiment B, six subjects carried out a full schedule of physically demanding tasks during a period of sleep deprivation lasting 47 hours. Some of the tasks were repeated at least once so that the effects of sleep loss and physical fatigue could be assessed. For the first 14 hours of experiment B, the subjects worked at an average HR of 120 beats/minute, equivalent to an energy expenditure of 35-40 percent of maximal oxygen uptake in fit young men. In the remainder of the sustained operation, work intensity declined and the subjects worked at HRs above 120 beats/minute for shorter periods. Rating scales confirmed these changes coincided with the development of physical fatigue. Since sleep deprivation was without effect in experiment A, the decline in self-paced work intensity in experiment B was attributed to the combination of physical fatigue and sleep deprivation.

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517. Naitoh, P., and Angus, R. G. 1987. **Napping and human functioning during prolonged work.** San Diego, CA: U.S. Naval Health Research Center. (NHRC Technical Report No. 87-21) {DTIC No. AD-A190-228}.

In prolonged work periods, men and women often forego satisfying their sleep need to complete their assigned jobs, resulting in an accumulation of performance/mood degrading sleep loss and fatigue. Sleep need can be satisfied only by a slow process of sleeping for an average of 7 to 8 consecutive hours per 24 hour period, i.e., a long period of "time-out." However, sleep management suggests recovery from fatigue and sleepiness during a prolonged work period can be accomplished by short or ultrashort sleep (naps) taken during a prolonged work period. Naps are shown not only to refresh and restore human functioning, but also to maintain performance and mood during a prolonged work period. In this paper, the power of naps as a computer-degradation measure is described first through literature review, and then through critical evaluation of studies conducted at the Defence and Civil Institute of Environmental Medicine, Canada, and the U.S. Naval Health Research Center. The need for research and recommendations about ultrashort naps are discussed in the context of refining sleep management techniques applied in the field work environments.

518. Naitoh, P., Englund, C. E., and Ryman, D. H. 1985. Circadian rhythms determined by cosine curve fitting: Analysis of continuous work and sleep-loss data. **Behavior research methods, instruments, and computers.** 17(6): 630-641.

This study reports the effects of sleep loss upon circadian rhythm parameters analyzed by the cosine curve fitting (cosinor) method. Rhythm alterations are described as reductions in rhythm strength, increases in individual variations producing an increase in the 95 percent confidence limits, and reductions in rhythm amplitude. Subjects worked continuously at tasks for 45 hours with time-of-day cues. Circadian cycles in physiological and mood variables remained intact, but rhythms in some task performance measures no longer showed significant 24-hour/cycle activities. The relationship between oral temperature, mood, and pulse rhythms continued undisturbed during the continuous work period; however, the performance linkage to oral temperature was lost. These findings direct attention to individual difference in susceptibility to continuous work periods and suggest that 24-hour rhythms in some performance and physiological measures perhaps are more readily responsive to an altered wake/sleep cycle than other circadian rhythms.

519. Naitoh, P., Englund, C. E., and Ryman, D. H. 1986. **Sleep management in sustained operations user's guide.** San Diego, CA: U.S. Naval Health Research Center. (NHRC Technical Report No. 86-22) {DTIC AD-A173-050}.

This report describes a sleep management (sleep logistics) guide for field commanders responsible for leading men and women to achieve mission objectives in a sustained operation. Section 1 of the guide introduces challenges which the field commanders are facing in sustained operations: Management of men and women under their command so as to keep them combat effective days and nights over the duration of sustained operations without proper rest and sleep. Section 2 offers details of what are sustained operations and sleep management, and explains what kind of work/rest and sleep loss problems occur during the predeployment, deployment, and precombat, combat, and postcombat phases. Section 3 reviews three ways by which sleep management copes with performance degradation caused by work/rest-sleep and sleep loss problems; identifying the signs of, preventing, and overcoming performance degradation. Section 4 details five psychophysiological techniques by which field commanders manage sleep in field training to assure optimal task performance of men and women under their charge during a future sustained operation. These techniques are: (1) To see if mission requires sleep management; (2) to recognize signs of degradation; (3) to know tolerance to sleep loss; (4) to develop self-control to sleep when they must; and (5) to use aids to measure sleep loss effects. In addition, sleep management requires field commanders to learn more facts about the human need for sleep.

520. Naitoh, P., Englund, C. E., and Ryman, D. H. 1987. **Sustained operations: Research results.** San Diego, CA: U.S. Naval Health Research Center. (NHRC Technical Report No. 87-17) {DTIC No. AD-A191-734}.

The effects of a laboratory simulated reconnaissance operation on behavioral and physiological performance were assessed in 7 separate sustained operations (SUSOP) studies involving a total of 112 U.S. Marine Corps volunteers. The scenario of this week-long SUSOP involved two 20-hour continuous work episodes with a break period of 3 to 4 hours of sleep or rest. Half of the volunteer subjects experienced 30-40 percent VO_2 max physical workload by walking on a motor-driven treadmill. All subjects performed psychological cognitive tasks. The immediate goal of these seven studies was to obtain an estimate of the performance recuperative power of a nap of 3 to 4 hours duration. Their long-term goal was to define the limits of human endurance in a SUSOP conducted under hostile environments. The results suggested that (1) starting time of a mission should be chosen to avoid extending a continuous work period into early morning hours of the circadian trough; (2) a 3-4 hour nap is not long enough to allow recovery from fatigue of a 20-hour continuous episode to maintain baseline level of performance during successive continuous work episodes; (3) a physical workload of 30 percent or greater VO_2-max will slow down reaction time post physical work period; and (4) time-of-nap is not as important as the duration of the nap. Management of sleep through the use of naps is recommended in redefining the limits of human endurance in any SUSOP.

521. Nicholson, A. N. 1984. Long periods of work and disturbed sleep. **Ergonomics.** 27(6): 629-630.

During the South Atlantic campaign (Falkland Islands) very high workloads were reached. Transport aircrew attained 150 flying hours within less than a month, though it is generally accepted that the "normal" maximum should be around 100. The crews often commenced duty during the late evening with a takeoff during the early hours of the morning, and a flight of up to 28 hours duration with air-to-air refuelling. The missions covered two consecutive nights without adequate sleep, and were repeated up to six times in about 4 weeks. The problem was one of a very unusual shiftwork pattern, excessively long periods of duty with irregularity of rest over several weeks. In view of previous experience, it was considered highly unlikely the crews would be able to obtain satisfactory sleep without the help of hypnotics.

Because of the previous experience with temazepam in a less demanding situation, it was made available, and during the South Atlantic campaign it was used widely. The majority of aircrews took 20 mg of temazepam to get to sleep at various times of the day and night, and obtained good sleep without side or residual effects. They were advised to take the hypnotic at least 8 hours before flight, and whenever possible were given an initial test dose to assess any untoward effect, though none was encountered. In some crews there were no ill effects. The safe use of temazepam in such a critical situation confirmed the recommendations which had been based on laboratory studies.

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522. O'Donnell, M. G. 1984. **Design of an evaluation system to measure performance degradation due to continuous operations**. Monterey, CA: U.S. Naval Postgraduate School. {DTIC No. AD-A148-188}.

This paper establishes guidelines for an evaluation system designed to measure performance degradation due to continuous operations for battalion-sized units of the U. S. Army. It serves to initiate direction for the evaluation system, provides the framework on how to accomplish the necessary data measurements for such an evaluation, and enumerates the performance indicators to be measured. Techniques to analyze different types of data are provided, along with examples of the use of those techniques. A discussion of the uses of the results is presented.

523. O'Donnell, V. M. 1986. Pharmacological optimization of performance: Sleep and arousal. In: Lee, G. E., ed. **Proceedings of the tenth symposium: Psychology in the Department of Defense**, pp.81-85. Colorado Springs, CO: U.S. Air Force Academy Department of Behavioral Sciences and Leadership.

Numerous hypnotic (sleep-inducing) drugs are approved and available in the United States. Of these drugs, the benzodiazepine hypnotics appear to be the potential drugs of choice for military operations due to their relatively minor performance effects as compared to other hypnotic compounds. Important differences exist, however, between the military and civilian applications of these drugs in terms of both efficacy and effects on human performance. Additional research is needed to answer questions raised by these application differences. The initial military use of hypnotic compounds may be most appropriate to long-distance air deployment of troops where there is a reasonable probability that personnel will be able to sleep for 6 or more hours subsequent to drug administration. Additional military uses for hypnotics may be dependent upon the fielding of a selective counteragent to the hypnotic compound.

524. Opstad, P. K., and Aakvaag, A. 1981. The effect of a high calorie diet on hormonal changes in young men during prolonged physical strain and sleep deprivation. **European journal of applied physiology**. 46: 31-39.

Major changes occur in the serum level of several hormones during 5 days of heavy and continuous physical activities, with less than a total of 2 hours of sleep. This investigation evaluated the importance of caloric deficiency, energy requirement being about 8,000-10,000 kcal/24 hours. A comparison between well fed subjects and those with food deprivation revealed significantly higher levels of triiodothyronine (T3), insulin, and thyroid stimulating hormone (TSH) in the well-fed subjects, who also had lower levels of growth hormone (hGH) and cortisol, whereas no difference was found between the two groups for thyroxin (T4). Increased levels were found for T3 and T4 in both groups during the first day of activity, with a concomitant decrease in TSH and a subsequent decrease of T4 during the next 2 days. T3 decreased only in the low-calorie group whereas increased levels were found in the isocalorie group throughout the course. The resting levels of insulin decreased during the course in the low-calorie group whereas it increased in the isocalorie group. High levels were maintained throughout the course for hGH. Cortisol showed high levels just before the start of the course and then decreased from day 2 to day 4. No difference was found between morning and evening levels for cortisol, indicating disappearance of the circadian rhythm. The investigation showed energy deficiency during prolonged physical strain is responsible for the decreased serum levels of T3 and insulin and may contribute to the decrease in TSH and the increase in hGH and cortisol.

525. Orr, W., Hoffman, H., and Hegge, F. 1974. Ultradian rhythms in extended performance. **Aerospace medicine.** 45(9): 995-1000.

Eleven healthy young male volunteers participated in an experiment which involved continuous monitoring of heart rate and performance on a complex vigilance task. Subjects were instructed to continue in the experiment for 48 hours or until they felt they could no longer. All subjects completed at least 21 hours and two went for 44 hours. Heart rate and behavioral measures were subjected to complex demodulation analysis to determine the phase and amplitude characteristics of cyclic activity with a period in the range of 90 minutes $\pm$ 5 minutes. The primary findings were a rather marked increase in the amplitude of the 90-minute rhythm, in both heart rate and performance measures, as the time on task increased, reaching their highest level near the end of the run. This response pattern was found in over three-fourths of the analyses done, and was independent of the total duration of the experiment. It is felt this marked rise is indicative of a cumulative stress response. In most subjects, the heart rate response did appear to show some similarity of patterning with at least one of the behavioral measures. Only three subjects showed an obvious dissociation between heart rate and the behavioral responses. There was, however, greater concordance of response patterning among the behavioral measures.

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526. Patton, J. F., Vogel, J. A., Damokosh, A. I., Mello, R. P., Knapik, J. J., and Drews, F. R. 1987. **Physical fitness and physical performance during continuous field artillery operations.** Natick, MA: U.S. Army Research Institute of Environmental Medicine. (USARIEM Technical Report No. T9-87) {DTIC No. AD-A185-008}.

The purposes of this study were to: 1) Determine the effects of a continuous field artillery scenario on physical fitness capacity and performance; 2) relate physical capacity to task performance during the scenario; and 3) estimate the physical intensity of the scenario by continuous heart rate monitoring. Twenty-four artillerymen comprising three eight-man guncrews participated in an 8-day, simulated combat operation. Body composition and measures of fitness (isokinetic strength of the arms and legs, isometric handgrip strength, dynamic lifting, and upper body anaerobic power) were determined before and immediately following the scenario.

Physical performance was assessed by daily ratings from senior noncommissioned officers experienced in artillery operations. The intensity of physical activity and amount of sleep were estimated from continuously recorded heart rate using Oxford Medilog electrocardiographic tape recorders worn by the soldiers. Weak, nonsignificant relationships were found between various measures of exercise capacity and physical task performance during the scenario. No changes occurred in body weight or upper body anaerobic power from pre- to postscenario. Measures of muscular strength and lifting capacity, however, increased by 12-18 percent postscenario. Physical performance scores were significantly higher on days 1 and 8 compared to the other days, but no differences were seen from days 2 through 7.

The mean daily amount of sleep obtained was $5.3 \pm 1/3$ hours. The soldiers averaged 2.5 hours, 22 minutes and 2.9 minutes per day at heart rates equal to or greater than 25, 50, and 75 percent of their maximal heart rates, respectively. The results: 1) Soldiers who are allowed 5 hours sleep per day and who are required to perform at relatively moderate levels of physical intensity show no decrements in physical fitness, capacity, or evidence of physical fatigue for up to 8 days of continuous operations; 2) the physical fitness of artillerymen was comparable to other Army populations of similar age and proved adequate to meet the physical demands of this scenario; and 3) soldiers undergoing realistic, continuous field artillery operations are able to obtain adequate sleep and spend only short periods at high levels of physical activity.

527. Patton, J., Vogel, J., Damokosh, A., and Mello, R. 1989. Effects of continuous operations on physical fitness capacity and physical performance. **Work and stress.** 3(1): 69-77.

This study determined the effects of a continuous field artillery scenario on physical fitness capacity and performance and to estimate the physical intensity of the scenario by continuous heart rate monitoring. Twenty-four artillerymen comprising three eight-man guncrews participated in an 8-day, combat-simulated operation. Body composition and measures of fitness (isokinetic strength of the arms and legs, isometric handgrip strength, dynamic lifting, and upper body anaerobic power) were determined before and immediately following the scenario. Physical performance was assessed by daily ratings from senior noncommissioned officers experienced in artillery operations. The intensity of physical activity and amount of sleep were estimated from continuously recorded heart rate using electrocardiographic tape recorders worn by the soldiers. No changes occurred in body weight or upper body anaerobic power from pre- to postscenario. However, measures of muscular strength and lifting capacity increased by 12-18 percent postscenario. Physical performance scores were significantly higher on days 1 and 8 compared to other days, but no differences were seen from days 2 through 7. The mean $\pm$SD for daily sleep was 5.3 ± 1.3 h. The soldiers averaged 22 minutes and 2.9 minutes per day, respectively, at heart rates equal to or greater than 50 percent and 75 percent of their maximal heart rates. The results suggest that soldiers who are allowed 5 hours sleep per day and who are required to perform at relatively moderate levels of physical intensity show no decrements in physical fitness capacity of evidence of physical fatigue for up to 8 days of continuous operations.

528. Peacock, B., Glube, R., Miller, M., and Clune, P. 1983. Police officers' responses to 8 and 12 hour shift schedules. **Ergonomics.** **26**(5): 579-493.

An extensive before and after study was conducted when a city police force changed from an 8-hour 12 day shift cycle to a 12-hour 8 day system. A physical fitness test, blood pressure, sleep duration, sleep quality, and subjective level of alertness measures showed improvements with the new system. Critical flicker fusion showed reliable within shift decrements, but no between system differences. Oral temperature showed the expected circadian changes with no indication of phase shift under either system. Urinary catecholamine and grammatical reasoning measures showed no influence of shift-related factors. The overwhelming support for the new system coupled with the absence of any negative ergonomics evidence led to its adoption on a permanent basis.

529. Pearson, R. G., and Byars, G. 1956. **The development and validation of a checklist for measuring subjective fatigue.** Randolph Air Force Base, TX: U.S. Air Force School of Aviation Medicine. (USASAM Report No. 56-115) {DTIC No. AD-128-756}.

Two 13-item equivalent-form fatigue checklists were developed by the scale discrimination method. In a laboratory study, both an experimental group (100 subjects tested 4 1/2 hours on a fatiguing perceptual motor-task) and a control group (100 subjects, no task) became significantly "tired" in terms of checklist data, but such data were able to reflect a significantly greater decline in feeling-tone for the experimental group. Equivalent-form reliability was .92 and .95 for experimental and control groups, respectively. The data adequately satisfied the requirements of scale analysis as to undimensionality. In a related study, checklist data reflected the expected differences in affective state for 120 subjects assigned equally to analeptic, depressant, and placebo drug treatment groups and observed 4 1/2 hours under control (no task) conditions.

530. Pearson, R. G., Shelnutt, J. B., and Casey, S. M. 1976. Combined tracking and monitoring performance over seven hours under noise. In: **Proceedings of the 6th congress of the international ergonomics association**, pp. 422-425. College Park, MD: University of Maryland.

Twenty volunteer, paid, males performed a task requiring (a) pursuit tracking of a CRT display target using a joystick control, plus (b) concurrent monitoring of a warning light and two panel meters located peripherally to the central task. During the task which lasted 7 hours, 10 subjects were exposed to rapid, intermittent pulses of broadband noise of 91 dB(A) peak intensity; the other 10 subjects performed in "quiet."

Recordings of eye movements were made to determine attention to the time-shared, peripheral tasks. No significant differences in performance were found (a) for the noise variables or (b) between "high" and "low" annoyance sensitive subjects as categorized by scores on a noise annoyance sensitivity scale. While tracking performance declined over time, meter monitoring performance did not, nor was there evidence that eye movements to the peripheral events decreased over time. The results fail to support the view that narrowing of attention occurs in perceptual motor tasks involving time-sharing of attention to central and peripheral events when such a task is performed over a prolonged period of time.

531. Pokorny, M. L., Blom, D. H., and VanLeeuwen, P. 1987. Shifts, duration of work and accident risk of bus drivers. **Ergonomics. 30**(1): 61-88.

This paper contains the results of a repetitive and comprehensive analysis of accidents of bus drivers, highlighting different aspects of the etiology of the accidents. Results indicate a strong effect of the type of shift on accident risk. Shifts starting in the morning appeared to have a higher risk than shifts starting in the afternoon. Furthermore, a certain association could be detected within each type of shift, with the starting hour of the service reflecting the influence of the starting condition of the worker.

The paper describes analyses of the pattern of accident risk during the course of various types of shift. A characteristic pattern demonstrated, that accident risk during the early shift is relatively low at the beginning of task operation, reaches a peak at about the third or fourth hour of service, followed by a decline and then another increase during the last hours of task operation. Accident risk during the late shift is relatively high at the beginning of service and then declines towards the end of service. In the first, morning part of the split shift a less clear picture can be detected, while in the second, afternoon part an inverted U-shape can be demonstrated. On the basis of the results of this study and a discussion about the role of time of day and time on task in influencing accident risk, it is concluded that, while allowance must be made for certain variations related to the time of day, in accident research one should take full account of the effects of the structure of the work together with the duration of the work, i.e., time on task.

532. Prescott, B. P., Cowles, T. J., and Bonee, J. C. 1988. **Methodology improvement program (MIP) for physiological and psychological effects of nuclear, biological, chemical, and sustained operations on systems in combat: Concept evaluation program (CEP): Interim test report.** Fort Knox, KY: Test and Experimentation Command, Armor and Engineer Board. (TRADOC Report No. TRMS No. 88-CEP-0532A) {DTIC No. AD-B130-452L}. Distribution of the document limited to U.S. Government.

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533. Rauch, T. M., Banderet, J. E., Tharion, W. J., Munro, I, Lussier, A. R., and Shukitt, B. 1986. **Factors influencing the sustained performance capabilities of 155mm howitzer sections in simulated conventional and chemical warfare environments.** Natick, MA: U.S. Army Research Institute of Environmental Medicine. (USARIEM Technical Report No. T11-86) {DTIC No. AD-A173-693}.

Factors which limit the performance capabilities of sustained artillery operations in simulated conventional and chemical warfare environments were studied. The results show that perceptions of psychological (mental) fatigue, rather than perceptions of muscular fatigue, were primary factors affecting sustained artillery performance. Furthermore, variations in these psychological states were correlated with artillery task performance during the sustained operation.

In the simulated chemical warfare environment, extreme symptom and mood changes resulted in medical casualties, combat ineffectiveness, and early termination of all testing. Significant personality differences existed between casualties and survivors. The majority of casualties voluntarily terminated operational duties because of intense symptoms associated with wearing the chemical protective mask and clothing system. These symptoms were manifestations of respiratory and thermal stress.

534. Redmond, D. P., and Hegge F. W. 1985. Observations on the design of a wrist-worn human activity monitoring system. **Behavior research methods, instruments and computers.** 17(6): 659-669.

Monitoring motor activity provides an important index of sleep, rest, and activity in field studies of sustained operations, shift-work schedules, and sleep deprivation. Poor results with previous methods led to a program to design a technologically improved wrist monitoring system. In this program, specific issues examined ranged from the empirical characteristics of the wrist movement signal and transduction methods, to conversion of that signal to a useful index of motility. This report discusses several design issues encountered, observations, and conclusions and resulting specifications. The product of this program is a microprocessor-controlled, self-contained activity recording system, with 16 kilobytes of digital storage and an operating life of over 30 days. The Walter Reed activity monitoring system will be applied to examine further the phenomena of wrist activity and their behavioral and physiological correlates. Generally, the wrist movement data permits one to infer when the wearer was awake or asleep, and when awake, either very active or moderately so, and when asleep, whether sleeping restfully or fitfully.

535. Reeves, D. L., and Gadolin, R. E. 1989. **Sustained/continuous operations subgroup of the DOD human factors engineering technical group: Program summary and abstracts from the 8th semiannual meeting.** Pensacola, Fl: Naval Aerospace Medical Research Laboratory. (NAMRL Technical Memorandum 89-2).

This document is a synopsis of the proceedings of the 8th meeting of the Department of Defense Human Factors Engineering Sustained/Continuous Operations Technical Subgroup (DOD HFE SUSOPS/CONOPS TG). The meeting was held in conjunction with the 21st meeting of the DOD HFE TG. The meeting was conducted as a symposium in which six presenters reviewed their research, test, and evaluation methodologies and technologies as they applied to the topic of sustained and continuous operations in the military. A broad spectrum of topics covered during the meeting ranged from computer modeling and expert systems for guiding military SUSOPS to development of dietary countermeasures for sustained diving operations.

536. Roessler, R. 1971. **Physiological correlates of optimal performance.** Washington, DC: National Aeronautics and Space Administration. (NASA Technical Report No. N71-35236 and CR-121903).

This research was directed to defining the utility of psychological and physiological variables in predicting human performance during extended periods of stress. Phase I was directed toward defining the baselines on psychological, physiological and performance variables and to determine their stability over time. It included 3 days of vigilance-shock avoidance tasks. On the third day, the subjects were kept awake through the night performing benign perceptual and motor tasks to provide a baseline of total sleep deprivation of a nonstressful nature for comparison with Phase II partial sleep deprivation under stress.

Phase II consisted of 3 continuous days and nights in the laboratory. During the morning, afternoon, and evening of each of the three 24-hour periods, the subjects performed vigilance tasks, each lasting 110 minutes. After the last task in the evening, the subject was permitted to sleep from 2300-0630.

The results were divided into five sections: Performance; personality and mood; catecholamines; sleep; and skin conductance, heart rate, finger pulse volume, galvanic skin response, and respiration. The data suggest well trained men can continue to perform well for extended periods (of at least 3 days) if the schedule is one permitting sleep and the tasks themselves can be performed with few errors. More prolonged sleep deprivation will result in performance decrement.

537. Rognum, T. O., Vartdal, F., Rodahl, K., Opstad, P. K., Knudsen-Baas, O., Kindt, E., and Withey, W. R. 1986. Physical and mental performance of soldiers on high- and low-energy diets during prolonged heavy exercise combined with sleep deprivation. **Ergonomics. 29**(7): 859-867.

A group of 24 men was studied during a period of heavy, sustained work lasting 107 hours, during which time they had less than 2 hours sleep during the entire period. Nine men received a diet providing 33.49 megajoules (MJ) (8000 kcal) and 15 a diet providing 6.30 MJ (1500 kcal) per day. The subjects were assessed by objective measurements of simulated military tasks and by subjective assessments using self-rated (Borg perceived exertion and Stanford sleepiness scales) and observer-rated scales. Although the high energy group tended to feel slightly more alert, there were no differences among the group in the test of military performance. After 4 days of sustained activity, all subjects were judged to be ineffective as soldiers. The high-energy diet was tolerated well. The average loss of body-fat in the high-energy group was 1.3 kg compared with 3.1 kg in the other group, suggesting that even the high-energy group was in energy deficit. These results suggest the major factor influencing performance in these experiments was sleep deprivation, and that the decline in performance as assessed by observers, could not be prevented by giving a high-energy diet alone.

538. Rosa, R., Bonnet, M., and Warm, J. 1983. Recovery of performance during sleep following sleep deprivation. **Psychophysiology. 20**(2): 152-159.

Very few studies systematically examine recovery of performance after sleep deprivation. In this study, 12 young adult males were sleep deprived for periods of 40 to 64 hours. Each period was preceded by baseline nights of sleep and followed by two recovery nights of sleep. Immediate recall and reaction time were tested at 2300, 0145, 0400, 0615, and 0830 during baselines, deprivation, and recovery nights. Performance efficiency showed a progressive decline after 2 hours of recovery sleep following both periods of deprivation. Return to baseline was apparent after 4 hours of sleep following 40 hours awake and after 8 hours of sleep following 64 hours awake. These results suggest that, in terms of behavioral efficiency, an equal amount of sleep is not required to compensate for sleep lost.

539. Rosa, R., and Colligan, M. 1988. Long workdays versus restdays: Assessing fatigue and alertness with a portable performance battery. **Human factors. 30**(3): 305-317.

A test battery designed to assess psychological/behavioral fatigue was used to compare restdays to a workweek of five 12-hour days at a data entry job simulation. Across both workdays and restdays, the battery was presented at regular intervals to test for fatigue effects and diurnal variations. Increased data entry errors across the workday and the workweek, as well as subjective reports of increased tiredness on workdays, indicated that the work regimen was fatiguing. Test battery performance paralleled those results. On workdays, as compared with restdays, grammatical reasoning was faster but less accurate; digit addition was slower; simple, dual, and choice reaction times were slower; and hand steadiness decreased. The results demonstrated the sensitivity of the battery to long hours of work. The results are discussed in terms of work-rest differences, changes across the workweek, diurnal variations and cognitive demand.

540. Rosa, R., Colligan, M., and Lewis, P. 1989. Extended workdays: Effects of 8-hour and 12-hour rotating shift schedules on performance, subjective alertness, sleep patterns, and psychosocial variables. **Work and stress. 3**(1): 21-32.

A newly instituted 3-4 day/12-hour rotating shift schedule was compared to the previous 5-7 day/8-hour schedule using standard laboratory-type measures of performance and alertness, and a questionnaire on sleep patterns and other personal habits. After 7 months of adaptation to the new schedule, there were decrements in the laboratory-type tests of performance/alertness which could be attributed to the extra 4 hours of work per day. There also were reductions in sleep, and disruptions of other personal activities during 12-hour workdays. However, increases in self-reported stress were attenuated by the shortened workweek. These results are discussed in terms of tradeoffs between longer workdays and shorter workweeks.

541. Rose, M. S., and Carlson, D. E. 1987. **Effects of A-ration meals on body weight during sustained field operations.** Natick, MA: U.S. Army Research Institute of Environmental Medicine. (USARIEM Technical Report No. T2-87) {DTIC No. AD-A176-270}.

Army rations are designed to provide enough energy and other nutrients to meet the nutritional demands and requirements of soldiers in the field. In spite of the availability of sufficient calories, body weight loss has been reported frequently during field studies especially when troops are required to subsist solely on packaged rations such as the meal, ready-to-eat (MRE). The body weight loss has been attributed to inadequate consumption of the rations. Food consumption and body weight data were collected from 31 soldiers in three artillery batteries involved in 8 days of sustained operations field exercises. Because of a temporary moratorium on the use of MREs, the soldiers were fed three hot A-ration meals/day during the exercise. The soldiers consumed an average of 3713 kcal/day to produce an overall body weight gain of 0.8 kg during the 8 days of sustained operations. Comparing the results of the present study with that of recent field studies indicated that soldiers consume more calories and lose less body weight when served three hot A-ration meals/day as opposed to two A-rations/one MRE, two B-rations/one MRE, one T-ration/two MREs, or three MREs per day. These data clearly indicate that soldiers served hot meals they like and given the time to eat these meals will consume sufficient calories to maintain energy balance even during sustained, physically demanding field operations.

542. Rutenfranz, J., Aschoff, J., and Mann, H. 1970. **Investigations concerning reaction time in relation to duration of sleep and time of day.** Paper presented at the NATO Advisory Group for Aerospace Research and Development meeting: Rest and activity cycles for the maintenance of efficiency of personnel concerned with military flight operations, pp. 2:1 - 2:3. (NATO AGARD No. CP-74-70) {DTIC No. AD-717-265}.

Investigations using a rotating shift operation system based on 4-hour period/3 day cycles showed: 1) The maximal value of the reaction time was between 2400 and 0400 hours. 2) Especially long reaction times were found on nights when the test persons were allowed to sleep without any additional shift-born interruptions. 3) The phenomenon mentioned in the second part was associated with a reductions in the duration of sleep to less than 5 hours during the preceding days of shift-operations. 4) The reaction time depended on the time of day as much as the preceding sleep duration. The consequences of shift operations are discussed.

543. Ryman, D., Naitoh, P., and Englund, C. 1989. Perceived exertion under conditions of sustained work and sleep loss. **Work and stress.** 3(1): 57-68.

The rated perceived exertion (RPE) for treadmill walking carrying a 22 kg pack was measured in two studies with heart rate, workload and psychological measures. Study 1 used an initial treadmill speed and grade producing 40 percent of maximal oxygen consumption. Exercise subjects walked 1/2 hour, then did other tasks for 1/2 hour for 16 sessions on two 20-hour long days. Group 1 had a 4-hour nap, while group 2 had 4 hours of rest between workdays. Subjects maintained the 40 percent workload throughout the 2 days with a 3-hour nap between days, one group starting exercise at midnight and one at noon.

A steady increase in RPE over the sessions each day was found in each study. There were no differences in RPE between nap and rest groups in study 1 or between the midnight and noon groups in study 2. RPE was higher on day 2 in each study. RPE correlated significantly with heart rate, distance walked or elevation at most periods on the first workday in study 1, but not study 2. RPE was positively correlated with fatigue, symptoms, sleepiness, and negative mood, and negatively correlated with vigor at most of the time periods day 1, study 2; with similar significant correlations at only one time period on day 1, study 1. RPE was lower the first session day 2 as compared to the last session day 1 in both studies. This prepost break recovery did not differ between groups in either study.

544. Samel, A., and Wegmann, H. M. 1987. Desynchronization and internal dissociation in aircrew. **Ergonomics.** 30(9): 1395-1404.

Continuous records of sleep, sleepiness, urine samples, and subjective fatigue ratings were obtained from and continuous monitoring of their temperature and electrocardiogram (ECG) was carried out on 12 Boeing B747 cockpit crewmembers during a baseline period of 36 hours, 3 days of operating regular passenger flights between Frankfurt and San Francisco and 44 hours after their return to Germany. This paper deals with the circadian aspects of hormone and electrolyte excretion in addition to those of rectal temperature and ECG. Normal circadian phase relations of these functions were disrupted due to the time zone transitions of 9 hours in both directions. Internal dissociation was most pronounced on the second day in San Francisco with maximum shifts in acrophases up to 12.5 hours for sodium and minimum shifts of about 2 hours for 17-hydroxycorticosteriod (17-OHCS) excretion rates. After the return flight, readaptation to local time in Germany also differed among functions, but to a minor degree: The range of internal dissociation was reduced to 3 hours, with extreme values observed in the curves of sodium excretion (delay of about 3.75 hours) and of heart rate (delay of 0.6 hour). The coupling with internal synchronizers varied considerably between the different measured parameters. Some body functions, such as 17-OHCS and temperature, were influenced only slightly by external factors. Other indices, such as heartrate and sodium excretion rates, were much more affected, e.g., by sleep, activity, and food intake. The authors conclude that, due to dissociation and desynchronization, irregular work hours for pilots lead to rhythm disturbances, which may impair the well-being and, in some cases, may also affect the performance of aircrew during duty.

545. Sing, H. C., Thorne, D. R., Hegge, F. W., and Babkoff, H. 1985. Trend and rhythm analysis of time-series data using complex demodulation. **Behavior research methods, instruments and computers.** 17(6): 623-629.

Biological time-series data collected over long intervals generally show combined systematic and periodic fluctuations. Comprehensive analysis of such data requires separation of the trend and rhythmic components. Most available time-series analytic techniques do not explicitly extract the trend, and do implicitly assume the underlying rhythms are simple symmetrical sinusoids, whose amplitude and phase values remain constant throughout the recorded interval. Neither assumption is very accurate when dealing with biological data, and the stationarity assumption in particular becomes harder to defend as experiments extend over days or even weeks. Complex demodulation (CD) is described here as a technique for separation of trend from cyclic components, and multiple complex demodulation (MCD) as a technique for extraction of all possible frequencies in the data set, along with their moment-by-moment amplitude and phase values.

546. Soule, R. G., and Goldman, R. F. 1973. Pacing of intermittent work during 31 hours. **Medicine and science in sports.** 5(2): 128-131.

Subjects walked 1 hour out of every 6 on a self-paced treadmill, during two separate 31-hour test periods, carrying either a 15 or 30 kg pack. During the 31-hour period, each subject walked for 6 1-hour periods (or walked 4.8 km each period) without sleep during the intervening periods. The average times with the 15 kg load for each 400 meters at each experimental hour only showed significantly faster times for hours 7 and 13 compared to hour 25. No differences at all existed for the heavier 30 kg load. The time to complete the 400 meters during each walk with the 15 kg load showed slower walk times from 0-400 meters and from 3200-4000 meters than for all the others; no differences were observed with the 30 kg load. The relationship between heart rate and reported perceived exertion level was not significant, but this perhaps reflected the narrow range of the heart rate data. Furthermore, there was clearly a progressive increase in the perceived exertion level reported for both loads, but the differences were not significant. It appears that an extended 31-hour operation, without sleep, is not sufficient to measurably change the voluntarily selected "hard work" rate. However, the subjective evaluation of perceived exertion level may very well increase despite constant work and physiological responses.

547. Spinweber, C. L. 1986. **Sedating and nonsedating sleeping aids in air operations.** San Diego, CA: U.S. Naval Health Research Center. (NHRC Technical Report No. 86-18) {DTIC No. AD-A173-503}.

Both sedating and nonsedating sleeping aids may be appropriate for use in specific operational environments to promote sleep and permit efficient utilization of rest periods. "Sedating" agents, such as the benzodiazepine triazolam, produce an "impairment window," a period of time postadministration when performance and responsivity during sleep are impaired. "Nonsedating" agents, such as the amino acid L-tryptophan, enhance sleep but do not alter performance or responsivity at any time post administration.

In field trial use of L-tryptophan in U.S. Marines airlifted from California to Okinawa, L-tryptophan increased total sleep time the first night after arrival. This sleep enhancement was associated with significantly faster reaction times the next day, sparing of short-term memory from "jet-lag" effects, and more rapid recovery of reaction time over the first 3 days after arrival. Which type of agent to use in support of an air operation will be determined by the nature of the environments in which rest periods will occur and the duration of scheduled sleep times.

548. Stambler, I. 1987. More than courage can be gleaned for the historic *Voyager* flight. **Research and development.** 29(2): 50.

With courage, and daring to match that of any pioneers in aviation history, the two pilots of *Voyager* took their fragile craft aloft from Edwards Air Force Base, California, in December 1986, and in 9 days successfully completed the first nonstop, unrefueled flight around the world.

Voyager was designed as a single-mission aircraft with almost every cubic inch of volume, including the mattress that the off-duty crew member rested on, filled with fuel. The 26,000-mile (41,800 km) flight had more than its share of drama. The crew had to deal with severe weather and errors in calculation that caused many fears that the plane might run out of fuel long before reaching the end of the voyage. Not the least of the problems was the crew's need to work in exceedingly cramped conditions where physical endurance was tested to the utmost. The *Voyager* was piloted from a cocoon seven and a half feet by two feet. For most of the flight, Jeanna Yeager navigated from the rear of the cockpit, while Dick Rutan piloted.

But Rutan, designer of the aircraft, said just prior to the end of the flight, "We have seen almost every emotion." Fatigue almost drove Dick Rutan and Jeana Yeager (pilot and copilot, respectively) to the point of incapacitation. At times, they were unable to read simple gages and were so hampered by their bodies' resistance to their efforts that they shed tears of frustration. Adding to their numbing fatigue was the often bone-bruising turbulence they encountered.

549. Stampi, C. 1984. Ultrashort sleep-wake cycles improve performance during one-man transatlantic races. In: Koella, W., Ruther, E., and Schulz, H., eds. **Sleep '84.** New York: Gustav Fisher Verlag. Also chapter 23 in: Redfern, P. H., Campbell, I. C., Davies, J. A. and Martin, K. F., eds. **Circadian rhythms in the central nervous system.** London: The Macmillan Press.

The possibility of adapting to artificial short or ultrashort sleep-wake schedules by adult man has been suggested by several laboratory experiments, There are several nonartificial situations where ultrashort sleep-wake schedules could be advantageous and in particular cases essential to the subject's performance, i.e., survival and/or emergency conditions, deep-sea workers, astronauts, sailors, mountain climbers, polar explorers, etc. As a preliminary analysis of sleep-requirements during these rather extreme situations, towards the design and optimization of a fractionated sleep pattern, a study was made of the spontaneous and self-determined sleep patterns of 54, 16, and 29 civilian yachtsmen, ages 20-67 (means 38.7, 29.7, and 35.6), participating in two oceanic one-man races and one two-man race respectively: The observer singlehanded transatlantic race (OSTAR) 1980, 3,000 miles; the minitransat (MT) 1983, 4,300 miles, and the round Britain race (RBR) 1982, 1,900 miles. A detailed description and analysis of medical, psychological and technical problems of a solo race are presented in a study by Bennet.

550. Stampi, C. 1989. Polyphasic sleep strategies improve prolonged sustained performance: A field study on 99 sailors. **Work and stress.** 3(1): 41-55.

In situations where continuous prolonged work demands exist, the habitual nocturnal monophasic (6-8 hour duration) sleep pattern rarely can be accomplished, and performance effectiveness sometimes may be severely compromised by accumulation of sleep debt. Several studies have shown that naps can be disproportionately effective in recovering functioning during continuous work (CW).

Sleep-wake patterns and their relationships to performance were studied for 99 sailors involved in solo and double-handed ocean sailing races (a model of a highly demanding CW situation). Most sailors spontaneously adopted multiple nap sleep-wake schedules and adapted without major difficulties to such polyphasic patterns. 66.5 percent had mean sleep episode durations (SEDs) ranging from 20 minutes to 2 hours. Overall mean total sleep time (TST) per 24 hours was reduced from a baseline of 7.5 to 6.3 hours. Race performance correlated negatively and significantly with mean SEDs and TSTs. Best performance results were obtained by those sleeping for periods of between 20 minutes and 1 hour and for a total of 4.5 to 5.5 hours of sleep per day.

The results are discussed together with several chronobiological, phylogenic, and experimental studies and issues, all of which suggest that adult humans may have a damped polyphasic sleep-wake tendency. It also is proposed that polyphasic sleep schedules could become promising and feasible solutions for the management of sleep requirements under prolonged CW situations.

551. Starkey, G., Babcock, C., Hershberger, R., and Williams, L. 1987. **CANE literature research compendium: Volume III P2NBC2 addendum.** U.S. Army Chemical School, Fort McClellan, AL. (ORI Technical Report No. TR-2532C), {DTIC No. AD-B109-017}. Distribution of document limited to the U. S. Government agencies and their contractors only.

This report contains a list of titles of documents relevant to the study of physiological and psychological effects on NBC and extended operations on crews, the U.S. Army's P2NBC2 project. This addendum is an update to the periodic chemical and nuclear environment (CANE) literature research compendium. The purpose of P2NBC2 is to examine, expeditiously, physiological effects of NBC and extended operations on combat vehicle crews, especially while operating them wearing chemical protective clothing.

552. Storm, W. F., Hartman, B. O., and Makalous, D. L. 1977. Aircrew fatigue in nonstop, transoceanic tactical deployments. Paper presented at the Aerospace Medical Panel Specialists Meeting, Studies on Pilot Workload, Cologne, Federal Republic of Germany, April 1977. (NATO AGARD Conference Preprint No. 217).

The central issue addressed by this study was operational effectiveness following long-range deployment. Stress and fatigue were evaluated in F-4D fighter aircraft crews before and after flying nonstop, transoceanic deployments from New Mexico to Germany and return. The measurement battery consisted of subjective fatigue ratings, self ratings of fitness to fly, sleep logs, and biochemical analyses of urine samples for norepinephrine, epinephrine, 17-hydroxycorticosteriods, urea, sodium, and potassium. The magnitude and the consistency of behavioral and physiological changes indicated the occurrence of mild fatigue immediately after both flights. The fatigue was acute and was ameliorated by one uninterrupted sleep period.

553. Storm, W. F., and Parke, R. C. 1987. FB-111A aircrew use of temazepam during surge operations. {DTIC No. AD-P005-662}. In: **Proceedings of the NATO advisory group for aerospace research and development aerospace medical panel specialist meeting in Paris, France,** pp. 12:1 - 12:12. Loughton, Essex, United Kingdom: Specialized Printing Services, Ltd. (NATO/AGARD Report No. CP-415){DTIC No. AD-A185-128}.

The objectives of this field study were to evaluate the performance capabilities and sleep patterns of USAF FB-111A fighter aircraft crews using temazepam as a sleep aid during premission crewrest. Seven 2-

man aircrews participated in two data collection periods. During each period, a crew flew a pair of extended duration nighttime missions, one each on consecutive nights. The mission on the first night was an actual FB-111A training mission. The mission the subsequent night was flown in a high-fidelity simulator. Crews were administered 30 mg temazepam for the daytime crewrest (measured by wrist-activity monitors) between the other pair of missions. Sleep during daytime crewrest was of longer duration and better quality with temazepam than with placebo. Twelve hours after drug ingestion, aircrew performance of the simulator missions and selected laboratory tests was similar to that with placebo.

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554. Takeuchi, L., Davis, G. M., Pyley, M., Goode, R., and Shephard, R. J. 1985. Sleep deprivation, chronic exercise and muscular performance. **Ergonomics. 28**(3): 591-601.

Muscular performance was tested during 64-hours of sleep deprivation with and without intermittent exercise (treadmill walking at 28 percent of maximum oxygen intake). The subjects (12 males aged 22.7 ± 2.2 years) carried out a crossover trial with an 8-week interval separating the two periods of sleep deprivation. The sleep deprivation did not change the time for a 40 meter dash, isometric handgrip force or balance (stabilometer test). Vertical jump height decreased, the change being significant for simple sleep deprivation, but not for the combination of deprivation and intermittent exercise. Sleep deprivation decreased isokinetic extension force at 60 degrees/second, while intermittent walking decreased isokinetic extension force at both 60 and 180 degrees/second; however, there was no significant difference between exercise plus sleep deprivation and sleep deprivation alone at either angular velocity. We conclude that the moderate intensity of physical activity likely in industrial work has little influence upon human performance under conditions of sleep deprivation.

555. Technical Cooperation Program Subcommittee on Non-Atomic Military Research and Development, Subgroup U Action Group U-1. 1974. **Human performance and military capability in continuous operations.** Bethesda, MD: The Technical Cooperation Program.

From 1969-1974, Action Group U-1 under the Technical Cooperation Program (TTCP) Subgroup U (Behavioral Sciences) carefully reviewed problems of defense research and technology on matters of "Human performance and military capability." More specifically, the issues of sustained performance in continuous operations wherein men must maintain a 24-hour readiness for extended periods of days, weeks, or months, be they soldiers, sailors, marines, or airmen were reviewed. Five annual workshops, continuous communication among scientific and staff officer participants from Australia, Canada, the United Kingdom, and the United States, and intensive efforts of task groups from among those participants resulted in the following products documented and reviewed in this report: (1) A user-oriented summary of the scientific literature on performance effects of work-rest schedules and sleep loss germane to continuous operations; (2) a summary of research topics recommended for future support in defense programs to further bridge the gap in our knowledge about sustained performance in military operations; (3) a summary of methodological strategies and technologies appropriate for field validation studies of workload, work schedule, and sleep loss effects on sustained performance; and, (4) a summary of strategies and procedures for translating and implementing the products of performance research into information useful to the field commander and his staff for the planning and conduct of continuous operations.

556. Technical Cooperation Program Subcommittee on Non-atomic Military Research and Development, Subgroup U Action Group UAG-4. 1979. **Performance limits in extended military operations.** Bethesda, MD: The Technical Cooperation Program.

This report is broken into three parts. Part I is an evaluation of information summarized in Action Group U-1 final report, **Human performance and military capability in continuous operations** (see entry number 555) and a report of the conclusions. Part II is the proceedings of a conference held in 1978 to determine the feasibility of developing a predictive model for sustained human performance in continuous operations and developing an outline of the research strategies for developing the model. Part III is the minutes of the executive meeting of subgroup UAG-4 and contains recommendations to further the effort of the Subgroup U.

557. Tepas, D. I., Armstrong, D. R., Carlson, M. L., Duchon, J. C., Gersten, A., and Lezotte, D. V. 1985. Changing industry to continuous operations: Different strokes for different plants. **Behavior research methods, instruments, and computers. 17**(6): 670-676.

A survey method was designed to evaluate the effect of shift work on industrial workers and to develop recommendations for 7-day around-the-clock production work systems. A work-sleep survey then was offered to 2,340 hourly and salaried workers at 4 plants. Each plant was in the rubber and plastic products industry and on 5-day around-the-clock operations using permanent shifts. Of the total workers, 90.38 percent responded to the survey. The results agree with the findings of a previous survey, offered to workers through their unions, using many of the same survey items. The plants were found to differ in worker demographics, habits, and preferences. This survey method is helpful as an aid for the design and evaluation of shift-work systems tailored to specific worker and plant requirements.

558. Tepas, D., and Mahan, R. 1989. The many meanings of sleep. **Work and stress. 3**(1): 93-102.

Reductions in sleep are concomitant with night shift work. Data presented show these robust differences in sleep are present even in experienced permanent night shift workers who most prefer to work nights. A model is presented which relates these reductions to chronic sleep deprivation. This, in turn, may be associated with performance decrements, and lead to accidents and illness. Better work schedule selection, worker training programs, and preventive medical action are unproven but promising approaches to overturning this model.

559. Tharion, W. J., Rauch, T. M., Munro, I., Lussier, A. R., Banderet, L. E., and Shukitt, B. 1986. **Psychological factors which limit the endurance capabilities of armor crews operating in a simulated NBC environment.** Natick, MA: U.S Army Research Institute of Environmental Medicine. (USARIEM Technical Report No. T14-85) {DTIC No. AD-174-273}.

Factors which limit the performance capabilities of sustained armor operations in simulated conventional and chemical warfare environments were studied. In the simulated chemical warfare environment, extreme symptom and mood changes resulted in medical casualties, combat ineffectiveness, and early termination of all testing. Significant personality differences existed between casualties and survivors. The majority of casualties voluntarily terminated operational duties because of intense symptoms associated with wearing the chemical protective mask and clothing system. These symptoms were manifestations of respiratory and thermal stress.

560. Tharion, W. J., Rauch, T. M., Strowman, S. R., and Shikitt, B. L. 1987. **The psychological attributes of ultramarathon runners and factors which limit endurance.** Natick, MA: U.S. Army Research Institute of Environmental Medicine. (USARIEM Technical Report No. T21-87) {DTIC No. AD-A185-015}

Psychological and training characteristics of 44 ultramarathoners competing in a 50-mile trail race were studied. These psychological and training variables were used to distinguish differences between survivors and casualties in the race and to predict race time. In addition, mood changes and runner's physical symptoms were examined to assess changes from pre- to postrace. Results show a mood profile and self-motivation scores similar to other athletic populations. Mood profile changed from pre to post race and training pace was found to be a highly significant factor in predicting finish time.

561. Torsvall, L., and Akerstedt, T. 1987. Sleepiness during day and night work: A field study of train drivers. **Abstracts -- Biological rhythms.** Stockholm, Sweden: Laboratory for Clinical Stress Research, Karolinska Institute.

The purpose of the study was to investigate the effects of night work and monotonous work tasks on wakefulness, fatigue, and well-being. Fifteen train drivers were monitored during day and night driving. This was done by portable tape recorders (Medilog) registering EEG (for subsequent power spectrum analysis), EOG (vertical, to reflect eye closure), and EKG. In regular intervals, sleepiness was rated and after each journey urine was collected for analysis of catecholamines. A before and after the journey sleep latency test was applied. Day driving did not affect any of the variables. During night driving the EEG content of alpha and theta frequencies increased sharply. Similarly, the amount of eye closure increased, heart rate decreased, and rated sleepiness increased. Sleep latency after the night journey was shortened significantly as compared to the day journey. Both noradrenaline and adrenaline were reduced during night driving. The results clearly demonstrated that night work is characterized by increased fatigue, even to the extent of short sleep episodes sometimes occurring during work. It is suggested that particular attention should be paid to work hour scheduling in occupations where high vigilance is important for safety. It also appeared the occurrence of severe fatigue varied considerably between individuals.

562. Torsvall, L., and Akerstedt, T. 1987. Sleepiness on the job: Continuously measured EEG changes in train drivers. **Electroencephalography and clinical neurophysiology. 66**: 502-511.

Eleven train drivers participated in the study during 1 night and 1 day journey (4.5 hours) over the same route. Their EEG, EOG, and ECG were recorded on portable tape recorders. The EEG records were subjected to spectral analysis (FFT) and the EOG was scored visually for slow eye movements (SEMs). The results showed that rated sleepiness increased sharply during the night journey. A similar pattern was seen for spectral power density in the alpha band, SEM and, to a lesser extent, also for power in the theta and delta bands. Heart rate was low during the entire night drive. The day journey showed low values without any trend for all variables. The intra-individual correlations were very high between rated sleepiness and, particularly, alpha and theta power density, as well as SEM. Further analyses showed that most of the night time increases in EEG/EOG parameters were confined to the six most sleepy subjects. Among these, four admitted to dozing off during the night drive and two of these four subjects failed to act on signals while exhibiting large bursts of alpha activity. It was concluded that EEG and EOG parameters closely reflect variations in sleepiness on the job and that parameters, together with self-ratings, demonstrate that severe sleepiness may occur in train drivers during night work.

563. Torsvall, L., Castenfors, K., Akerstedt, T., and Froberg, J. 1987. Sleep at sea: A diary study of the effects of unattended machinery space watch duty. **Ergonomics. 30(9)**: 1335-1340.

Forty-nine engineer officers in the Swedish merchant marine were asked to keep a sleep/wake diary during one tour of duty (1-3 months) on ocean-going container ships. Every 2-4 nights the officers had watch duty during which they were allowed to sleep, but were awakened by an automatic alarm system in the case of machinery malfunction. The diaries showed that 40 percent of all nights at sea were spent on such watch duty. Fifteen per cent of all nights were disturbed by alarms (and 13 percent for other reasons). Having watch duty, particularly with alarms, reduced ratings of sleep length (-1.5 hours), sleep quality and recuperation. The latter also was negatively affected by the frequency of watch duty. Of particular interest was the fact that nights on watch also were perceived as disturbed when no alarms occurred. Such nights also were characterized by a higher level of uneasiness. It was concluded that the watch duty system significantly affected sleep and well-being, and that these effects appeared irrespective of whether any alarms occurred. The latter was interpreted as an effect of apprehension stress.

564. TRADOC Combined Arms Test Activity. 1986. **Phase IIA (company-battalion level) combined arms in a nuclear and chemical environment force development test and experimentation (Phase IIA CANE FDTE).** Fort Hood, TX: U.S. Army Training and Doctrine Command Combined Arms Test Activity. (TCATA Technical Report No. FT453A) {DTIC No. AD-BO98-895L}. Distribution of abstract and document limited to U.S. Government agencies.

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565. U.S. Army Armor and Engineer Board. 1986. **Extended operations in contaminated areas.** Fort Knox, KY: U.S. Army Armor Center. (USACACDA Field Circular 50-12).

This report provides training, leadership, and tactical guidance for conducting combat operations where chemical agents are a threat. Topics include enemy capabilities; contamination duration; agent persistency; agent symptoms; coping strategies; work rate time charts for protective clothing; collective survival measures for crews, squads, and platoons; sample acclimation program; company unit guidance for wearing protective equipment, unmasking and crossing contaminated areas; and problems encountered in close combat and combat support.

566. U.S. Army Field Artillery Board. 1985. **Phase I, 155mm howitzer section, physiological and psychological effects of NBC and extended operations on combined arms crews (P2NBC2).** Fort Sill, OK: U.S. Army Field Artillery Board. (Final Report, Project No. 85-CEP-260).

The U.S. Army Field Artillery Board tested task performance and thermal response of a 155mm self-propelled howitzer section under normal conditions and during extended operations (up to 24 hours) under realistic simulated NBC conditions. Human endurance levels were recorded and the physiological responses of personnel to the stresses of extended NBC operations were measured. Psychological responses were assessed through task performance and administration of minimally intrusive test instruments. Observations on the tests and suggested improvements are included. Further information is available in reports written by the various individual test teams involved.

567. U.S. Army Soldier Support Center. 1983. **Management of stress in Army operations.** Washington, DC: Headquarters, Department of the Army. (Field manual No. 26-2). Distribution of document limited to U.S. Government agencies.

This manual informs leaders that stress is a command problem. It makes commanders aware that understanding and dealing with stress on and off the battlefield can be very beneficial to individuals and the unit as a whole, and stress can be not only tolerated but managed. The chapters in this manual include discussions on such topics as the effects of stress in the soldier; the response stages of stress, and differences among individuals; stress as a military problem, especially in combat and continuous operations; stress in military life; stress recognition and coping techniques; and stress management for leaders. Each chapter contains its own summary. Appendixes include lists of signs of stress, their definitions and examples; and particular coping techniques for the individual and for commanders to use with the unit.

568. Utterback, R. A., and Ludwig, G. D. 1949. **A comparative study of schedules for standing watches abroad submarines based on body temperature cycles.** Bethesda, MD: Naval Medical Research Institute. (NMRI Technical Report No. 1) {DTIC No. AD-667-707}.

A new watch schedule is proposed for use on naval vessels at sea. This schedule required of each person in a section in a 24-hour cycle, three watches of 3-, 3-, and 2-hour durations with periods of 2- or 3-hours break in between and a continuous period of off duty of 10 to 12 hours. This schedule has been compared with the present system of 4-hour watches separated by eight hours off duty (4 on, 8 off in a 24-hour period). Comparisons have been made during two short cruises and during two long simulated war patrols. The rapidity with which the men adapted to the schedules was determined by means of oral temperature cycles which also afford an indication of the alertness and efficiency of men on watch.

On the basis of the body temperature studies, the proposed schedule was found to be a definite improvement over the present one. Subjective reactions to the proposed schedule were obtained from the men, and suggestions for overcoming the chief sources of complaints are made.

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569. Verhaegen, P., Maasen, A., and Meers, M. 1981. Health problems in shift workers. In: Johnson, L. C., Tepas, D. I., Colquhoun, W. P., and Colligan, M. J., eds. **The twenty-four hour workday: Proceedings of a symposium on variations in work-sleep schedules, pp. 335-346. Cincinnati, OH:** U.S. Department of Health and Human Services. {DTIC No. AD-A097-589}.

This paper was written as part of an ongoing longitudinal study of the health of shiftworkers in a wire mill. The 104 male subjects were selected randomly out of the total work force. They were extensively interviewed and all were asked to fill out questionnaires, rating themselves on various scales. The subjects were examined at 6 months, 4 years 4 months, and 7 years. Attention was paid not only to the health complaints of the workers still at the mill, but also to the reasons (health or other) why the 53 that quit the mill did so. This study was based on "subjective" data as reported from the individuals' questionnaires.

570. Vidacek, S., Kaliterna, L., Radosevic-Vidacek, B., and Folkard, S. 1988. Personality differences in the phase of circadian rhythms: A comparison of morningness and extraversion. **Ergonomics. 31**(6): 873-888.

Individual differences in the phase of circadian (around 24 hours) rhythms are thought to be important in determining adjustment to shift work and rapid time-zone transitions. Attempts to predict such phase differences on the basis of paper and pencil "personality" tests concentrated on extraversion and "morningness," of which Kerkhof, in a 1985 review of this literature, concluded "morningness" was the more important. However, the literature on which this conclusion was based suffers from a number of problems. The present study attempted to overcome these problems by examining the trends over a complete 24 hour-cycle for a range of performance and psychophysiological measures in students with extreme scores for both extraversion and "morningness." In general, the results support Kerkhof's conclusion. However, reliable phase differences associated with morningness were confined to subjective ratings of alertness, oral temperature, and in combination with extraversion, choice reaction time. Two alternative interpretations of this pattern of results are considered, and their practical implications discussed.

571. Von Restorff, W., Kleinhanss, G., Schadd, G., and Gorges, W. 1989. Combined work stresses: Effect of reduced air renewal on psychological performance during 72h sustained operations. **Work and stress. 3**(1): 15-20.

Human tolerance limits for sustained operations under the combined stress of stale air and sleep loss were studied in two groups of 10 male volunteers over a 72 hour-period, with only 1 hour of sleep permitted after 32, 48, and 60 hours. The experiment investigated whether such sustained performance might be additionally influenced by mild hypoxia (15 volume percent O_2) together with correspondingly increased carbon dioxide levels (5 volume percent).

Performance on various psychological tests showed the expected decrease with increasing duration of sleep loss. However, there were no clear cut differences in performance between the control and hypoxia groups. There were, however, more pronounced decreases with time in either group in the more complex tasks as compared to simple reaction time and vigilance tasks. Short-term memory improved probably due to learning. The missing effect of hypoxia could be attributed to a hyperventilation response in the experimental subjects and an increase in cerebral blood flow initiated by the hypercapnia.

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572. Warm, J. S. 1984. **Sustained attention in human performance.** New York: John Wiley and Sons.

The first chapter in this book gives a short sketch of the history of vigilance and an outline of the book's structure, which is to progress from laboratory-based studies and theory toward applied research and practicalities --- applied research emphatically included. Chapters include "The psychobiology of sustained attention," "Environmental stressors," "Theories of vigilance," "Vigilance and inspection," "Human engineering: The control of vigilance," and others. Much of the material printed has direct relevance to sustained performance studies.

573. Webb, W. B., ed. 1982. **Biological rhythms, sleep, and performance.** New York: John Wiley and Sons.

This book contains chapters covering three largely independent areas: Performance measurement, biological rhythms, and sleep with emphasis on performance variations resulting from sleep variations. The chapters cover topics such as the analytical methods of the biological rhythm research area, performance measurement in a biological rhythm framework, a review of sleep with a biological rhythm perspective, performance changes and sleep deprivation, performance effects and sleep structure, shift work/sleep schedules, performance during sleep, and ultraradian (less than 24 hours) rhythms.

574. Webb, W. B., and Agnew, H. W. 1973. Effects on performance of high and low energy expenditure during sleep deprivation. **Perceptual and motor skills.** 37: 511-514.

Eight subjects were sleep deprived for 2 nights, using two different deprivation conditions. In the bed-rest condition subjects rested in bed while being sleep deprived. In the exercise conditions, subjects remained active and exercised for 15 minutes on an exercise bicycle every other hour. Performance measures were obtained before, during, and after sleep deprivation. The two conditions did not affect sleep differentially during recovery nor did they have differential effects on performance during deprivation. From these results, the authors infer that in operational settings it is unlikely that performance decrements during sleep deprivation can be offset by having personnel reduce their activity level.

575. Webb, W. B., and Levy, C. M. 1984. Effects of spaced and repeated total sleep deprivation. **Ergonomics.** 27(1): 45-58.

Six young adult males were sleep deprived for 2 nights on five successive occasions at 3-week intervals. During the deprivation period, they completed subjective ratings and performed on an extensive battery of tasks. Subjective measures and vigilance tasks showed substantial deprivation effects; the cognitively-demanding tasks were less affected. Where repetition of sessions resulted in changes, relative to sleep deprivation the effects were those of "sensitization" rather than "immunization."

576. Welford, A. T. 1965. Fatigue and monotony. In: Edholm, O. G., and Bacharach, A. L., eds. **The physiology of human survival.** New York: Academic Press.

This chapter examines the terms "fatigue" and "monotony" with the classical type of experiment on neuromuscular fatigue and then examines the more complex problem of mental fatigue. First considerations are the peripheral and central limitations of neuromuscular fatigue. The phenomena of mental fatigue is examined with regard to sensory changes, slowing of performance, performance irregularity, performance disorganization, temporary improvement of performance at onset of fatigue, and transfer of reduction of, and specificity of fatigue effects. Some explanatory models of mental fatigue are given. Findings in research and theories of vigilance are discussed with regard to vigilance and fatigue. Examples of the effects of fatigue outside the laboratory setting are given.

577. Wilkinson, R. T. 1964. Effects of up to 60 hours sleep deprivation on different types of work. **Ergonomics**. 7: 175-186.

The effects of sleep deprivation upon performance vary widely with the nature of the work being carried out. In the present study, impairment was almost complete towards the end of 20 minutes repetitive serial responding and 30 minutes inspection work (vigilance). On the other hand, tactical decision making of a complex, but absorbing and realistic nature was completely unaffected by the same degree of stress even towards the end of 1 hour's continuous work. What are the features of a task which determine whether its performance will be impaired by loss of sleep or not? Two are suggested. A task will be vulnerable to sleep deprivation (1) as it is complex, and (2) as it is lacking in interest, incentive and reward. Of the two factors, that of incentive may be the more influential, such that a highly complex task may be little affected by sleep deprivation if it is complex in an interesting or rewarding way.

578. Williams, H. L., Kearney, O. F., and Lubin, A. 1965. Signal uncertainty and sleep loss. **Journal of experimental psychology**. 69(4): 401-407.

During a 3-5 day baseline period, 2 days of sleep loss, and 3 days of recovery, 52 subjects performed three visual vigilance tasks, of 10 minutes each ranging in signal uncertainty from complete redundancy of .84 bit per second. The major effect of uncertainty was to cause errors of omission which increased with sleep loss. The interaction between signal uncertainty and sleep loss was significant. Task duration (of 10 minutes) caused no impairment during the baseline and recovery phases, but during sleep loss, errors of omission rose sharply on the last 3 minutes of each task. There was no significant interaction between uncertainty and task duration. Decrement was considerably greater for subjects working alone than for subjects working in a group. Oral temperature had no consistent relation to errors of omission or to sleep loss.

579. Williams, H. L., Lubin, A., and Goodnow, J. J. 1959. Impaired performance with acute sleep loss. **Psychological monographs,** 73(14). (STK)

With 49 subjects, deprived of sleep for 72-98 hours, performance deteriorated on a variety of tasks, an unusual result in studies of sleep loss. Deficit took the form of lapses (brief periods of no response accompanied by extreme drowsiness and a decline in EEG alpha amplitude). Four features of lapses were noted: 1) They occur in other conditions such as fatigue and hypoxia and appear to characterize impairment in general; 2) they increase in both frequency and duration as sleep loss progresses; 3) they are affected strongly by stimulus monotony; and 4) their specific effect on performance varies with the properties of the task. In subject paced tasks, for example, speed is the critical measure; in experimenter paced tasks, errors are critical. To identify the sensitive aspect of performance becomes the crucial problem. This classic article gave rise to references to the now well-known Walter Reed lapse hypothesis.

580. Wing, J. F. 1965. **A review of the effects of high ambient temperature on mental performance.** Wright-Patterson Air Force Base, OH: U.S. Air Force Aerospace Medical Research Laboratory. (USAF AMRL Technical Report No. 65-102){DTIC No. AD-624-144}.

Fifteen experiments done in various laboratories assessed the effects of high thermal stress on mental performance. These experiments represent different combinations of exposure time and effective temperature.

These studies were reviewed, and the upper thermal limit for unimpaired mental performance was found to vary systematically with exposure duration. Specifically, the lowest test temperatures yielding statistically-reliable decrements in mental performance decline exponentially as exposure durations are increased up to 4 hours. When this temperature-duration curve for mental performance is compared with physiological tolerance curves, it is found to lie well below them at every point in time.

581. Wyatt, S., Langdon, J. N., and Stock, F. G. 1937. Fatigue and boredom in repetitive work. In: Rodger, A., ed. **A borstal experiment in vocational guidance**. London: His Majesty's Stationery Office.

This chapter on fatigue and boredom collects and analyzes information on the nature, causes, and prevalence of boredom and discontent among operatives employed on simple types of repetitive work. Since boredom and discontent are personal experiences which cannot be directly observed it is necessary to induce individuals to describe their thoughts and feelings. In the inquiry of workers at four factories across England, free expression of opinion and response to questions were used to gather the information. Discussion on the results obtained include topics such as symptoms of boredom for the different factory groups, the type of work causing boredom, characteristics of the individual, rate of working -- also as affected by music, the different attitudes towards work, and important factors i.e., wages, that have an effect on job satisfaction. A summary of the results and discussion are included.

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582. Zinchenko, V. P., Leonova, A. B., Strelkov, and Yu, K. 1984. **The psychometrics of fatigue.** Philadelphia: Taylor and Francis.

This book analyzes data obtained during work on the development of a system of automated tests for assessing the functional state of automatic control system operators. Since information processes play an important part in their work (detection, information search and storage, operative memorizing, data preparation, and decision making), the authors evaluated the performance of various operations involved in the receptions and processing of incoming information.

Fatigue may be applied to the subjective feeling of tiredness after a hard day's work, a sleepless night, or being subjected to unusual stress. Fatigue also could relate to changes in indices of physiological functions, accompanying a change in functional state; or it may define specific alterations in working capacity. The research cited here expresses the third of these definitions more fully.

The authors studied changes in working capacity of subjects at the end of the working day, when changes in performance cannot be attributed to the direct effect so "fatigue," but may also reflect job monotony, changes in the motivation sphere, and the influence of factors such as diurnal rhythm. For practical purposes, the primary consideration was to evaluate the subject's fitness to continue at his work, of fatigue can be interpreted more widely. "Influence of the fatigue factor" and "morning to evening changes in performance indixes" are synonymous.

Reference index for two-volume bibliography

The body of this bibliography, in two volumes, contains a listing of the references in alphabetical order by the last name of the first author of each reference. The following index contains a listing of the references by number, 1 through 582, under categories describing the contents of each reference.

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