SPECIAL SECTION

Methodological Approaches to the Study of Sustained Work/Sustained Operations

Introduction

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The advent of a society intent upon maintaining high productivity levels 24 h per day, and on providing a variety of services around the clock, has produced occupations and circumstances requiring prolonged, continuous work periods. Night factory production lines, power plants that operate continuously, ubiquitous commercial air travel schedules, overnight mail services, nonstop radio, television, and night club entertainment programs, police, fire, and security coverage, all involve people engaged in continuous work or operations.

In the nineteenth century, work weeks were commonly 60 h long to meet high industrial and agricultural productivity goals. However, in twentieth-century Western civilization, it is conventional to work only 40 h per week, whether it be the common 8 h per day, 5 days per week, four 10-h days, or some other flexible 40-h schedule. To meet the continuous service work loads, and to maintain a 40-h work week, a variety of shift work systems have evolved to rotate workers through the jobs (Naitoh, Englund, & Ryman, 1982; Tepas, 1979; for a review, see Alluisi & Morgan, 1982). As Naitoh (1982) noted, we have exploited the darkness of night, institutionalized shift work, and evolved into a society that no longer

sleeps. Work in one form or another goes on continuously.

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 8-10-h work day. In fact, in many of these sustained work situations, the termination point for a shift is unknown. When the job requires services for such prolonged periods, the work continues and no thought is given to adding shifts. Examples of this sustained/continuous work or sustained operations include the performance of lengthy medical surgery, responding to civil emergencies/catastrophes, fighting forest fires, conducting search and rescue missions, military airlifts, field training exercises, and combat operations. Even seasonal changeovers in industry and some theatrical road shows involve sustained, continuous work.

Such activities usually require prolonging physical stamina and sustaining high levels of organizational and cognitive effectiveness. These continuous operations can be of two types: (1) *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/she will be relieved or able to rest. (2) *Sustained operations*—planned or unplanned, goal-oriented, nonstop continuous performance/operations without rest or sleep, in which the worker is expected to keep going as long as he/she can. Both have very important worker performance and behavioral implications. Either type can be applied on a successive basis with repeated episodes of sustained work experienced by the worker.

The study of worker performance in extended/sustained operations invokes eclectic methodologies drawn from those who have studied classical shift work systems and from the research on sleep deprivation. There is a rich

The articles presented here were developed from a workshop and a symposium, both 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). Both meetings were organized and cochaired by Dr. Carl E. Englund and Dr. Gerald P. Krueger. Dr. Englund's mailing address is: Environmental Physiology Department, Naval Health Research Center, P.O. Box 85122, San Diego, CA 92138-9174. Dr. Krueger's mailing address is: Division of Neuropsychiatry, Walter Reed Army Institute of Research, Washington, DC 20307.

history of studies on shift work schedules, productivity levels, the schedule preferences, amounts of rest, quality of life, and the health of workers who engage in rotating shift work systems (Alluisi & Morgan, 1982; Rentos & Shepard, 1976; Tepas, 1979; Webb, 1982). There is also a rich history of studies on sleep, sleep loss, sleep deprivation, and vigilance, with particular intent upon explaining sleep mechanisms, the impact of partial or complete sleep loss, and phenomena of chronobiology (e.g., see Kleitman, 1963; Mackie, 1977, and Webb, 1982).

Worker performance during extended and sustained working conditions is influenced by the interaction of several factors: prior rest quantity, physical fitness, endurance, work/rest cycles, environmental conditions, number of sustained episodes, time of day of performance, task type, work load, and motivation (Englund, Naitoh, Ryman, & Hodgdon, 1983). Research on sustained work performance is therefore an interdisciplinary problem. Such complexities prompted Alluisi (1969, p. 62) to declare earlier that research would have to be performed "to discover how sustained performance can be assessed."

Historically, studies of shift work and work/rest schedules have occurred when expectations of worker productivity change and health and welfare considerations become public issues (Alluisi & Morgan, 1982). Recently, renewed interest in such methodologies and their various combinations have been spurred by needs in various industrial settings, such as the nuclear power industry, certain semiautomated material production plants, the aviation industries, and, especially, military organizations charged with predicting performance expectations of personnel engaged in sustained operations, frequently for days at a time, with little or no opportunity for sleep. Prior to the studies reported here, interested researchers depended upon data and methodologies scattered through the literature in a myriad of journals, books, and technical reports, which often were unavailable or difficult to find.

The effects of sustained work and sleep loss on human performance have been studied in both laboratory and field settings over the last two decades, but the number of studies directed at sustained work/operations is relatively small. Usually, the laboratory studies consist of small *N* designs and are directed at continuous task performance, with or without sleep loss, for short (4 h) or extended (2 days) periods. Sleep-deprivation studies indicate performance decrements as a result of the duration of sleep loss. Researchers in this area tend to measure performance intermittently, and the subjects do not work continuously (Mullaney, Kripke, Fleck, & Okudaira, 1983). On the other hand, field studies are usually large-scale military operations, in which experimenters "piggyback" studies of certain factors on a nondisruptive basis. The research, laboratory or field, involves the investigation of variables contributing to performance degradation, fatigue, productivity decreases, temporal changes, biological impairments, and enhancement methods/means. (For a brief

review of earlier work and references, see Alluisi & Morgan, 1982, and Morgan, 1974).

The results of sustained work/operation studies have highlighted the complexities of human research, in particular, interaction effects over time. For example, Mullaney, Kripke, Fleck, and Okudaira (1983) reported that performance deteriorates more rapidly during continuous sustained conditions than with sleep loss alone, and in some situations may produce disturbing psychological events (Mullaney, Kripke, Fleck, & Johnson, 1983). Subjects in sustained operation studies are often unable to complete the investigation (Banderet, Stokes, Francesconi, Kowal, & Naitoh, 1981; Englund et al., 1983; Haslam, 1982; Mullaney, Kripke, Fleck, & Johnson, 1983); however, motivation, competition, and incentive may at times temporarily resolve this problem (Alluisi & Childs, 1967; Englund et al., 1983; Haslam, 1983).

Time-of-day effects have been reported to be stronger than fatigue effects in sustained operations (Englund et al., 1983; Mullaney, Kripke, Fleck, & Johnson, 1983). Additionally, unique uses of computers, wherein subjects become subject-experimenters have been reported in sustained work studies (Mullaney, Kripke, Fleck, & Okudaira, 1983; Ryman, Naitoh, & Englund, 1984). New methodologies (Englund, 1981; Naitoh, Englund, Moses, & Spinweber, 1979), novel methods of data transformation (Thorne, Genser, Sing, & Hegge, 1983), and different variables (Englund et al., 1983; Thorne et al., 1983) have been identified.

The papers in this special section provide an overview of the methodologies used in current studies of sustained work/operations. Supporting data are provided to demonstrate the efficacy and validity of the techniques. The methods include work quality and completion incentives for subjects in field trials in which the length of the trial is unknown to the subjects, the use of portable physiologic recorders for ambulatory subjects, the integration of fitness evaluations into data examination, procedures for examining circadian rhythms in free-running experiments with isolated subjects, methods for studying post-sleep performance without confounding it with time and sleep structure, field test batteries sensitive to fatigue, several automated systems for simultaneously administering and measuring continuous work, and sleep-deprivation continuous work techniques effective for the older subject.

Obviously, the design of a study depends upon the particulars of the research question at hand. However, as the articles in this series portray, two major differences in sustained work/operations research methodology involve the way an investigator designs the continuous work schedule and when and how performance is sampled. Some researchers keep subjects awake for extensive periods doing things unrelated to the work of interest and only periodically require the subjects to perform tasks during which performance is measured. Others keep subjects working at assigned tasks for extended periods and sample performance periodically. Still others have subjects

work for extended periods and measure task performance continuously throughout the study.

Some of this research necessitates designs with repeated measures: But subjects who work for such extended periods usually perform better as a function of practice, even in the face of modest sleep deprivation. Thus, study designs must account for learning variables. Boredom can easily set in during such extended work periods, and thus face validity of the tasks and meaningfulness of the work are important in motivating the participants.

Many different measurement probes and experimental tasks are included in study designs. These variously purport to measure: vigilance, memory, reaction time, decision making, psychomotor and cognitive performance; psychological measures of mood, affect-activation, fatigue and sleepiness scales; and biochemical and physiological measures, levels of stress hormones, cardiovascular indices of attentiveness, and body temperature measures for circadian periodicity, etc.

The reports in this special section describe diverse contemporary methodologies use in laboratory and field research on sustained work and sustained operations. A forthcoming, second special section of *Behavior Research Methods, Instruments, & Computers* will also be dedicated to the continuation of this topic.

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