Alertness Management: Strategic Naps in Operational Settings

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Introduction

Today, 24-hour operations are necessary to meet the demands of society and the requirements of an industrialized global economy. These around-the-clock demands pose unique physiological challenges for the humans who remain central to safe and productive operations. Optimal alertness and performance are critical factors that are increasingly challenged by unusual, extended, or changing work/rest schedules. Technological advancements and automated systems can exacerbate the challenges faced by the human factor in these environments.

Shift work, transportation demands, and continuous operations engender sleep loss and circadian disruption. Both of these physiological factors can lead to increased sleepiness, decreased performance, and a reduced margin of safety. These factors can increase vulnerability to incidents and accidents in operational settings. The consequences can have both societal effects (e.g., major destructive accidents such as Three Mile Island, Exxon Valdez, Bhopal) and personal effects (e.g., an accident driving home after a night shift) (US Congress, Office of Technology Assessment 1991; National Commission on Sleep Disorders Research 1993).

Alertness management in operational settings

Alertness management strategies can minimize the adverse effects of sleep loss and circadian disruption and promote optimal alertness and performance in operational settings. Sleep and circadian physiology are complex, individuals are different, the task demands of settings are different, and schedules are extremely diverse; therefore, no single strategy will fully address the fatigue, sleepiness and performance vulnerabilities engendered by 24-hour operational demands. Rather than attempt to eliminate fatigue, it may be more useful to consider the critical factors that can promote and optimize alertness management. There are at least six critical factors that can be addressed for their role in managing fatigue in operational settings. These factors include: hours of service, scheduling, education and training, countermeasures, technology, and research. Each of these factors deserves attention to determine how scientific findings on fatigue, sleep, and circadian physiology can be incorporated and addressed in each area.

The application of 'strategic countermeasures' involves three components:

- understanding the physiological principles related to sleep and circadian rhythms;
- determining the specific alertness and performance requirements of a given operation;
- taking deliberate actions to apply the physiological principals to meet the operational requirements.

Whenever possible, deliberate actions should be part of a comprehensive plan to manage alertness and performance.

Alertness management strategies can be categorized as preventive and operational strategies (Rosekind *et al*. 1991). Preventive strategies, which are used before a duty or shift period, can address the underlying physiological mechanisms associated with sleep and circadian factors. For example, some preventive strategies might facilitate circadian adaptation prior to an altered work/rest schedule. These might include the use of bright light or melatonin to promote circadian adaptation before beginning a series of night shifts. Other preventive strategies might promote sleep quantity and quality before a period of sleep loss or disruption. Operational strategies are used during a duty or shift period to maintain performance and alertness. These strategies might include strategic caffeine consumption, physical activity, or social interaction. These strategies are intended to maintain alertness and performance during an operational requirement but may have no, or minimal, effect on underlying physiological mechanisms (i.e., sleep loss and circadian disruption). A combination of strategies may provide the greatest potential to meet the physiological challenges posed by 24-hour operational demands.

Strategic naps as an alertness management strategy

Applying the three components outlined for 'strategic countermeasures', a 'strategic nap' involves :

- understanding the physiological principles that relate to napping, including the benefits (e.g. • improved performance and alertness) and potential negative effects (e.g. sleep inertia);
- determining the operational requirement (e.g. timing of critical phases of operation);
- deliberately planning a nap of a specific duration at a specific time to promote performance and alertness during the operation.

Naps are a useful strategy that can be used in both a preventive and an operational manner. As a preventive strategy, naps can be used prophylactically to maintain alertness and performance during a subsequent period of prolonged wakefulness (Dinges *et al*. 1987; Dinges, *et al.* 1988). A nap can also be used to reduce the hours of continuous wakefulness before a shift or duty period and the total hours awake at the end of the subsequent work period. For example, a shift worker who awakens at 08.00 hours, reports to a 23.00 hours shift, and finishes the shift at 07.00 hours, is returning home in the 24th hour of wakefulness. An afternoon nap in the 15.00 hours&endash17.00 hours window of sleepiness will decrease the number of continuous hours of wakefulness to 14 (i.e., 17.00 hours-07.00 hours). Naps also can be used as an effective operational strategy. Naps used to interrupt sustained periods of wakefulness during a continuous operation can help to maintain the level of subsequent performance and alertness (Naitoh and Angus 1989; Naitoh *et al*. 1992). Therefore, a nap can be used as an alertness management strategy during operations, such as in shift work and transportation environments.

Beneficial effects of naps

Naps can maintain or improve subsequent performance, physiological and subjective alertness, and mood. Naps can have adverse effects on these factors immediately upon awakening and these will be discussed in a later section on sleep inertia. This initial discussion will focus on nap effects that occur 30 min. or longer after awakening.

Generally, studies have demonstrated that naps maintain performance compared to baseline conditions or improve performance compared to conditions of prolonged wakefulness without naps (e.g. Nonnet *et al*. 1995; Dinges 1989; Dinges et al. 1988; Gillberg 1984; Nicholson *et al*. 1985; Taub 1977). Orne (Dinges, *et al*. 1987) has suggested that 'prophylactic napping,' which is essentially a preventive strategy taken prior to a period of sustained wakefulness, helps to maintain performance and alertness by reducing or delaying the expected decrement. Others have demonstrated that naps taken during periods of sustained wakefulness (an operational strategy), also can reduce or delay the expected decrement (for review, Niatoh and Angus 1989). Physiological measures of alertness (i.e. MSLT) also have demonstrated improvements following a nap (e.g. Bonnet et al. 1995; Carskadon & Dement 1986; Gillberg 1984). Generally, both subjective alertness and mood ratings are improved following naps (e.g. Dinges *et al*. 1980; Evens *et al.* 1977 Taub 1982; Taub *et al*. 1976).

Experiments have examined naps of varying lengths, from 20 min to 8 hr. (e.g Akerstedt and Gilbert 1986; (Bonnet *et al* . 1995; Dinges *et al* 1987; Dinges, *et al*. 1988; Stampi *et al*. 1990; Haslam 1984). Generally, there appears to be a relative dose-dependent effect: more sleep is associated with greater improvement. For example, Bonnet *et al* (1995) recently showed that an 8 hr "nap" showed more improvement in performance and physiological alertness than a 2 or 4 hr. nap . In fact, there was no significant difference in the effects of the 2 and 4 hr. nap conditions and these were combined for analysis. However, some studies suggest that shorter naps can be more effective than longer ones or show no significant differences in performance (e.g., Stampi *et al.* 1990; Haslam 1984) This issue is made complex in that the length and subsequent effects of a nap are related to the circadian timing of the nap and the infrastructure of sleep stages (to be addressed later).

An important operational consideration is the duration of the beneficial effects obtained from a nap. Studies suggest that a nap can maintain or improve subsequent performance and physiological alertness from 2 to 12 hr. following the nap. For example, Dinges *et al*. (1988) found a beneficial effect on performance 10 hr. after a 2-hr. nap, while Gillberg (1984) found improvement 10 hr. after a 1-hr. nap. Carskadon and Dement (1986) found improved physiological alertness on the MSLT up to 6 hr. after 45-min. naps.

Potential negative effects of naps

There are two potential negative effects of naps that should be considered prior to operational use. The first is sleep inertia, the grogginess, disorientation, and sleepiness that can accompany awakening from deep sleep. Sleep inertia can be associated with an initial performance decrement immediately upon awakening from a nap. Estimates on the duration of sleep inertia effects vary from a few minutes to 35 minutes, though most negative residual effects appear to dissipate in about 10-15 minutes (Akerstedt et al. 1989; Dinges 1989). Sleep inertia is affected by a variety of factors and therefore, specific predictions of its duration or severity can sometimes be difficult. However, two factors seem most related to the severity of effects: duration of deep sleep and circadian time of nap (Akerstedt and Gillberg 1979; Dinges et al. 1987; Dinges et al. 1985; Langdon and Hartman 1961). Similar to effects found in nocturnal awakenings, the sleep stage (NREM 3 & 4) and duration of SWS will affect subsequent sleep inertia. These can be affected by the circadian timing of the nap and the homeostatic drive.

Sleep inertia is a consideration when naps are used in an operational setting. This factor should be considered if an operator is likely to have a nap interrupted by an emergency requiring a quick response with a high level of performance. However, the potential for such an emergency response must be weighed in relation to the potential benefits of improved alertness and performance following a nap during regular operations and the related increase in the safety margin.

A second potential negative consequence of naps is the effect on subsequent sleep periods. A long nap, at certain times of the day, can disrupt the quantity and quality of later sleep periods (Akerstedt et al. 1989; Dinges 1989). The disturbance could affect both the duration of the sleep period and its infrastructure. While the nap can improve waking alertness and performance, it might increase subsequent sleep loss by disrupting a later sleep period.

No alertness management strategy will address all of the sleepiness and performance decrements associated with operational sleep loss and circadian disruption. It is also clear that each strategy will present both positive and potentially negative consequences that must be weighed prior to implementation. This reinforces the idea that combining strategies provides the best way to optimize operational performance and alertness.

Strategic naps in an operational setting

The following study is described to demonstrate the effectiveness of a planned nap in maintaining alertness and performance during regular operations. Long-haul flight operations can involve multiple time-zone changes, long duty periods, and can engender sleep loss and circadian disruption. Anecdotal reports, logbook studies, and confidential incident reports to the National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System clearly demonstrate that as a consequence, flight crews can experience spontaneous and unplanned sleep episodes. A NASA/Federal Aviation Administration (FAA) study examined the effectiveness of a planned in-flight nap to maintain performance and alertness in long-haul flight operations (Rosekind et al. 1994).

This study involved non-augmented three-person, 747-200 aircraft flying regularly scheduled transpacific flights. The trip schedule involved 8 flight legs in 12 days. Each flight was about 9 hours in duration with an approximately 25-hour layover between flights. The volunteer flight crewmembers were randomly divided into two groups: Rest Group and No-Rest Group. Pilots in the Rest Group were provided a 40-min., planned, in-flight nap opportunity during cruise over water. The 40-min. nap duration was designed to minimize the opportunity for the occurrence of SWS and its duration. One pilot rested while the other two crewmembers maintained the flight. The nap opportunity was spent in the cockpit seat. The No-Rest Group had a 40-minute control period identified during cruise, during which they were instructed to maintain their usual flight activities. Both groups were evaluated with the same measures. Prior to, during, and after the trip schedule, flight crewmembers completed a daily logbook and wore an actigraph to estimate 24-hour rest/activity patterns. Two NASA researchers accompanied the crews during the four middle legs of the trip schedule for intensive monitoring. This involved continuous ambulatory physiological monitoring of brain (EEG) and eye (EOG) activity and vigilance performance during flight.

On 93% of the nap opportunities, Rest Group crewmembers were able to sleep. On average, they fell asleep in 5.6 minutes and slept for 25.8 minutes. To determine the effects of this brief nap, subsequent performance and physiological sleepiness was compared between groups. The No-Rest Group demonstrated reduced performance on night flights compared to days, at the end of flights compared to the beginning, and after multiple flight legs. The Rest Group, however, maintained consistent performance night and day, at the end of flights, and after multiple flight legs. The Rest Group demonstrated vigilance performance improvements from 16% in median reaction time to 34% in lapses compared to the No-Rest Group. Physiological sleepiness was examined by analyzing changes in EEG (alpha and theta activity) and EOG (SEMs) during the last 90 minutes of flight, through descent and landing (Torsvall and Akerstedt 1988; Torsvall et al. 1989). The total number of microevents associated with physiological sleepiness that occurred in the No-Rest Group (9 Ss) was 120, including 22 during the last 30 min. of flight (descent and landing phase). The total number for the Rest Group (12 Ss) was 34 microevents, with none occurring in the last 30 min. With appropriate statistical transformation, microevents in the No-Rest Group occurred at a rate twice that of the Rest Group (p=0.02). The brief, planned, in-flight nap obtained by the Rest Group was associated with better subsequent performance and physiological alertness compared to the No-Rest Group. Specific procedural and safety guidelines were utilized in the study to facilitate operational implementation. For example, a 20-min. period was allowed after awakening from the nap to examine potential inertia effects. Partially as a result of this study, the FAA convened an aviation industry/government working group to draft advisory material to sanction controlled rest on the flight deck. Several non-U.S. air carriers have already successfully implemented programs for controlled rest on the flight deck.

This study also emphasizes the need for empirical evaluation of potential alertness management strategies in operational settings. While anecdotal reports suggest that in-flight rest is used to maintain alertness and performance by flight crews, it is not currently sanctioned under Federal Aviation Regulations. It was critical to provide empirical data obtained during usual operations before regulatory action would be considered.

Implementation in operational settings

The following factors should be considered before implementing naps or other alertness management strategies in real-world operational settings:

- An identifiable benefit: an alertness management strategy should provide a clear and identifiable benefit to the human operator and the operational environment (e.g., increased safety margin). It should minimize some adverse consequence or promote a particular positive outcome;
- Opportunity: an appropriate opportunity for implementation should be identified. In some operational circumstances it may not be appropriate to consider a certain strategy (e.g., napping during a shift with high work demand or potential for emergency);
- Corporate climate/culture: some strategies may be explicitly or implicitly supported, while others are actively suppressed;
- Operational demands: the specific work demands and circumstances of a particular work environment may exclude some potential strategies;
- Safeguards: alertness management strategies are intended to promote safety and productivity.
- Specific safeguards should be employed to ensure that strategies do not negatively affect the safety margin.

Other considerations

As attention to issues of work hours, sleepiness, and accidents increases, more approaches to address the issues will emerge. Therefore, it will be critical that empirical evaluations be used to demonstrate a quantifiable positive effect of proposed alertness management strategies. Empirical data will support the implementation of approaches that show a worthwhile effect and will expose ineffectual strategies. An important aspect of these evaluations is a demonstration of effectiveness in actual operational settings. This challenges researchers to take significant and provocative laboratory findings and translate them to the complexity of real-world demands. The premature application of strategies that are eventually determined to be ineffective may impede the implementation of future approaches.

Combined strategies should be evaluated to determine the potential emergent effects of combination. For example, a comprehensive alertness management approach might utilize bright light or melatonin to facilitate circadian adaptation, strategic caffeine consumption during a window of circadian sleepiness, and a nap. Guidelines for implementing strategies in a particular environment should be developed and clearly stated.

Defining 'safety' and establishing what constitutes a 'significant performance decrement' are extremely difficult but important tasks. These delimitations are essential to determining the effects of work hours, sleepiness, and performance degradation on operational incidents and accidents. In turn, evaluating the effectiveness of alertness strategies in attenuating these effects relies on the quantitative definition and assessment of the effects. Clearly, these can change with the specifics of a work setting, but this area remains difficult to quantify.

Finally, education and training programs provide crucial support to all of these activities (e.g. Rosekind et al. 1995) individuals involved in all aspects of 24-hour operations must be informed of the fatigue factors that pose challenges to human physiology . This includes understanding potential strategies to minimize adverse effects and to promote optimal alertness and performance during operations. This information should be provided to operators, schedulers, regulatory agencies, accident investigation personnel, and others.

The physiological and performance capabilities of human operators remain critical to safety, performance, and productivity in 24-hr operational settings

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