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Effects of Napping on ATC Night-shift Performance

An experimental study of the effects of planned napping by U.S. air traffic controllers during simulated work on a night shift found significant benefits, including enhanced ability to complete tasks and greater vigilance. Whether they had a 45-minute nap or a 120-minute nap, however, all controllers found arising from sleep moderately difficult and reported low-to-moderate feelings of being rested.

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Sleepiness on the first night shift of a work schedule — 2300–0700 — is common among shift workers when their circadian rhythms are day-oriented.[1,2] Effective countermeasures for sleepiness are important for employees in a safety-critical job such as the U.S. Federal Aviation Administration's (FAA) air traffic control specialist (ATCS). An experimental study of 65 air traffic controllers employed by FAA and the U.S. Army suggests that naps taken during the night shift could be useful as a countermeasure to performance decrement and sleepiness on the night shift.

The shift schedules worked by ATCSs often minimize employees' exposure to the night shift.[3] Since ATCSs generally are scheduled for only one night shift or two night shifts per work week, it is undesirable to adapt their circadian rhythms to a night shift. They generally work only one night shift or two night shifts consecutively. Thus, a circadian-adaptation strategy of adapting the human body's biological clock to a night orientation is not practical for controllers because of the time required to reset the clock to a night orientation and return to a day orientation. Therefore, a coping strategy such as scheduled napping was a more reasonable possibility as a sleepiness countermeasure.

FAA's Miami (Florida, U.S.) Air Route Traffic Control Center (ARTCC) asked the Human Factors Research Laboratory at the FAA Civil Aeromedical Institute (CAMI; Oklahoma City, Oklahoma, U.S.) to investigate sleepiness on the night shift. The Miami ARTCC specifically requested information about the possibility of using a scheduled nap as a method to reduce sleepiness and maintain alertness during this shift.

Researchers at CAMI and the U.S. Army Aeromedical Research Laboratory (USAARL; Fort Rucker, Alabama, U.S.) collaborated to investigate the effects of napping on the night shift. The purpose of the study was to determine the effect of naps taken during a night shift on sleepiness and performance after awakening and throughout the duty hours following the nap. Issues related to sleep duration and sleep inertia (the decrease in performance shortly after awakening) were investigated. The researchers examined the patterns of performance degradation and the subjective measures of mood, sleep quality and sleepiness as a function of napping condition and time-on-task during the night shift.

The hypothesis was that allowing a nap during the work shift may provide the following benefits:

- Improve alertness and maintain performance;
- Strengthen the normal rise and fall of the core-body-temperature curve;
- Provide sleep that could maintain stability in the sleep/wake cycle; and,
- Decrease the amount of unscheduled napping by workers who have difficulty staying awake, thus enhancing safety during the shift.

The CAMI/USAARL study examined the effects of two different nap lengths scheduled before and during the approximate circadian trough on the ability of both male controllers and female controllers to maintain alertness and performance levels during a night shift.

The following research questions were addressed:

- Does a nap during a night shift decrease subsequent sleepiness and maintain performance during the remainder of the shift when compared with alertness and performance without a nap?
- Do the effects of a 45-minute nap differ from the effects of a 120-minute nap on alertness and performance?
- Are there gender differences in response to a nap during the night shift?

The controllers were assigned randomly to one of three night-shift napping conditions: a long nap of 120 minutes, a short nap of 45 minutes, and no nap. The controllers participated in a four-day study during which they worked three morning shifts (0700–1500) followed by a rapid rotation to one night shift. They completed three 1.5-hour test sessions — one session before the nap and two sessions after the nap — during the night shift. Each session involved two computer-based tasks relevant to air traffic control (ATC): the Air Traffic Scenarios Test (ATST), a high-workload task developed for selection of ATCSs; and a modified Bakan test, a low-workload vigilance task (Table 1, page 3).[4] Appendix A (page 16) describes the statistical research design.

As subjective measures, the Stanford Sleepiness Scale (SSS)[5] and the Positive and Negative Affect Schedule (PANAS)[6] were used to assess sleepiness and mood at various times throughout the study. The SSS was composed of seven statements ranging from "feeling active and vital; wide awake" to "almost in reverie; sleep onset soon; losing struggle to remain awake." The PANAS was composed of 20 adjectives (10 representing positive affect [emotions/feelings] and 10 representing negative affect) and a five-point scale ranging from "very slightly or not at all" to "extremely." A four-item sleep-quality questionnaire also was used to assess difficulty falling asleep, depth of sleep, difficulty arising from sleep and level of restedness yielding sleep-quality ratings (SQRs).[7]

The subjective measures were recorded in daily logbooks. In addition, the logbooks were used to record self-reports of sleep times, awakenings, physical symptoms, meals, beverages, activities and comments. The daily logbook was modified from logbooks developed by the U.S. National Aeronautics and Space Administration (NASA).[8]

The controllers rated sleep quality subjectively upon arising each day and upon arising from the nap. The PANAS was administered upon arising, at the beginning of the workday, at the end of the workday and at bedtime. The SSS was administered during each workday and before and after each test-battery session on the night shift.

All data were analyzed with statistical tests discussed in Appendix A (page 16). Both cognitive-performance measures and subjective measures of sleepiness supported the use of naps during the night shift. Both the long nap of 120 minutes and the short nap of 45 minutes resulted in better performance by these controllers than no nap on the Bakan test at the end of the night shift. A dose-response relationship existed such that the long nap also resulted in better performance than the short nap.[9]

Results Show Attenuated Degradation in Performance

The CAMI/USAARL study supports the work of research that indicated that a nap taken during a night-work period can alleviate fatigue.[10] Another study, however, found that a one-hour nap at 0200 during a work period had limited beneficial effects on performance compared to a no-nap condition.[11] Another study indicated that naps taken during the circadian troughs led to greater performance decrements than did naps taken during the circadian peaks.[12] This study showed post-nap sleepiness was higher and performance was lower when participants were awakened from a nap during the circadian trough as compared to a nap taken during the circadian peak. One researcher advocates prophylactic napping — that is, napping before a period of extended sleep loss — and taking naps before a person's sleep loss extends beyond 36 hours.[13] This advice is also applicable for air traffic controllers or other personnel in safety-critical jobs or aviation-related jobs. These

Table 1
CAMI/USAARL Nap Study
Night-shift Schedule for Each Nap Condition

Time	Test Session	No-nap Group1	Short-nap Group2	Long-nap Group3
2300–0030	Session 1	ATST[4]-Bakan[5]-ATST	ATST-Bakan-ATST	ATST-Bakan-ATST
0030–0100		Break	Break	Break
0100–0130		ATST	ATST	ATST
0130–0145		Break	Break	Break
0145–0300		Break	Break	Nap
0300–0345		Break	Nap	Nap
0345–0520	Session 2	ATST-Bakan-ATST	ATST-Bakan-ATST	ATST-Bakan-ATST
0520–0530		Break	Break	Break
0530–0700	Session 3	ATST-Bakan-ATST	ATST-Bakan-ATST	ATST-Bakan-ATST
0700–1200		Sleep	Sleep	Sleep
1300–1330		ATST	ATST	ATST

ATST = Air Traffic Scenarios Test
Bakan = Modified Bakan Test
CAMI = U.S. Federal Aviation Administration Civil Aeromedical Institute
USAARL = U.S. Army Aeromedical Research Laboratory

[1] The no-nap group of air traffic controllers did not take a nap during simulated work on a night shift.

[2] The short-nap group of air traffic controllers took a 45-minute nap from 0300–0345 during simulated work on a night shift.

[3] The long-nap group of air traffic controllers took a 120-minute nap from 0145–0345 during simulated work on a night shift.

[4] The Air Traffic Scenarios Test is a computer-based set of low-fidelity, high-workload problems developed for the selection of air traffic control specialists.

[5] The modified Bakan test is a computer-based, low-workload vigilance task that measures cognitive performance.

Source: U.S. Federal Aviation Administration Civil Aeromedical Institute

work forces should be advised to nap prior to arriving at work for a night shift.

The CAMI/USAARL study revealed that both a long nap of 120 minutes duration and a shorter nap of 45 minutes duration can significantly protect performance — in other words, prevent decrements in cognitive performance — during a night shift. The long nap, however, resulted in more consistent findings. The results in this study were most evident in the Bakan-test vigilance task and subjective ratings. The protection of performance on the Bakan test suggests that naps during the night shift would be useful as a countermeasure to performance decrement and sleepiness on the night shift during low-workload conditions. From these data, the two-hour nap appeared to be more protective. The findings showed the effectiveness of napping as a countermeasure to performance decrement and sleepiness on the night shift on tasks requiring skills and abilities similar to those required in safety-critical jobs such as ATCS. Future studies should examine a comparison between a prophylactic nap and a nap during the night shift.

The findings from the Bakan test revealed the anticipated performance decrement across the night shift in the no-nap group in both correct responses and false responses. The decrements in the no-nap group between the first session and last session represented a decrease of 23 percent in correct responses and an increase of 600 percent in false responses from an average of 1.5 false responses in Session 1 to 9.0 false responses in Session 3 (Figure 1, page 4). Therefore, the test was demonstrated in this study to be sensitive to sustained wakefulness and possibly the circadian trough in the performance rhythm.

The long nap provided the best protection on the Bakan test. Performance on both correct responses and false responses overall was better for the long-nap group than the no-nap group for both sessions after the nap. The long-nap group also performed better than the short-nap group for correct responses in the final session of the night shift (Figure 2, page 5). Examination of the five-minute blocks within each 30-minute session revealed no significant decrements within any of the sessions for the long-nap group. Results from the short-nap group were less robust in the protection provided.

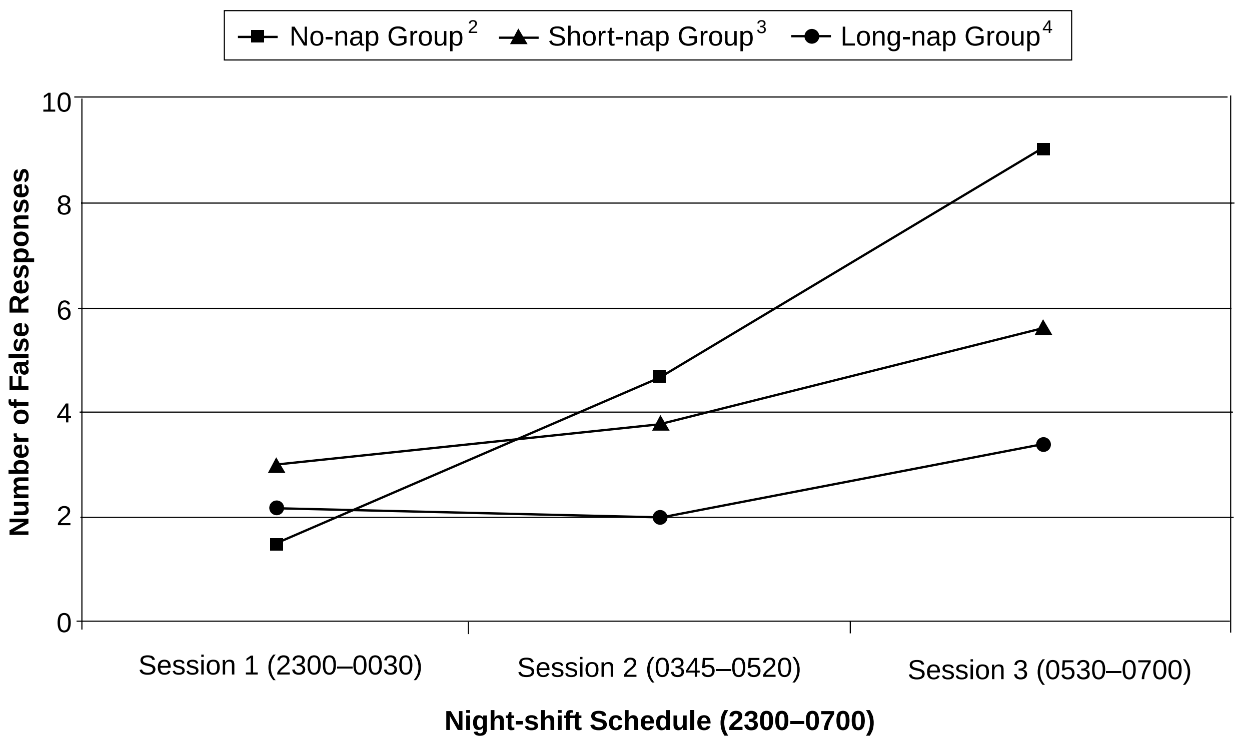
No consistent significant differences on correct responses were found between the short-nap group and the no-nap group on the session level until the end of the night shift. This difference was revealed by the analysis of blocks where the final three blocks were significantly better for the short-nap group. A significant decrement in performance in the final session of the night shift was observed for both the long nap and short nap on correct responses and for the short nap on false responses (Figure 3, page 6). Nevertheless, these decrements represented an 8 percent decrease in correct responses for both groups and less than double the number of false responses for the short-nap group when Session 1 is compared to Session 3 — from an average of 3.0 to an average of 5.6. This represented substantial protection compared to the no-nap group.

The ATST, on the other hand, was much less sensitive to differences in napping condition and even to the natural circadian trough, which would have been expected to affect all groups. Sleepiness ratings on the SSS suggested that, while sleepiness increased across the night shift for all groups, ratings were generally lower for the long-nap group and were lower for males in the short-nap group, when compared with the no-nap condition.

As with the cognitive findings on the ATST and the Bakan test, results of the subjective measures supported the use of naps during the night shift. Specifically, the analysis of sleepiness ratings across the night shift indicated that naps could result in reduced sleepiness at the end of the shift. With the exception of the females in the short-nap group, mean (M) response was 3.9 on the SSS of 1 to 7, sleepiness was rated

CAMI/USAARL Nap Study
Total False Responses on Modified Bakan Test1

(Nap Condition by Session)



[1] The modified Bakan test was a computer-based, low-workload vigilance task that measured cognitive performance. While comparing sequences of three-digit numbers every 1.5 seconds for 30 minutes, air traffic controllers pressed the space bar on a keyboard to indicate when a number was repeated in sequence. Each group's correct responses and false responses were counted for each of three test sessions during simulated work on a night shift.

[2] The no-nap group of air traffic controllers did not take a nap during simulated work on a night shift.

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Source: U.S. Federal Aviation Administration Civil Aeromedical Institute

Figure 1

similarly by each of the other groups at the beginning of the shift (M = 2.5 to 2.9).

Over the course of the night shift, however, both the males and females in the no-nap groups rated their sleepiness increasingly higher so that by the end of the night shift, the no-nap groups were significantly more sleepy than males or females in the long-nap group or males in the short-nap group. Females in the short-nap group continued to rate their sleepiness higher than controllers in the other groups throughout the entire shift.

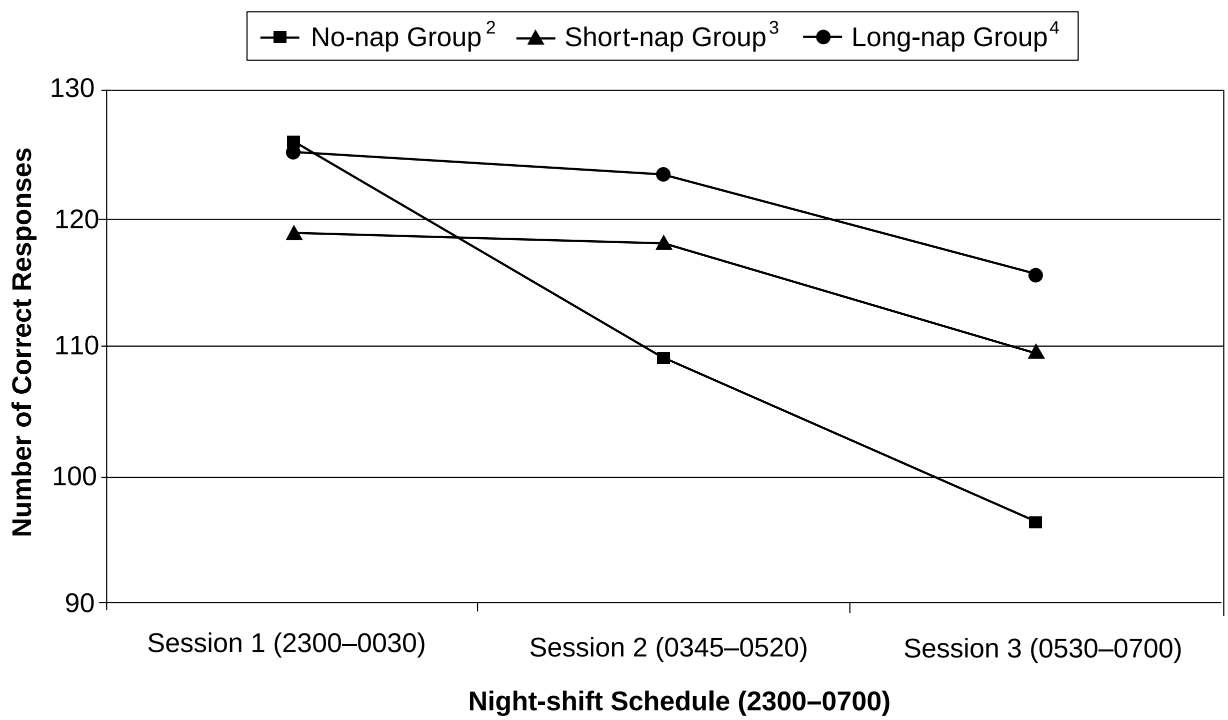
In addition to lower ratings of sleepiness as a result of napping, ratings of mood on the PANAS mood scale were not adversely or differentially affected by napping condition. Analysis of SQRs revealed that the controllers believed that naps were fairly easy to obtain. They also indicated that sleep during the naps was deep. All the controllers in the napping conditions found it moderately difficult to arise from sleep and reported low to moderate feelings of restedness, with short-nap females reporting feeling the least rested and long-nap females feeling the most rested.

Computer-based Test Scenarios Provided Synthetic ATC Work

The ATST[14] was a low-fidelity simulation of radar-based ATC used by the FAA for a couple of years in the controller-pretraining screen (PTS) test battery. The modified Bakan test[15] previously was shown to be sensitive to alertness degradation

CAMI/USAARL Nap Study
Total Correct Responses on Modified Bakan Test[1]

(Nap Condition by Session)



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Source: U.S. Federal Aviation Administration Civil Aeromedical Institute

Figure 2

CAMI/USAARL Nap Study
Correct Responses on Modified Bakan Test1 During Test Session 3 of Night Shift

(Nap Condition by Five-minute Blocks)

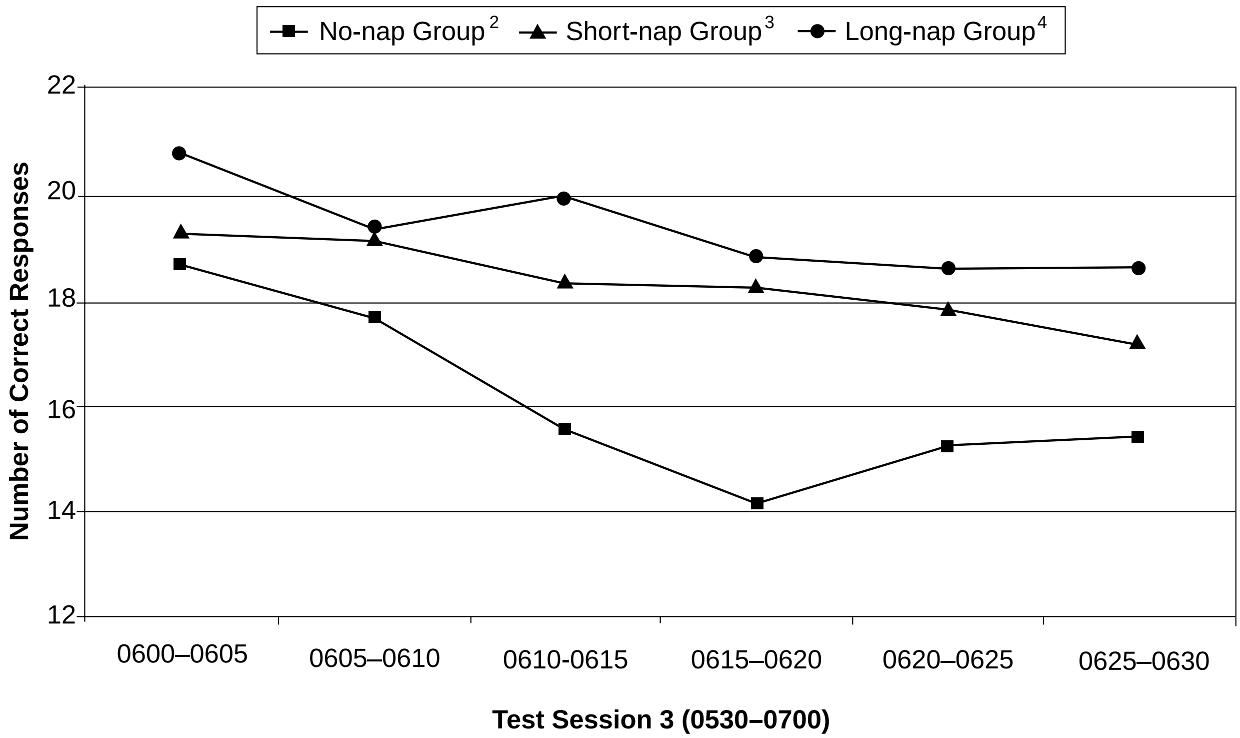

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Figure 3

and variations in alertness and sleepiness.[16,17] The ATST and Bakan test were selected because they assessed different abilities. The ATST simulated ATC tasks. The simulation created a scenario in which a napping controller would be asked to resume ATC duties during a high-workload condition. The Bakan test was selected because it imposed a boring, low-workload vigilance condition.

The ATST software used in this study was from the disk operating system (DOS)-based, international air traffic control specialist version (termed Eurotest) of the PTS battery.[18] The ATST served as a computer-administered, low-fidelity work sample that required the controller to control a predetermined number of aircraft within a simplified, simulated airspace, directing them to their destinations according to a limited set of rules. A computer-based instruction module provided standardized training. Twenty-two practice scenarios and seven test scenarios were administered. The scenarios were escalated in complexity by increasing the number of aircraft and changing the duration of the scenarios.

The practice scenarios ranged from 11 aircraft in 16 minutes to 45 aircraft in 28 minutes. The test scenarios all involved 45 aircraft in from 27 minutes to 28 minutes. The sequence of the practice scenarios and test scenarios was modified from the Eurotest version.[19] During the practice scenarios, two additional practice scenarios were added by duplicating scenario 10 and scenario 12 to provide an eight-hour simulated work day for three days.

Measures included from the ATST were in two categories: errors and delays. Errors included incorrect landing speed and level, incorrect gate speed and level, destination errors, separation errors and crashes. [“Landing speed and level” were ATST names for artificial variables that controllers managed while vectoring simulated aircraft to arrive at simulated airports on a computer screen; errors were generated if these aircraft deviated from the rules at specific positions on the computer screen. “Gates” were airspace-exit points identified on the computer screen during the simulation. “Destination errors” were generated if the simulated aircraft was vectored to the wrong airport or was vectored to exit the airspace from the wrong gate. “Separation errors” were generated when lateral and vertical distance between simulated aircraft deviated from the separation rules. “Crash” errors were generated according to various criteria, such as a simulated aircraft violating an airspace boundary on the computer screen or arriving at an airport at the wrong landing speed and level.] All of these errors added together were analyzed as total errors. The errors were divided into procedural and safety errors. Safety errors included crashes and separation errors. Procedural errors included incorrect landing speed and level, incorrect gate speed and level and destination errors.

Delays were a measure of time (in minutes) required to handle the aircraft. Handoff delays were computed from the time an aircraft, requiring acceptance of the handoff, was presented on the screen to the time the controller accepted the handoff. For en route delays, the system computed the difference between the actual time to reach the destination for each aircraft and the time required if the aircraft had flown the optimum flight path. Total delays were the sum of handoff delays and en route delays.

Study Compared Two Nap Durations vs. No Nap

The research involved nine days of controller participation. During the first five days, the controllers were asked to wear an activity monitor on one wrist and to maintain a sleep/wake cycle ensuring day-orientation of the circadian rhythms. Wrist activity monitors were used to provide data on the rest/activity cycles of the controllers.[20] The wrist activity monitor’s threshold-crossing mode provided a measure of frequency of movement and was programmed to operate for the duration of the study. Rest/activity data were analyzed to document each controller’s sleep schedule for the five days before coming to the laboratory. Wrist activity monitors were worn 24 hours per day for the duration of the study, with the exception of during bathing. Upon the controllers’ arrival and departure from the laboratory, data were transferred to permanent storage in a personal computer and analyzed off line.

Physiological activity during sleep was recorded using an electroencephalograph (EEG).[21] The wrist activity monitor data collected at the laboratory were used as a secondary measure to the EEG data for sleep duration and immobility.

On the fifth day, the controllers reported to the USAARL sleep laboratory where they maintained residence for the remainder of the study. The laboratory study involved three days of synthetic work (simulation of work using a computerized test battery) on an early morning schedule (0700-1500) followed by a quick turnaround (eight hours off duty) to a night shift (2300-0700). The controllers were trained on the computerized test battery during the three day shifts. The effects of napping were assessed on the night shift.

U.S. Army controllers were recruited through the commander’s office of the 1–11th Aviation Regiment. FAA controllers were recruited through active assistance of the National Air Traffic Controllers Association and coordination with FAA regional air traffic offices.

FAA ATCSs were required to hold FAA medical certification. Army air traffic controllers underwent a brief medical examination by the USAARL medical monitor to ensure that they met FAA Class II standards. Volunteers were excluded for hypertension, use of medication that could not be discontinued during study participation, use of tobacco products, high caffeine consumption (more than three cups of coffee or six soft drinks containing caffeine per day, or six cups or glasses of tea per day), or any medical disorder that sleep deprivation may exaggerate.

A total of 65 air traffic controllers completed the study protocol. Table 2 (page 8) shows demographic data. Four controllers were members of the Army 1–11th Aviation Regiment and worked in a tower. The remaining 61 controllers were ATCSs employed by the FAA. The FAA ATCSs were from both terminal and en route facilities, representing all geographic regions of the United States. Two additional FAA ATCSs began participation but withdrew from the study before completing the study. One of these controllers experienced insomnia during the first two nights of the study; the other controller did not like wearing the EEG electrodes.

Data from a total of 59 controllers were analyzed. Data from six of the 65 original controllers were not included in these analyses. Of those six, four controllers’ computer files for the night shift performance on the ATST were unrecoverable, and two controllers assigned to the no-nap condition were determined by EEG scoring to have taken naps of at least 30 minutes in length on the night shift.

The controllers were assigned randomly to nap condition by gender, resulting in the following groups:

- 10 short-nap males;

Table 2
CAMI/USAARL Nap Study
Demographics of Air Traffic Controllers

Gender	
Males	28
Females	31
Average Age	33.4 years
Education	**Percent**
High School	3.4
Some College	39.0
College Degree	39.0
Some Postgraduate Work	11.9
Graduate Degree	1.7
Unknown	5.1
Air Traffic Control Facility Type	**Percent**
En Route	37
Terminal	63
Average Experience (Full Performance Level)	6.4 years

CAMI = U.S. Federal Aviation Administration Civil Aeromedical Institute
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Source: U.S. Federal Aviation Administration Civil Aeromedical Institute

- 10 short-nap females;
- 10 long-nap males;
- 10 long-nap females;
- Eight no-nap males; and,
- 11 no-nap females.

The mean age of the 59 volunteers was 33.4 years with standard deviation (sd) = 3.9 years. The female controllers were slightly younger on average (M = 32.2 years, sd = 4.0 years) than the male controllers (M = 34.8 years, sd = 3.3 years).

The four Army participants were tower controllers and reported an average of 4.5 years as full performance level (FPL) controllers. Of the 56 FAA ATCSs, 42 (75.0 percent) reported being FPL controllers; four (7.1 percent) were developmental controllers; four (7.1 percent) were staff specialists; two (3.6 percent) were area supervisors; three (5.4 percent) did not respond to the question; and one (1.8 percent) worked in the traffic management unit. Twenty-two ATCSs were from the en route option and 37 were from the terminal option. The participants in the study reported having an average of 9.2 years experience as air traffic controllers and 6.4 years of experience as FPL controllers. Table 3 (page 9) provides a breakdown by gender and geographic region for the controllers included in the data analysis.

Study Design Controlled Participants' Behavior

The controllers arrived at the laboratory on Sunday evening and departed on Thursday afternoon. After the three day shifts (0700-1500) they were required to retire to their bedrooms at 2230, and turn lights out no later than 2300. The controllers were awakened each morning at 0530. Naps during the day were not allowed.

On Monday morning, the controllers began training on the cognitive tasks. Training sessions were administered for the three day shifts, with the night test sessions beginning Wednesday night and ending Thursday morning.

Following the final training session at 1500 on Wednesday, the controllers were allowed to break but not allowed to nap before the night shift. Electrode placement for the night shift was initiated at approximately 2100. The night shift began at 2300. Table 1 (page 3) shows the schedule for the night shift.

All groups received a 30-minute break following the first test session (0030-0100), after which a 30-minute ATST problem was administered to all groups. The controllers were informed about their napping-condition assignments at 0130. At 0145, the 120-minute nap was initiated. Short-nap controllers were placed on break at 0130 and in bed by 0300 and awakened by 0345. The no-nap group was placed on break at 0130 and returned for testing at 0345. During the break for the short-nap group and no-nap group, the controllers relaxed in the break area. The controllers were not allowed to sleep during their break, but were permitted to read, watch television or interact with other controllers.

The second test session (0345-0520) was administered within five minutes after awakening from the nap, but no later than 0345. The controllers in all the nap/no-nap conditions received a break after this session. At 0530, the final test session began. Upon completing the third test session, the controllers were allowed to eat a light meal and return to their bedrooms to sleep/rest for five hours. After a lunch break, the controllers completed a final ATST scenario from 1330 to 1400. Finally, the controllers were debriefed and dismissed from the study.

The CAMI/USAARL researchers controlled timing and content of meals. Breakfast, lunch and dinner were scheduled at 0600, 1230 and 1800, respectively, during the day shifts. A snack before the first test session on the night shift was allowed at 2200. The controllers were allowed to consume light snacks during scheduled breaks. No foods or beverages were allowed during the three 90-minute test sessions. Only light snacks and noncaffeinated beverages were allowed at any time during the night shift. One caffeinated beverage was allowed with breakfast if the controller normally consumed caffeine. No alcohol consumption was allowed throughout the laboratory

Table 3
CAMI/USAARL Nap Study
Geographic Region and Gender of Air Traffic Controllers

Place of Employment	Males	Females	Regional Total
U.S. Army (Fort Rucker, Alabama, U.S.)	3	0	3
U.S. Federal Aviation Administration Region			
Alaska	3	1	4
Central	2	3	5
Eastern	2	4	6
Great Lakes	2	11	13
New England	3	2	5
Northwest Mountain	3	1	4
Southern	2	4	6
Southwest	6	5	11
Western Pacific	2	0	2
Total	**28**	**31**	**59**

CAMI = U.S. Federal Aviation Administration Civil Aeromedical Institute USAARL = U.S. Army Aeromedical Research Laboratory

Source: U.S. Federal Aviation Administration Civil Aeromedical Institute

protocol. All food and drink intake was recorded in the daily logbook.

Practice Preceded Synthetic-work Sessions

During orientation, the controllers completed the computer-based instruction on the ATST and completed four practice sessions. They were also instructed on the Bakan test. The controllers were provided feedback about performance after each training test. Each session on the computerized test battery lasted approximately 90 minutes and consisted of two 27-minute or 28-minute ATST scenarios, separated by 30 minutes of the Bakan test. The controllers were given a total of 11 practice sessions on the three day shifts and three full test sessions on the night shift. A single ATST problem was administered just prior to notifying the controllers about their napping conditions. A final session was administered after a rest period following the night shift to diminish the potential end-of-study effect on performance.

The EEG electrodes were attached the evening before the second night of sleep. The controllers slept with sensors attached to their scalp beginning the second night in the laboratory (Monday night). The stages of sleep were determined by guidelines set forth by Rechtschaffen and Kales.[22]

Monitoring Determined Sleep Stages, Alertness

Sleep EEG data and wrist activity monitor measures were used to conduct the following elements of the study:

- Assess sleep quality before the night shift;
- Determine the quality of the nap and ensure that the no-nap controllers did not sleep;
- Determine sleep stage at the termination of the nap; and,
- Examine alertness during performance on the last day shift and the night shift.

The EEG data will be presented in a separate report; however, nap data were examined to ensure that each of the controllers actually met napping-condition criteria. Data from the wrist activity monitors were used to determine each controller's activity before coming to the laboratory and were analyzed to determine sleep during the nap when EEG data were unavailable.

Records of the controllers in the short-nap condition were scored for sleep from approximately 0245-0345, while records from the controllers in the long-nap condition and no-nap condition were scored from 0145-0345. EEG records were visually examined to identify and determine the time of day for analysis. The actual beginning of the time period varied from controller to controller because the period was set to the time in which EEG channels and electromyogram (EMG) channels exhibited a clear reduction in muscle activity as the controller sat on the bed and lay down to sleep. Sleep stages were identified using Rechtshaffen and Kales' guidelines as implemented in the software that analyzed physiological activity during sleep.[23]

Five records could not be scored automatically because of faults in the electromagnetic storage medium. In these cases, an experienced polysomnography scorer visually scored the records using Rechtshaffen and Kales' guidelines. Records of the controllers in the no-nap condition were screened for evidence of sleep of 30 minutes or more. Two controllers' records were found to meet this criteria, but no other records were found to have evidence of sleep. Data from the controllers who exhibited sleep episodes lasting 30 minutes or more were excluded from the analysis of performance.

Experimental Method Did Not Consider Controllers' Experience

Results from the ATST revealed that the test was less sensitive than the Bakan test to the sustained wakefulness induced by the protocol in the no-nap group, the circadian trough expected to affect all groups, or the napping conditions. The only nap-condition-related finding was a shorter average en route-delay time for the short-nap group compared to the no-nap group on the last scenario.

The following factors may have contributed to the ATST's lack of sensitivity to the factors which frequently induce decrements in performance:

- The ATST was selected as a quasi-work sample. All of the participants were active air traffic controllers. Even though the ATST was a low-fidelity simulation, the skills required to perform the task may have been well practiced in this sample and were very robust. In addition, many of the controllers were required to work night shifts or had been required to work night shifts during their careers and many may have brought coping strategies to this study;

- The ATST scenarios were designed to present a high workload. The high workload may have had an alerting effect for all groups and maintained performance;

- Controllers were selected from all types of facilities, from Level 1 FAA towers to Level 3 en route centers. Because of differences in job duties and traffic workload at their facilities, the controllers came to the study with a wide variation of skill levels within the air traffic control occupation. Controllers from the Level 1 towers, for example, did not use radar separation on their job, and they probably were not trained in radar procedures. In contrast, en route controllers use radar separation procedures daily in their jobs. This difference in skills may have introduced extraneous variability into these analyses;

- The within-group data comparisons were statistically confounded by differences in the scenarios. Different scenarios were administered for each test. Even though the scenarios had a similar number of aircraft and duration, it was not possible to equate the complexity of scenarios. The best method would be to obtain normative data for the problems from a large number of FPL controllers. Such data were unavailable. Therefore, the degree to which scenario complexity and experimental factors were confounded was not adequately assessed by the CAMI/USAARL study; and,

- Even though some ATST measures, such as handoff delays, might appear to be a measure which would be affected by fatigue analogous to a reaction-time measure, the nature of controlling air traffic may not be as directly sensitive to fatigue effects. Individual controllers may have compensated for the effects of fatigue in a number of ways in which they controlled the scenario traffic so that the effects were not reflected in the ATST measures in this study.

It was encouraging that performance on the ATST failed to demonstrate sensitivity to such factors as circadian trough, sustained wakefulness and naps. This is especially true in light of the decrements on the Bakan test. The ATST with high-workload scenarios was selected for the study to simulate a situation where an ATCS who was napping would be required to arise and immediately return to the radar to work traffic.

The placement of the naps in this study was designed to occur just prior to or during the circadian trough in temperature and performance rhythms such that performance would be measured during the "red zone." Because circadian rhythms were not measured, they only could be implied to result from the sleep/wake cycle and subsequent exposure to daylight imposed by the experimental schedule. The Bakan-test data for the no-nap group would suggest that the experimental design — which included early morning shifts combined with a prohibition of napping at any time — induced a significant level of fatigue.

Study Advances Research on Effects of Napping

The problems associated with night work and shift work have been investigated by many researchers over the past several years.[24] These problems include physiological, psychological and social difficulties experienced by people who must change their sleep/wake schedule from day activity and night sleep to day sleep and night activity.[25]

Research indicates that a major problem among shift workers is disturbed sleep. Daytime sleep is shorter than nighttime sleep and tends to be fragmented.[26] The order of slow-wave sleep (SWS) and rapid-eye-movement (REM) sleep is disturbed, with more REM sleep occurring at the beginning of the sleep period and more SWS occurring at the end, the opposite of the natural SWS/REM pattern.[27] Due to the disturbance in sleep, research shows that shift workers nap more frequently than daytime workers to compensate for the sleep loss.[28]

Research also shows that night workers have increased sleepiness during work, with most sleepiness occurring during the last half of the work shift.[29] This increase in sleepiness during work leads to a decrease in performance,[30] an increase in accidents[31] and an increase in spontaneous naps on the job.[32] According to a report by the Association of Professional Sleep Societies' Committee on Catastrophes, Sleep and Public Policy, heart attacks, vehicular accidents, performance errors and major disasters are more likely to occur during the early morning hours of shift work.[33] Other researchers have reported increased accidents due to sleepiness in night workers.[34] Abuse of substances such as nicotine, caffeine and other stimulants to help maintain alertness, and sleeping pills to help obtain sleep, also have been reported.[35]

One group of researchers has found that the problems associated with night work — sleep problems, fatigue and sleepiness, and decreased performance — result from a desynchronization of the circadian cycle.[36] Other problems in shift workers stem from the social disruptions and family disruptions associated with shift work.[37] Workers desiring to spend time with family and friends may not sleep when the opportunity comes, leading to more fatigue and lack of sleep due to social activities and family activities.

Because of the problems inherent in night work, many interventions have been attempted to alleviate the ill effects. Some of the methods undertaken during the night shift to increase arousal and performance include rest breaks, social activity during breaks, increasing task demands, feedback about work performance, exercise, bright lights and naps.[38] Napping seems to be an effective, inexpensive way to help alleviate the sleepiness experienced during night work, particularly for those night workers whose schedules require minimal exposure to night work and for whom circadian adaptation to a night shift is not desirable.

Much research has been conducted to determine the circadian pattern of sleep and alertness and to study circadian placement of the nap. Sleep tendency is highest when core body temperature is in its trough, around 0300, and is lowest when core body temperature is at its peak, around 1500.[39] The effects of naps taken during the circadian trough are different from the effects of naps taken during the circadian peak.

One group of researchers said that the following variables must be considered when scheduling naps during a prolonged work period: the extent of sleep loss prior to the work period (i.e., sleep deprivation), the length of the nap, the placement of the nap within the circadian phase, and the length of time between the end of the nap and the work period.[40]

Research in which a two-hour nap was scheduled at five different times within a 24-hour period indicated that a nap during the early morning reinforced the circadian rhythm of temperature, strengthening the normal fall and rise of core body temperature.[41] One study indicated that a three-hour nap between 0400 and 0700 after 20 hours of continuous wakefulness reduced the amount of performance degradation seen upon awakening when compared to a no-nap group.[42]

One researcher examined the effects of a one-hour nap on subjects after 24 hours of sleep deprivation.[43] Two nap times were tested: 2100 and 0430. Both naps — but especially the nap taken at 0430 — improved performance the following morning when compared to a no-nap group. Other studies indicated that early morning naps are beneficial in restoring alertness and performance.[44] One study found that a nap taken at any time during the circadian cycle before a sleep-loss period will be beneficial in maintaining performance across the sleep-loss period.[45]

Another use of naps is as an adjunct to the regular sleep period. There is substantial evidence that a nap during the day before an all-night work shift, but no sleep loss prior to the shift, will result in less performance decrement over the night than without the nap. One group of researchers measured performance and alertness in subjects who had a two-hour nap to three-hour nap before the night shift.[46] Although the usual circadian trough was seen in the early morning, the nap attenuated the decline in performance when compared to a night when no nap was taken prior to the shift.

Another study indicated that a nap taken during the night work period can help alleviate the fatigue caused by night work, a practice commonly used in Japan.[47] Another study found that a one-hour nap taken at 0200 during a work period had limited beneficial effects on performance compared to a no-nap condition.[48]

Time between the nap and the work period should be considered. When scheduling a nap, a person should consider whether performance is required immediately upon awakening. Performance is generally low immediately upon awakening, but recovers usually after 15 minutes to 30 minutes.[49]

Several factors will lead to extensive sleep inertia: awakening from nonrapid-eye-movement (NREM) sleep, especially SWS, awakening within the first few hours of sleep and sleep following a long period of sleep deprivation.[50] Studies show that postnap sleepiness is higher and performance is lower when a person is awakened from a nap during the circadian trough as compared to a nap taken during the circadian peak.[51] Two researchers found that, after 32 hours of sleep deprivation, a two-hour nap at 1500 produced less sleep inertia than a two-hour nap at 1900.[52] Nevertheless, the later nap was more successful in reducing sleepiness levels during the early morning (2300 to 0400) than the early nap.

In another study, subjects deprived of sleep for 54 hours were scheduled for two-hour naps at various times in the circadian cycle, corresponding to peaks and troughs in the cycle.[53] The results indicated that naps taken during the circadian troughs led to greater performance decrements than did naps taken during the circadian peaks. The authors of that study concluded that during continuous-performance operations, naps in the circadian trough should be avoided, and naps should be taken before a person's sleep loss extends beyond 36 hours.

Generally, previous studies conclude that a nap of one hour in length to four hours in length prior to a night work period improved morning performance and alertness above the performance seen without a nap. As summarized by one researcher, results from many studies indicate that naps do not totally eliminate the circadian dip seen in the early morning (around 0500), but the degradation in both cognitive performance and alertness is attenuated.[54]

To summarize previous findings, some research indicates that a nap during the night shift would be beneficial in reducing the circadian trough in performance usually seen in the early morning hours. When a person must return to work immediately upon awakening, sleep inertia should be considered. This decrease in performance due to sleep inertia is worse when one is awakened from SWS, during the circadian trough, or after a long period of sleep deprivation.

Several Factors Affect Strategy for Napping

The length of the total sleep-deprivation period is an important factor when determining whether a nap will be beneficial. Most data suggest that the best time to nap is before significant sleep loss has occurred; naps do not completely reverse the effects of sleep loss, however.[55] In one study, subjects were kept awake for 52 hours.[56] A nap taken before the continuous-wakefulness period was beneficial in keeping performance and alertness from decreasing for up to 24 hours of sleep loss, as compared to a no-nap condition. By the second night of sleep loss, the benefit of the naps could not be measured reliably. Other studies have found similar results using only 24 hours of sleep deprivation.[57] The findings from each of these studies indicate that a prophylactic nap will attenuate considerably the decrease in performance during a night shift.

It is very difficult to compare many of the nap studies due to variations in methodology. Nevertheless, most studies indicate that naps from one hour to eight hours will improve performance and alertness during continuous operations.[58] In one study, subjects were scheduled for a three-hour nap after being awake for approximately 24 hours.[59] After the nap, they were required to stay awake an additional 20 hours. Results indicated that this three-hour nap reduced the decline in performance over the additional work period.

Another study deprived subjects of sleep for 24 hours, after which a nap of 15 minutes, 30 minutes, 60 minutes or 120 minutes was scheduled.[60] The results indicated that alertness increased with the increase in nap length, with the highest level of alertness occurring after the 60-minute nap. There was no difference between the 60-minute nap and the 120-minute nap, possibly due to fragmentation of the sleep in the longer nap. The authors of that study concluded that the alerting effects of naps are related to the length of the nap.

The same relationship between nap length and performance was found in a study that allowed subjects a two-hour nap, four-hour nap or 8-hour nap before 52 hours of continuous operations.[61] The results indicated a dose-response relationship between the length of the nap and performance during the first 24 hours of sleep deprivation. Based on this type of nap, the author concluded that the nap that a person takes before an all-night shift should be as long as possible to have a maximum benefit on performance. The author of that study also said that a nap ideally should be prophylactic, and not used to replace lost sleep from the regular sleep period. Prophylactic naps may be more beneficial during a sleep-deprivation period than a nap during the continuous-wakefulness period.[62]

In a study by NASA, one group of pilots was scheduled for a 40-minute rest period followed by a 20-minute recovery period during a long-haul flight.[63] Performance was maintained at consistent levels, and physiological alertness was higher during the last 90 minutes of flight. These naps were implemented with no evidence of compromised safety. In a group that was not allowed a rest period, the occurrence of reduced physiological alertness (micro-events) was five times higher than in the group of subjects who took a nap. Although U.S. Federal Aviation Regulations [do not permit controlled rest] in the cockpit, the results of this study indicated that a planned rest period during the cruise portion of long-haul flights may increase safety by reducing uncontrolled napping and involuntary napping, and increase safety associated with higher alertness at the end of the flight.

[Some non-U.S. airlines, for example, acknowledging the debilitating effects of in-flight fatigue on pilot performance, have established formal policies for providing pilots in both two-person crews and three-person crews with the opportunity for controlled rest. Lufthansa German Airlines, Swissair and British Airways have allowed planned in-flight crew rest during low-workload periods near the end of the flight, but not within the 30 minutes before beginning the letdown to their destination. Generally, rest periods are from 30 minutes to 45 minutes, only one crew member may rest at any one time and rest is taken in the respective pilot's cockpit seat. Eyeshades and earplugs may be used, if desired, to help the resting pilot fall asleep. Depending on the airline, the preflight planning includes the crew-rest sequence, criteria for unplanned wakeup and coordination with cabin staff.]♦

[Editorial note: This article has been edited for style, length and clarity from the original report "The Effects of Napping on Night Shift Performance" by Pamela S. Della Rocco, Carlos Comperatore, Lynn Caldwell and Crystal Cruz of the U.S. Federal Aviation Administration (FAA) Civil Aeromedical Institute. The 33-page report was published in February 2000 by the FAA Office of Aviation Medicine (OAM) as OAM Report no. DOT/FAA/AM-00/10. The report contains the complete data and statistical analyses, 18 tables and 13 figures.]

Notes and References

1. The authors' original report uses "midnight shift" and "night shift" for the time period studied; night shift is used in this article. Terminology and scheduling of the 24-hour day into shift-work periods vary among employers. One schedule in the United States, for example, is 0800–1600 for the day shift, 1600–0000 for the evening shift (or swing shift) and 0000–0800 for the night shift (or midnight shift).

2. The human body's circadian rhythms are clocklike biological mechanisms that control many functions essential to human health and do not adjust rapidly to change. The circadian trough (also called circadian low) is a stage of the sleep-wake cycle that typically occurs between 0200 and 0600 for people who are adapted to a day-wake/night-sleep schedule. Body temperature, alertness and performance reach their lowest point during this stage.

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4. The modified Bakan test had two components: a stimuli comparison and an estimation task. Three-digit numbers were presented on a cathode-ray-tube (CRT) screen every 1.5 seconds for 30 minutes. When a three-digit number was repeated in sequence, depressing the space bar on the keyboard indicated a correct response. A single digit or letter was presented simultaneously to the right of the three-digit number. At the end of each five-minute block of trials, the controller was required to estimate the proportion of numbers to letters presented during that block. Six blocks of 200 trials were presented in each session, which lasted approximately 30 minutes.

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crew rest in aviation operations and maritime operations. He has collaborated extensively with CAMI on ATCS shift-work schedules and fatigue countermeasures.

J. Lynn Caldwell, Ph.D., a USAARL research psychologist and board-certified sleep specialist, was a consultant to CAMI for this study. She has been conducting research with aviators for more than 10 years, including studies of sleep deprivation, shift lag and jet lag, and countermeasures to alleviate related problems. Caldwell also has conducted training for physicians, flight surgeons and U.S. Army commanders regarding problems associated with fatigue, sleep deprivation and changes in the sleep/wake cycle.

Crystal Cruz is a psychology technician at CAMI.

Appendix A
Research Design

The experimental design was a 3 (nap condition) x 2 (gender) x 3 (session) mixed-factorial design with repeated measures. Data from the three test sessions on the night shift were analyzed using SPSS Version 7.5 for Windows general linear model for repeated measures. Pillai's Trace multivariate analysis of variance results was used to test the within-subjects effects. Significant interaction and main effects were analyzed with post-hoc multiple comparisons for between groups and within subjects. (Toothaker, L. *Multiple Comparisons for Researchers*. Newbury Park, New York: Sage Publications, 1991.) Comparisons of the repeated factor(s), either within groups or collapsed over groups, were conducted using two correlated-sample t-tests and Dunn critical values (CV). Between-group comparisons, either within session or collapsed over session, were conducted based on the t-statistics — tG and tG@T — where G equals group and T equals time, using Tukey CVs as described by Toothaker. [The complete CAMI/USAARL report of this study discusses all of the analyses conducted and the handling of missing data according to conventions of statistical research.]

Two no-nap-male controllers were excluded from these analyses because they exhibited in electroencephalographic data one sleep episode for a period of 30 minutes or greater during their break on the night shift. The remaining no-nap controllers did not exhibit sleep episodes during the break. Data from the controllers in both nap conditions revealed sleep episodes consistent with the assigned nap condition.♦

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