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The Effects of Napping on Night Shift Performance

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16. Abstract

This study represents a collaborative effort between the Federal Aviation Administration's Civil Aeromedical Institute and the US Army Aeromedical Research Laboratory to investigate the effects of napping on the midnight shift as a potential countermeasure to sleepiness during the shift. The purpose of the present paper was to examine the patterns of performance degradation along with the subjective measures of mood, sleep quality, and sleepiness as a function of napping condition and time on task during the midnight shift. Sixty Air Traffic Control Specialists (ATCSs) were randomly assigned to one of the three midnight shift napping conditions: a long nap (LN) of 2 hours, a short nap (SN) of 45 minutes, and a no nap condition (NN). ATCSs completed a four-day protocol during which they worked three early morning shifts (0700-1500) followed by a rapid rotation to the midnight shift (2300-0700). Subjects completed three 1.5 hour test sessions (one session before the nap and 2 sessions after the nap) during the midnight shift involving two computer-based tasks: 1) the Air Traffic Scenarios Test (ATST), a task developed for selection of ATCSs, and 2) the Bakan, a test of vigilance. Data were analyzed using repeated measures analysis of variance and post-hoc multiple comparisons. Both cognitive performance and subjective measures of sleepiness supported the use of naps during the midnight shift. In fact, both the long nap of 2 hours and the short nap of 45 minutes resulted in better performance than no nap on the Bakan test at the end of the midnight shift. A dose-response relationship existed such that the long nap also resulted in better performance than the short nap. 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 Stanford Sleepiness Scale suggested that, while sleepiness increased across the midnight shift for all groups, ratings were generally lower for the LN condition and were lower for males in the SN condition, when compared with the NN condition. The present study suggests that naps taken during the midnight shift could be useful as a countermeasure to performance decrement and sleepiness on the midnight shift.

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THE EFFECTS OF NAPPING ON NIGHT SHIFT PERFORMANCE

Sleepiness on the first midnight shift of a work schedule is common among shiftworkers when their circadian rhythms are day-oriented. Effective countermeasures for sleepiness are important for employees in a safety critical job such as the Federal Aviation Administration's (FAA) Air Traffic Control Specialist (ATCS). The Human Factors Research Laboratory (HFRL) at the Civil Aeromedical Institute (CAMI) was asked by the Miami Air Route Traffic Control Center to investigate sleepiness on the midnight shift. They specifically requested information about the possibility of using a scheduled nap as a method to reduce sleepiness and maintain alertness during this shift.

The shift schedules worked by ATCSs often minimize the employee's exposure to the midnight shift (Cruz & Della Rocco, 1995). ATCSs generally work only one or two midnight shifts in a row. Thus, a circadian adaptation strategy of shifting the biological clock to a night orientation is not practical in this population because of the time courses required to shift the clock to a night orientation and return back to a day orientation. An acutely administered coping strategy, such as scheduled napping, therefore, was a more reasonable candidate for a sleepiness countermeasure.

The purpose of this 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 were investigated. The study specifically compared two napping conditions, a Long Nap (2 hours) and a Short Nap (45 minutes), to a No Nap condition. Performance was examined on two tasks, an air traffic scenarios task (high workload) and a vigilance task (low workload).

BACKGROUND

The problems associated with night and shift work have been investigated by many researchers over the past several years (Folkard, 1989; Wilkinson, 1992). 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 (Anch, Browman, Mitler, & Walsh, 1988).

Research indicates that a major problem among shift workers is disturbed sleep. Daytime sleep is shorter than nighttime sleep and tends to be fragmented (Torsvall, Akerstedt, Gillander, & Knutsson, 1989; Tilley, Wilkinson, Warren, Watson, & Drud, 1982). In addition, 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 (Tilley et al., 1982). Due to the disturbance in sleep, research shows that shift workers nap more frequently than daytime workers to compensate for the sleep loss (cf Rosa, 1993; Akerstedt & Torvsall, 1985).

Research also shows that night workers have increased sleepiness during work, with most sleepiness occurring during the last half of the work shift (Akerstedt, Torsvall, & Gillberg, 1982). This increase in sleepiness during work leads to a decrease in performance (Mitler, Carskadon, Czeisler, Dement, Dinges & Graeber, 1988), an increase in accidents (Ribak, Ashkenazi, Klepfish, Avgar, Tall, Kallner & Noyman, 1983), and an increase in spontaneous naps on the job (Torsvall & Akerstedt, 1987; Torsvall et al., 1989). 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 (Mitler et al., 1988). Other researchers have reported increased accidents due to sleepiness in night workers (Hamelin, 1987; Ribak et al., 1983; Torsvall & Akerstedt, 1987). 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 (cf Penn & Bootzin, 1990).

According to Czeisler and his colleagues (Czeisler, Kronauer, Allan, Duffy, Jewett, Brown & Ronda, 1989; Czeisler, Johnson, Duffy, Brown, Ronda &

Kronauer, 1990), the problems associated with night work — sleep problems, fatigue and sleepiness, and decreased performance — result from a desynchronization of the circadian cycle. Other problems in shift workers stem from the social and family disruptions associated with shift work (Penn & Bootzin, 1990). 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 and family activities.

Because of the problems inherent with 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 (Penn & Bootzin, 1990; Bonnet, 1990). 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 circadian adaptation to a night shift is not desirable.

Naitoh, Englund, and Ryman (1982) indicate that several variables must be considered when scheduling naps during a prolonged work period. These variables are as follows: 1) the extent of sleep loss prior to the work period (i.e., sleep deprivation), 2) the length of the nap, 3) the placement of the nap within the circadian phase, and 4) the length of time between the end of the nap and the work period.

Sleep deprivation. 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; however, naps do not completely reverse the effects of sleep loss (Bonnet, 1991; Dinges, Orne, Whitehouse, & Orne, 1987). In a study conducted by Bonnet (1991), subjects were kept awake for 52 hours. A nap taken before the continuous wake 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 reliably measured. Other studies have found similar results using only 24 hours of sleep deprivation (Dinges et al., 1987; Gillberg, 1984; Nicholson, Pascoe, Roehrs, Roth, Spencer, Stone & Zorick, 1985; Bonnet, 1990). The findings from each of these studies indicate that a nap taken before an extended sleep loss period, called "prophylactic naps", will considerably attenuate the decrease in performance during a night shift.

Length of nap. It is very difficult to compare many of the nap studies due to variations in methodology, however, most studies indicate that naps from 1 hour to 8 hours will improve performance and alertness during continuous operations (Bonnet, 1991). In a study by Naitoh and colleagues (1982), subjects were given a 3-hour nap after being awake for approximately 24 hours. After the nap, they were required to stay awake an additional 20 hours. Results indicated that this 3-hour nap reduced the decline in performance over the additional work period.

Another study (Lumley, Roehrs, Zorick, Lamphere, & Roth, 1986) deprived subjects of sleep for 24 hours, after which a nap of either 15, 30, 60, or 120 minutes was given. 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 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 by Bonnet (1991) which allowed subjects either a 2, 4, or 8-hour nap before 52 hours of continuous operations. 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, Bonnet concluded that the nap one takes before an all-night shift should be as long as possible to have a maximum benefit on performance. He also states that a nap should ideally 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 (Mullaney, Kripke, Fleck, & Johnson, 1983; Gillberg, 1984; Nicholson et al., 1985; Carskadon & Dement, 1982; Haslam, 1985).

In a study by NASA (Graeber, Rosekind, Connell, & Dinges, 1990), one group of pilots was given a 40-minute rest period followed by a 20-minute recovery period during a long-haul flight. 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 which was not allowed a rest period, the occurrence of reduced physiological alertness (micro-events) was five times higher than in the group who took a nap. Although current regulations prohibit sleep 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 and involuntary napping and increase safety associated with higher alertness at the end of the flight.

Generally, studies conclude that a nap of 1 to 4 hours in length prior to a night work period improved morning performance and alertness above that seen without a nap. As summarized by Bonnet (1990), 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.

Circadian placement of nap. Much research has been conducted to determine the circadian pattern of sleep and alertness. 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 (Dinges, 1986). The effects of naps taken during the circadian trough are different from the effects of naps taken during the circadian peak. Research in which a 2-hour nap was given at five different times within a 24-hour period indicated that a nap taken during the early morning reinforced the circadian rhythm of temperature, strengthening the normal fall and rise of core temperature (Matsumoto, 1981). A study by Naitoh, Englund, and Ryman (1982) indicated that a 3-hour nap taken 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. Gillberg (1984) examined the effects of a 1-hour nap on subjects after only 24 hours of sleep deprivation. Two nap times were tested — 2100 and 0430. Both naps improved performance the following morning when compared to a no nap group, especially the nap taken at 0430. Other studies indicated that early morning naps are beneficial in restoring alertness and performance (Matsumoto, 1981; Naitoh, Englund, & Ryman, 1982; Gillberg, 1984). Dinges and colleagues (Dinges, Whitehouse, Orne & Orne, 1988) found that a nap taken anywhere in the circadian cycle before a sleep loss period will be beneficial in maintaining performance across the sleep loss period.

Another use of naps is as an adjunct to the regular sleep period. There is substantial evidence that a nap taken 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. Schweitzer, Muehlback & Walsh (1992) measured performance and alertness in subjects who received a 2- to 3-hour nap before the night shift. 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.

A study by Matsumoto and Harada (1994) 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. A study by Rogers, Spencer, Stone, & Nicholson (1989) found that a 1-hour nap taken at 0200 during a work period had limited beneficial effects on performance compared to a no nap condition.

Time between the nap and the work period. When scheduling a nap, one should consider whether performance is required immediately upon awakening. Performance is generally low immediately upon awakening, but recovers usually after 15 to 30 minutes (Dinges, Orne, & Orne, 1985). This decrease in performance shortly after awakening is called “sleep inertia.” Several factors will lead to extensive sleep inertia: awakening from non-rapid eye movement (NREM) sleep, especially slow wave sleep (SWS); awakening within the first few hours of sleep; and sleep following a long period of sleep deprivation (Dinges, Orne, & Orne, 1985). Studies show that post-nap sleepiness is higher and performance is lower when one is awakened from a nap during the circadian trough as compared to a nap taken during the circadian peak (Dinges, Orne, & Orne, 1985). Lavie and Weler (1989) found that, after 32 hours of sleep deprivation, a 2-hour nap taken at 1500 produced less sleep inertia than a 2-hour nap taken at 1900. However, the later nap was more successful in reducing sleepiness levels during the early morning (2300 to 0400) than the early nap. In a study by Dinges and associates (1985), subjects deprived of sleep for 54 hours were given 2-hour naps at various times in the circadian cycle, corresponding to peaks and troughs in the cycle. 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 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.

In summary, 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 slow wave sleep, during the circadian trough, or after a long period of sleep deprivation.

Miami ARTCC ATCSs requested a study examining the utility of naps taken on the night shift as a way to alleviate sleepiness and maintain alertness. Since ATCSs are generally scheduled for only one or two night shifts per work week, it is undesirable to shift their circadian rhythms to a night shift. Allowing a nap during the work shift may serve to: 1) improve alertness and maintain performance, 2) strengthen the normal rise and fall of the temperature curve, 3) provide an anchor sleep that could maintain stability in the sleep/wake cycle, and 4) decrease the amount of unscheduled napping by workers who have a difficult time staying awake, thus enhancing safety during the shift.

The present study examined the effects of two different nap lengths scheduled prior to and into the approximate circadian trough on the ability of both male and female ATCSs to maintain alertness and performance levels during a night shift. The questions addressed were as follows: 1) Does a nap taken 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? 2) Do the effects of a 45-minute nap differ from the effects of a 120-minute nap on alertness and performance? 3) Are there gender differences in response to a nap taken during the night shift? The two types of performance tasks, the low fidelity air traffic control (ATC) simulation and the vigilance task, were used to assess performance relevant to ATC.

METHODS

The study compared naps of two different durations to a No Nap (NN) condition. The long-nap (LN) was 120 minutes. The short-nap (SN) was 45 minutes. The protocol involved 9 days of subject participation. During the first five days, subjects were asked to wear wrist activity monitors and to maintain a sleep/wake cycle ensuring day-orientation of the circadian rhythms. On the fifth day (Sunday evening), subjects reported to the sleep laboratory at the U.S. Army Aeromedical Research Laboratory in Ft. Rucker, Alabama where they maintained residence for the remainder of the study. The laboratory protocol involved three days of synthetic work (computerized test battery) on an early morning schedule (0700-1500) followed by a quick-turn-around (8 hours off duty) to a night shift (2300-0700). Subjects were trained on the computerized test battery during the three day shifts. The effects of napping were assessed on the night shift.

Subjects

Subject recruitment and reimbursement. Army participants were recruited through the Commander's office of the 1-11th Aviation Regiment. The study was coordinated with the FAA Office of Air Traffic Program Management (ATZ-1). FAA participants were recruited through active assistance of the National Air Traffic Controllers Association (NATCA) and coordination with FAA Regional Air Traffic Offices. Information regarding the study was distributed to FAA Air Traffic Regional Vice Presidents. A contact in each region was established to coordinate participation in the study with CAMI staff. Individuals interested in participating provided their name to the regional contact person. CAMI staff contacted volunteers to conduct screening and to obtain informed consent to participate in the study. In addition to their normal salary for a 40-hour work week for the 5-day period of travel and participation, FAA ATCSs received 5 hours of overtime pay, 2 hours of Sunday premium pay, and 8 hours of midnight shift differential. All travel expenses and per diem were paid by the FAA.

Subject selection. 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 Class II standards. Volunteers were excluded for 1) hypertension, 2) taking medication which could not be discontinued during study participation, 3) use of tobacco products, 4) high caffeine consumption (more than 3 cups of coffee or 6 colas containing caffeine, or 6 cups or glasses of tea per day), or 5) any medical disorder which sleep deprivation may exaggerate. All subjects were selected between the ages of 20 and 40. One female ATCS was included even though she turned 41 prior to being scheduled to participate.

A total of 65 air traffic controllers completed the study protocol. Four of the controllers were members of the Army 1-11th Aviation Regiment and worked in a tower. The remaining 61 controllers were employed by the FAA. Two additional FAA ATCSs began participation but withdrew from the study before completing the protocol. One of these participants experienced insomnia during the first two nights of the protocol. The other participant who withdrew from the study did not like wearing the EEG electrodes. The FAA ATCSs were from both terminal and enroute facilities, representing all geographic regions of the United States. Subjects were randomly assigned to Nap Condition by Gender resulting in the following groups: 1) Short Nap male (SNM), 2) Short Nap female (SNF), 3) Long Nap male (LNM), 4) Long Nap female (LNF), 5) No Nap male (NNM), and 6) No Nap female (NNF).

Data from 59 participants are reported here. Data from six of the 65 were not included in these analyses. Of those six, four subjects' computer files for the midnight shift performance on the Air Traffic Scenarios Test were unrecoverable, and two subjects assigned to the No Nap Condition were determined by EEG scoring to have taken naps of at least 30 minutes in length on the midnight shift. The resulting groups were as follows: 1) SNM, (n=10), 2) SNF, (n=10), 3) LNM, (n=10), 4) LNF, (n=10), 5) NNM, (n=8), and 6) NNF, (n=11).

Subject demographics. The average age of the 59 volunteers was 33.4 years (sd=3.9 years). The female participants were slightly younger on average (M=32.2 years, sd=4.0 years) than the male participants (M=34.8 years, sd=3.3 years). The majority of participants (n=54, 91.5%) were Caucasian; two (3.4%) were Hispanic; two (3.4%) were Black; and one (1.7%) was American Indian. More than half of the participants were married (n=33; 55.9%); 15 were single (25.4%); 6 were divorced or separated (10.2%); 3 did not respond to the question (5.1%); and 2 were cohabitating (3.4%). Two participants were high school graduates (3.4%); 23 completed some undergraduate college (39.0%); 2 held Associate's degrees (3.4%); 21 held Bachelor's degrees (35.6%); 7 completed some post-graduate work (11.9%); 1 held a Master's degree (1.7%). Three subjects did not complete the question on educational background (5.1%). Table 1 presents demographic data.

Table 1. Selected Demographics of Study Participants.

Gender	
Males	28
Females	31
Average Age	33.4 years
Education	
High School	3.4%
Some College	39.0%
College Degree	39.0%
Some Post-graduate Work	11.9%
Graduate Degree	1.7%
Unknown	5.1%
Facility Type	
Enroute	37%
Terminal	63%
Average Years Full Performance Level	6.4 years

The Army participants were tower controllers and reported an average of 4.5 years as Full Performance Level (FPL). Of the 56 FAA ATCSs, 42 (75.0%) reported being FPL controllers; four (7.1%) were developmental controllers; four (7.1%) were staff specialists; two (3.6%) were area supervisors; three (5.4%) did not respond to the question; and one (1.8%) worked in the Traffic Management Unit.

Twenty-two were from the enroute option and thirty-seven 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 2 provides a breakdown by Gender and geographic region for the participants included in the data analysis.

In previous studies the Digit Span from the Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1955) and the Shipley Institute of Living Scale (Zachary, 1986) have been administered for purposes of matching non-ATCS volunteers with ATCSs. These tests were administered to support selection of noncontroller subjects in case an insufficient number of Army or FAA ATCSs volunteered for the study. Although enough ATCSs volunteered, the data from these measures are presented in Table 3.

Measures

Cognitive performance measures. Evaluations of performance were measured by two tests, the Air Traffic Scenarios Test (ATST) (Broach & Brecht-Clark, 1994), and a modified version of the Bakan vigilance test (Dollins, Lynch, Wurtman, Deng, Kischka, Gleason, & Lieberman, 1993). The ATST was a low fidelity simulation of radar-based air traffic control used by the FAA for a couple of years in the Pre-Training Screen (PTS) test battery to screen air traffic controllers before they were hired. The modified version of the Bakan previously has been shown to be sensitive to alertness degradation (Dollins et al., 1993).

The ATST software used in this study was from the DOS-based, International Air Traffic Control Specialist (termed Eurotest) version of the PTS battery (Broach, Enos & Moore, 1994). The ATST served as

Table 2. Breakdown of Study Participants by Region and Gender.

Region	Males	Females	TOTAL
Army (Ft. Rucker, AL)	3	0	3
Southern Region	2	4	6
Eastern Region	2	4	6
New England Region	3	2	5
Alaska Region	3	1	4
Great Lakes Region	2	11	13
Southwest Region	6	5	11
Central Region	2	3	5
Western Pacific Region	2	0	2
Northwest Mountain	3	1	4
Total	**28**	**31**	**59**

Table 3. Descriptive Statistics from Digit Span and Shipley Institute of Living Scale Tests.

	Males		**Females**		**Total**	
	(N=28)		**(N=31)**		**(N=59)**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Digit Span						
Forward	10.5	2.3	10.4	2.3	10.5	2.3
Backward	7.8	2.1	8.1	2.5	8.0	2.3
Shipley Institute of Living Scale						
Verbal	34.2	2.4	33.3	3.2	33.7	2.9
Abstract	34.2	3.5	34.3	3.1	34.3	3.3
Combined	68.3	5.0	67.7	4.6	68.0	4.8
WAIS-R Equivalent	109.9	4.6	109.6	4.5	109.7	4.5

a computer-administered, low fidelity work sample that required the subject to control a predetermined number of aircraft within a simplified synthetic airspace, directing them to their destinations according to a small set of rules. A computer-based instruction module provided standardized training. Twenty-two practice scenarios and seven test scenarios were administered. The scenarios escalated in complexity by increasing the number of aircraft and changing the duration of the scenarios. The practice problems ranged from 11 aircraft in 16 minutes to 45 aircraft in 28 minutes. The test scenarios all involved 45 aircraft in 27-28 minutes. The sequence of the practice and test problems was modified from the Eurotest version (Broach, Enos, & Moore, 1994). During the practice sessions, two additional practice scenarios were added by duplicating scenario 10 and 12 to provide an 8-hour synthetic work day for 3 days. The seven test scenarios were administered in the following order: EX1, EX4, EX2, EX5, EX3 EX6, and EX1.

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. All of these 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 Enroute Delays, the system computed the difference between the actual time to reach destination for each aircraft and the time required if the aircraft had flown the optimum flight path. Total Delays were the sum of Handoff and Enroute Delays.

The modified Bakan test had two components: a stimuli comparison and an estimation task. A sequence of three-digit numbers was presented on a 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. In addition to the three-digit stimuli, a single digit or letter was presented simultaneously to the right of the three-digit stimuli. At the end of each 5-minute block of trials, subjects were required to indicate 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.

Sleep EEG measures. Polysomnography was recorded using Oxford Instruments ambulatory Medilog electroencephalograph (EEG). Ag-AgCl Grass electrodes were fixed to the scalp with collodion, and plugged into the Medilog unit. Polysomnography records were recorded from scalp sites C3 and C4 with the low-pass filter at 35 and the high-pass filter at 0.3. For the electrooculograms (EOGs), the low-pass filter was set at 5 and the high-pass filter was 0.003. Electromyograms (EMG) were measured with the low-pass filter set at 120 and the high-pass filter set at 1.

Subjective measures. The Stanford Sleepiness Scale (SSS) (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973) and the Positive and Negative Affect Schedule (PANAS) (Watson, Clark, & Tellegen, 1988) were used to assess sleepiness and mood at various times throughout the protocol. 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 [PA] and 10 representing negative affect [NA]) and a five point scale ranging from “Very slightly or not at all” to “Extremely.” A 4-item sleep quality questionnaire was used to assess sleep quality in terms of difficulty falling asleep, depth of sleep, difficulty arising from sleep, and level of restedness (Cruz & Della Rocco, 1995).

The subjective measures were collected in daily logbooks. In addition, the logbooks were used to collect self reports of sleep times, awakenings, physical symptoms, meals, beverages, activities, and comments. The daily logbook was modified from those developed by the National Aeronautics and Space Administration (Gander, Myhre, Graeber, Andersen, & Lauber, 1989).

Activity measures. Activity monitors (AMA 32C, version 8.6) from Precision Control Design were used to study the rest/activity cycles of participants. Rest/activity data were analyzed to document each participant’s sleep schedule for the 5 days before coming to the laboratory. The data collected at the laboratory was used as a secondary measure to the EEG data for sleep duration and immobility.

The activity monitor was an 8-bit (expandable to 16-bit), lithium battery-powered microprocessor with 32 kB of nonvolatile RAM. The battery power was sufficient for 10-14 days of continuous operation. The monitor was approximately 44 mm x 33 mm x 13 mm, made of water-resistant metal, and was worn on the nondominant arm. It contained a piezoelectric motion sensor and a real-time clock. Depending on the parameters chosen, the monitor has a recommended operating range of accelerations from 0.3 to 2.0 Gs, however it can handle as much as 10 Gs. The monitor compares each signal against a threshold of detection. The activity monitor was used in the threshold crossing mode. In this mode, a count was registered for each occurrence of a signal greater than the threshold of detection. Counts were accumulated for the duration of the user selected epoch (60 seconds) and were then stored in memory. This mode provided a measure of frequency of movement. It was programmed to operate for the duration of the study. Upon the participants' arrival and departure from the laboratory, data were transferred to permanent storage in a personal computer and analyzed off-line.

Procedures

The protocol was reviewed and approved by the USAARL Human Use and Scientific Review Committees. Subjects were briefed about the study by CAMI or USAARL staff over the phone, and the informed consent form was discussed in detail at least 5 days prior to the study. Subjects signed the consent forms and returned them to CAMI. At least five days prior to arriving at the USAARL laboratory, participants received and were briefed on how to wear the Wrist Activity Monitor. Monitors were worn 24-hours per day for the duration of the study, with the exception of during showers.

Participants arrived at the laboratory on Sunday evening and departed on Thursday afternoon. They completed three day shifts (0700-1500) and one midnight shift (2300-0700). Up to five subjects could participate at the same time. A total of nineteen groups were required to complete data collection. Upon arrival Sunday evening, subjects checked in and were oriented to the laboratory. They completed biographical questionnaires, the Shipley Institute of Living Scale, and the Digit Span tests. All subjects were assigned to a semi-private bedroom and shower area. Subjects were required to retire to their bedrooms at 2230, and lights out was no later than 2300. Subjects were awakened each morning at 0530. They were allowed time to shower, dress, and eat breakfast before the first training session of the day. Naps during the day were not allowed.

On Monday morning, subjects began training on the cognitive tasks. Training sessions were administered for the 3 day shifts, with the test sessions beginning the night of day 3 and ending the morning of day 4. Table 4 presents the schedule for the training days.

Following the final training session at 1500 on Day 3, subjects were allowed to break but not allowed to nap before the midnight shift. Electrode placement for the midnight shift was initiated at approximately 2100. The night shift began at 2300. Table 5 presents the protocol schedule for the midnight 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. Subjects were informed about their napping condition assignments at 0130. At 0145, the 120-minute nap was initiated. Short Nap subjects were placed on break at 0130 and in bed by 0300 and awakened by 0345. The No Nap group was placed on break at

Table 4. Study Protocol.

Training Sessions for All Napping Conditions		
Training Day 1	**Training Day 2**	**Training Day 3**
0700-0830 Orientation	0700-0830 Training 1	0700-0830 Training 1
0830-0900 Break	0830-0900 Break	0830-0900 Break
0900-1030 Training 1	0900-1030 Training 2	0900-1030 Training 2
1030-1100 Break	1030-1100 Break	1030-1100 Break
1100-1230 Training 2	1100-1230 Training 3	1100-1230 Training 3
1230-1330 Lunch	1230-1330 Lunch	1230-1330 Lunch
1330-1500 Training 3	1330-1500 Training 4	1330-1500 Training 4

Table 5. Midnight Shift Schedule for Each Nap Condition.

TIME	No Nap Group	Short Nap Group	Long Nap Group
2300-0030	ATST-Bakan-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	ATST-Bakan-ATST	ATST-Bakan-ATST	ATST-Bakan-ATST
0520-0530	Break	Break	Break
0530-0700	ATST-Bakan-ATST	ATST-Bakan-ATST	ATST-Bakan-ATST
0700-1200	Sleep	Sleep	Sleep
1300-1330	ATST	ATST	ATST

0130 and returned for testing at 0345. During the break for the Short Nap and No Nap groups, subjects relaxed in the break area. The subjects were not allowed to sleep during their break, but were permitted to read, watch television, or interact with other subjects during the break time. Test Session 2 was administered within 5 minutes after awakening from the nap, but no later than 0345. Subjects in all the conditions received a 15-minute break after Test Session 2 (0515-0530). At 0530, the final test session began. Upon completing Session 3, subjects were allowed to eat a light meal and return to their bedrooms to sleep/rest for five hours. After a lunch break, subjects completed a final ATST scenario from 1330 to 1400. Finally, subjects were debriefed and allowed to return to their homes.

The investigators 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 midnight shift was allowed at 2200. The subjects were allowed to consume light snacks during scheduled breaks. No foods or beverages were allowed during the testing period. Only light snacks and non-caffeinated beverages were allowed at any time during the night shift. One caffeinated beverage was allowed with breakfast if the subject normally consumed caffeine. No alcohol consumption was allowed throughout the laboratory protocol. All food and drink intake was recorded in the daily log book.

Cognitive performance. During orientation, subjects completed the computer-based instruction on the ATST and four practice sessions. They were also instructed on the Bakan. Subjects 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 or 28-minute ATST scenarios, separated by 30 minutes of the Bakan. The participants 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 participants 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.

Sleep EEG. The electrodes were attached the evening before the second night of sleep. Subjects slept with sensors attached to their scalp beginning the second night in the laboratory (Monday night). To attach the EEG electrodes, the scalp was measured according to the International 10-20 system for proper location of sites C3 and C4. Each placement site was rubbed with acetone to clean the scalp. Electrodes were placed on the site and secured with collodion. After each electrode was secured, it was filled with electrode paste. All impedances were maintained below 7-10 Kohms. EEG electrodes were referenced to the contralateral mastoid. The EOG and EMG sites were cleaned with acetone and the electrodes were filled with electrode cream, placed on the cleaned sites, and secured with tape. EOG was recorded from electrodes placed approximately 2 cm below the outer canthus of the left eye and 2 cm above the outer canthus of the right eye. Both eye electrodes were referenced to the left mastoid. Muscle tone was measured by submental electrodes. Only the EOG and EMG electrodes were removed each morning.

These were reattached before bedtimes each night, before testing on day 3, and before the midnight shift. The stages of sleep were determined by guidelines set forth by Rechtschaffen and Kales (1968).

Subjective measures. Subjects rated sleep quality 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 including the night shift before and after each test battery session.

Data Analysis

Sleep EEG and Wrist Activity Monitor measures. Data were used to: 1) assess sleep quality before the night shift, 2) determine the quality of the nap and ensure that the No Nap subjects did not sleep, 3) determine sleep stage at the termination of the nap and 4) to examine alertness during performance on the last day shift and the night shift. The EEG data will be reported elsewhere; however, nap data were examined to ensure that each of the participants actually met napping condition criteria. Data from the wrist activity monitors were used to determine the subject's activity before coming to the laboratory and were analyzed to determine sleep during the nap when EEG data were unavailable.

Records of participants in the Short Nap condition were scored for sleep from approximately 0245-0345, while records from subjects in the Long and No Nap conditions 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 subject to subject because it was set to the time in which EEG and EMG channels exhibited a clear reduction in muscle activity as the subject sat on the bed and lay down to sleep. Sleep stages were identified using Rechtshaffen and Kales (1968) as implemented in the Oxford polysomnography analysis software. 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 subjects in the No Nap condition were screened for evidence of sleep of 30 or more minutes in duration. Two subjects' records were found to meet this criteria, but no other records were found to have evidence of sleep. Data from subjects which exhibited sleep episodes lasting 30 or more minutes were excluded from the analysis of performance.

Study design and analyses. 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 midnight shift were analyzed using SPSS version 7.5 for Windows General Linear Model for repeated measures. Pillai's Trace multivariate analysis of variance results were 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 per Toothaker (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.

Cognitive performance measures. Analyses and handling of missing data were conducted for the ATST and Bakan as follows:

ATST — A total of 7 ATST scenarios were administered on the midnight shift. Only those scenarios that were included in a complete Session of ATST-Bakan-ATST were analyzed here. The third scenario was administered as a single problem prior to the napping conditions being announced and was not included in these analyses. A 3 (Nap Condition) X 2 (Gender) X 3 (Session) X 2 (Pre-Post Bakan) factorial design with repeated measures on Session and Pre-post was analyzed for Enroute Delay (ERD), Handoff Delay (HOD), Total Delay (TD), Procedural Errors (PE), Safety Errors (SE) and Total Errors (TE) for each of six ATST scenarios on the midnight shift. The ATST scenarios before and after each Bakan task were considered Pre- and Post-Bakan in the model.

Examination of the ATST data revealed 4 subjects with data consistently identified as outliers on a number of ATST measures. These subjects were excluded from the ATST analyses. The number of subjects in each group for analyses of the Error measures were as follows: 1) SNM, n=9; 2) SNF, n=10; 3) LNM, n=9; 4) LNF, n=9; 5) NNM, n=7; and 6) NNF, n=11. Data were lost for the Delay times (Enroute, Handoff and Total) for an additional 4 subjects. Because this occurred for all of the scenarios on the night shift, they were dropped from the analyses and no attempt was made to estimate values. The remaining number of subjects in each group for analyses of the Delay times were as follows: 1) SNM, n=8; 2) SNF, n=10; 3) LNM, n=8; 4) LNF, n=9; 5) NNM, n=7; and 6) NNF, n=9.

Bakan — A 3 (Nap Condition) X 2 (Gender) X 3 (Session) factorial design with repeated measures on Session was analyzed for 1) Correct Responses, 2) False Responses, and 3) Number/Letter Ratio Estimation. A total of three 30-minute Bakan Sessions were administered and analyzed for the midnight shift. To investigate the effects of time on task, each Bakan Session was broken down into six 5-minute blocks, resulting in a full model with two between-subjects factors (Nap Condition and Session) and two within-subjects factors (Session and Block). Planned multiple comparisons examined changes within and between groups for each Session.

Files for two subjects' performance data on the Bakan were corrupted, and therefore lost for the analyses. This included the second midnight shift session for one subject in the NNM group and the first three of the five-minute blocks during the first midnight shift session for one subject in the NNF group. Both cases were handled by substituting the missing values with the NNM and NNF group averages for those particular data points, respectively.

Subjective ratings. Analyses were conducted for three subjective measures, Sleep Quality Ratings (SQR), the PANAS, and the Stanford Sleepiness Scale (SSS). Subjective ratings of the four sleep quality dimensions and for the Overall Sleep Quality score were analyzed for the nap on the midnight shift in a 3 (Nap Condition) x 2 (Gender) factorial model. For the scores on the PANAS, subjective ratings of NA and PA for the beginning of the midnight shift and the end of the midnight shift were analyzed in a 3 (Nap Condition) x 2 (Gender) x 2 (Time) model with repeated measures on Time. One subject in the LNM group failed to respond to one adjective on the PANAS at the beginning of the midnight shift. The missing rating was replaced with the mean of all of the subject's own ratings for that adjective. SSS subjective ratings of sleepiness over the course of the midnight shift were analyzed in a 3 (Nap Condition) x 2 (Gender) x 3 (Session) x 2 (Pre-Post) model with repeated measures on Session and Pre-Post. A total of seven subjects failed to respond to the SSS questionnaire following the last work session of the midnight shift (1 NNF, 1 SNF, 1 SNM, 2 LNM, and 2 LNF). Scores were replaced for these individuals by group mean substitution.

RESULTS

EEG Analyses

Two NNM subjects were excluded from these analyses because they exhibited one sleep episode for a period of 30 minutes or greater during their break on the midnight shift. The remaining No Nap subjects did not exhibit sleep episodes during the break. Data from subjects in both Nap Conditions revealed sleep episodes consistent with the assigned Nap Condition.

Air Traffic Scenarios Test (ATST) Results

Results from this low fidelity air traffic control simulation were reported for six measures from the ATST: Enroute Delay (ERD), Handoff Delay (HOD), Total Delay (TD), Safety Errors (SE), Procedural Errors (PE), and Total Errors (TE).

Delay time. Analyses revealed significant Session by Nap Condition interactions for both HOD, $F(4,90)=3.03$, $p=.022$, and ERD, $F(4,90)=2.51$, $p=.047$. There were no significant findings for Total Delay or for Gender on any of the Delay measures. Tables 6 and 7 and Figures 1 and 2 present descriptive information for HOD and ERD by Nap Condition and Session, respectively, collapsed across Gender.

Multiple comparisons to investigate differences between Nap Conditions at each level of Session revealed no significant differences in HOD. The No Nap group ($M=45.7$) was found to have a significantly higher ERD on the last scenario at the end of the midnight shift than the Short Nap group ($M=35.3$), $t=2.03$, $p<.05$.

ATST errors. Results of the analyses of the three error measures — SE, PE, and TE — revealed no effects of Nap Condition. However, a significant interaction of Session by Gender was present for SE, $F(2,48)=4.19$, $p=.021$. Table 8 and Figure 3 present descriptive statistics for SE by Gender and Session.

Bakan Results

The Bakan provided a measure of vigilance. Three measures on the Bakan <Bullet>— Correct Responses, False Responses, and Number/Letter Ratio Estimation — were analyzed. Results from the three sessions on the night shift were as follows:

Correct responses. Results of the analysis revealed a significant interaction for Nap Condition by Session, $F(4.106)=5.097$, $p=.001$. Table 9 and Figure 4 present descriptive information for Correct Responses by Nap Condition and Session.

Table 6. Handoff Delay on the ATST Scenarios by Session and Nap Condition.

	Session					
	1		2		3	
	Pre	Post	Pre	Post	Pre	Post
No Nap Group (n=16)						
mean	10.0	9.3	9.2	8.9	10.7	10.5
sd	4.1	3.1	3.3	2.4	4.8	4.4
Short Nap Group (n=18)						
mean	8.4	8.6	9.3	9.3	8.9	9.6
sd	1.5	1.8	2.3	4.2	2.4	6.0
Long Nap Group (n=17)						
mean	9.6	8.8	10.1	8.3	9.6	9.1
sd	2.1	1.5	2.7	1.2	1.9	2.5

Table 7. Enroute Delay on the ATST Scenarios by Nap Condition and Session.

	Session					
	1		2		3	
	Pre	Post	Pre	Post	Pre	Post
No Nap Group (n=16)						
mean	44.4	37.6	40.6	45.3	45.0	45.7
sd	16.1	12.5	14.0	22.3	18.5	15.9
Short Nap Group (n=18)						
mean	40.5	33.5	37.5	38.3	39.8	35.3
sd	16.4	11.3	14.1	17.9	23.5	11.7
Long Nap Group (n=17)						
mean	48.3	36.8	42.2	38.7	41.6	39.9
sd	16.5	7.6	12.2	8.3	13.9	10.1

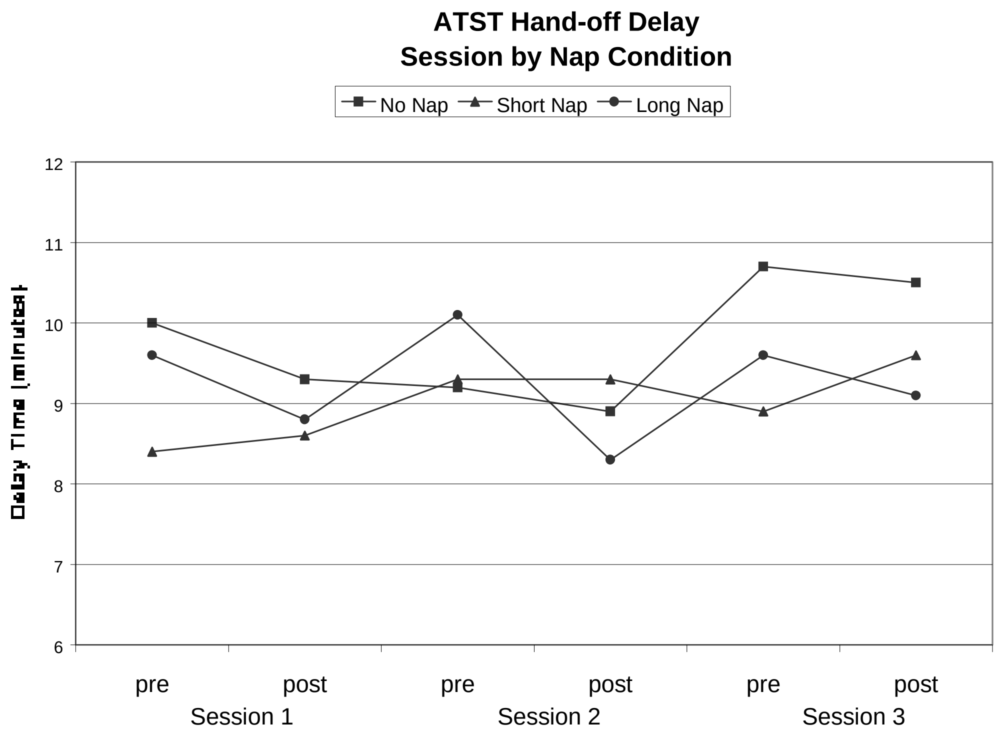

Figure 1. Handoff Delay Times by Nap Condition and Session.

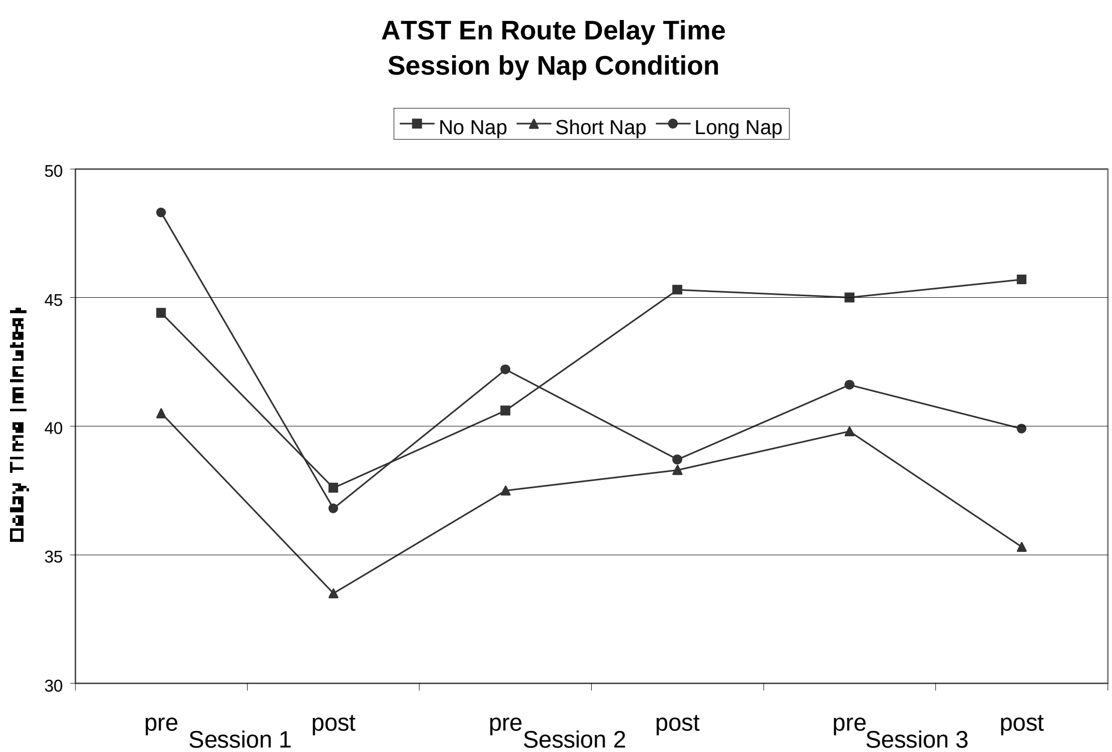

Figure 2. Enroute Delay Times by Nap Condition and Session.

Table 8. Safety Errors on the ATST Scenarios by Gender and Session.

	Session					
	1		2		3	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Males (n=25)						
mean	0.8	1.2	1.9	1.0	1.4	0.4
sd	1.9	1.2	2.1	1.6	1.7	1.0
Females (n=30)						
mean	1.3	0.9	1.5	0.8	1.4	1.6
sd	2.0	1.2	1.8	1.0	1.6	2.1

Table 9. Correct Responses on the Bakan by Nap Condition and Session.

	Session 1	**Session 2**	**Session 3**
No Nap (n=19)			
mean	125.8	109.1	96.5
sd	4.5	17.1	28.3
Short Nap (n=20)			
mean	118.7	118.1	109.7
sd	14.7	11.8	19.0
Long Nap (n=20)			
mean	125.1	123.4	115.7
sd	7.1	7.9	16.9

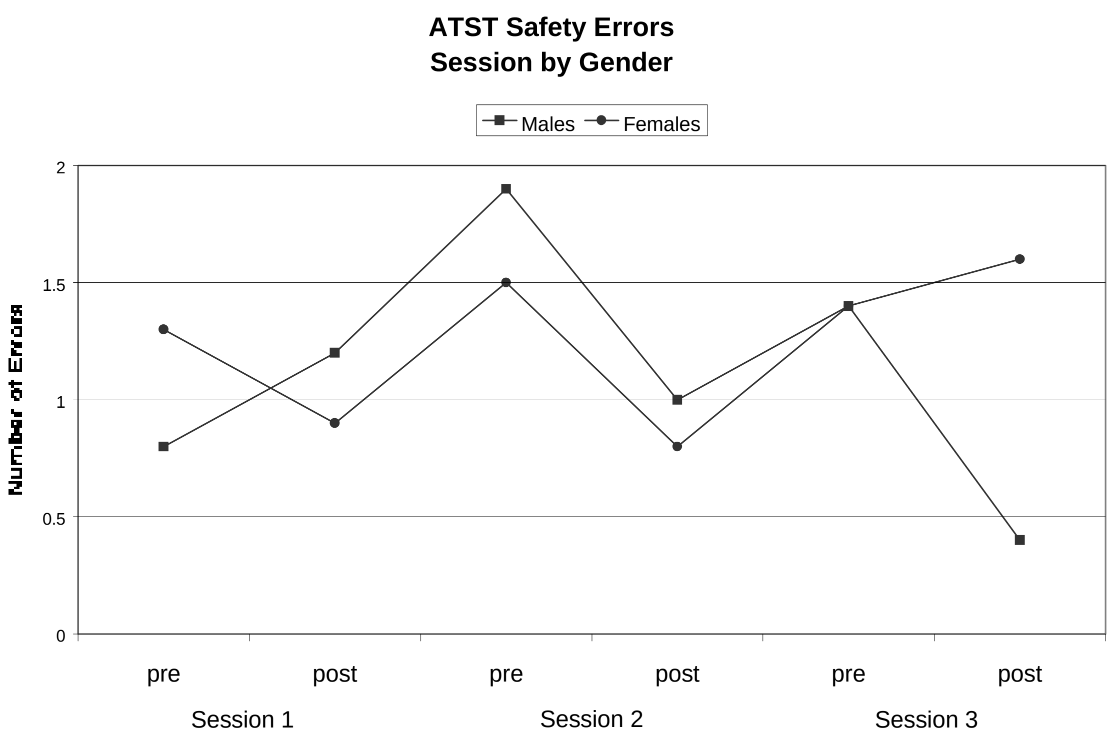

Figure 3. ATST Safety Errors by Gender and Session.

Multiple comparisons to investigate the differences between Gender at each level of Session revealed that the males (M=0.4) had 1.2 fewer errors on average than the females (M =1.6) in the last scenario of the midnight shift, t=3.09, p<.05.

Multiple comparisons to investigate cell mean differences within each level of Session and Nap Condition revealed a pattern of decline in performance in all of the nap groups. The No Nap group demonstrated a consistent, significant pattern of decline at each Session from M=125.8 in Session 1 to M=96.5 in Session 3. Within both of the Nap Conditions, only the performance on the third Session was found to be significantly lower than Sessions 1 and 2. Thus, both Nap Conditions protected performance on Correct Responses in the Session following the nap, but some decrement was observed in the final Session of the midnight shift. Results of the multiple comparisons were as follows:

No Nap Group (CV(18,3)=2.64):

- Session 1 was significantly higher than Session 2, $t(18)=4.46$, $p<.05$
- Session 1 was significantly higher than Session 3, $t(18)=4.67$, $p<.05$
- Session 2 was significantly higher than Session 3, $t(18)=3.16$, $p<.05$

Short Nap Group (CV(19,3)=2.62):

- Session 1 was significantly higher than Session 3, $t(19)=4.30$, $p<.05$
- Session 2 was significantly higher than Session 3, $t(19)=3.93$, $p<.05$

Long Nap Group (CV(19,3)=2.62):

- Session 1 was significantly higher than Session 3, $t(19)=3.05$, $p<.05$
- Session 2 was significantly higher than Session 3, $t(19)=3.15$, $p<.05$

Multiple comparisons between groups at each level of Session revealed a pattern in which the Long Nap condition protected performance compared to the Short Nap and No Nap groups. Results revealed the following significant differences.

- LN Session 2 was significantly higher than NN Session 2, $t=2.78$, $p<.05$
- LN Session 3 was significantly higher than NN Session 3, $t=2.14$, $p<.05$
- LN Session 3 was significantly higher than SN Session 3, $t=2.57$, $p<.05$

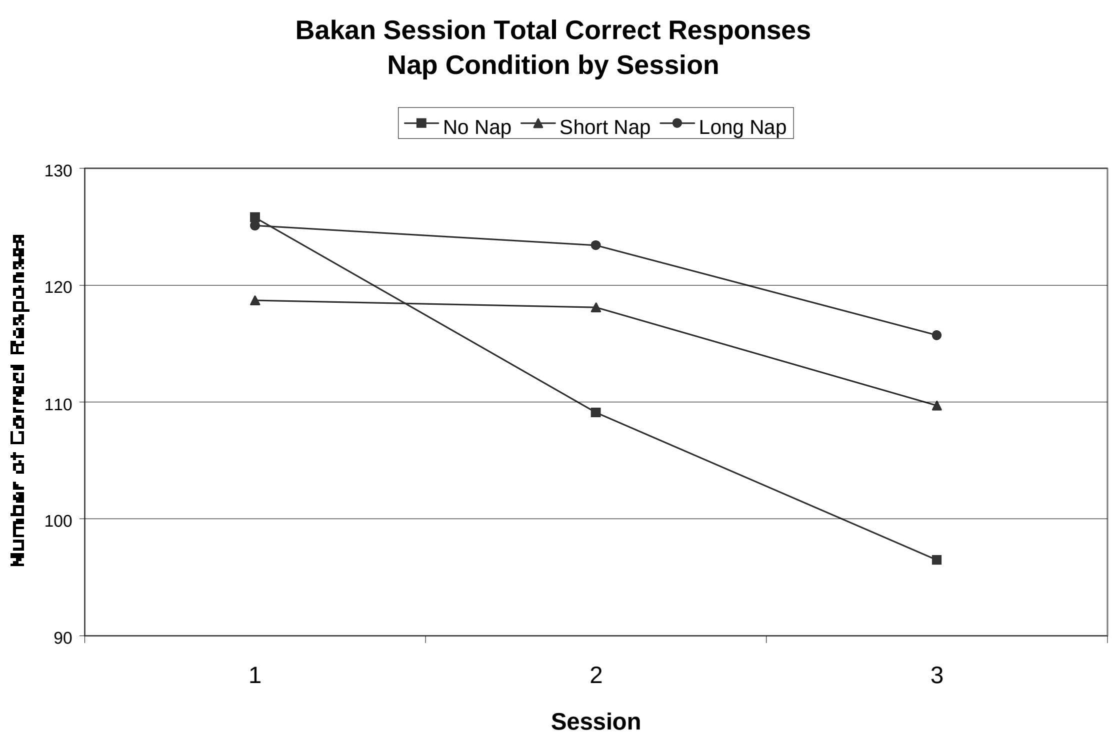

Figure 4. Bakan Correct Responses by Nap Condition and Session.

Table 10. False Responses on the Bakan by Nap Condition and Session.

	Session 1	Session 2	Session 3
No Nap (n=19)			
mean	1.5	4.7	9.0
sd	1.2	4.2	5.9
Short Nap (n=20)			
mean	3.0	3.8	5.6
sd	2.8	3.7	5.0
Long Nap (n=20)			
mean	2.2	2.0	3.4
sd	1.9	1.9	3.7

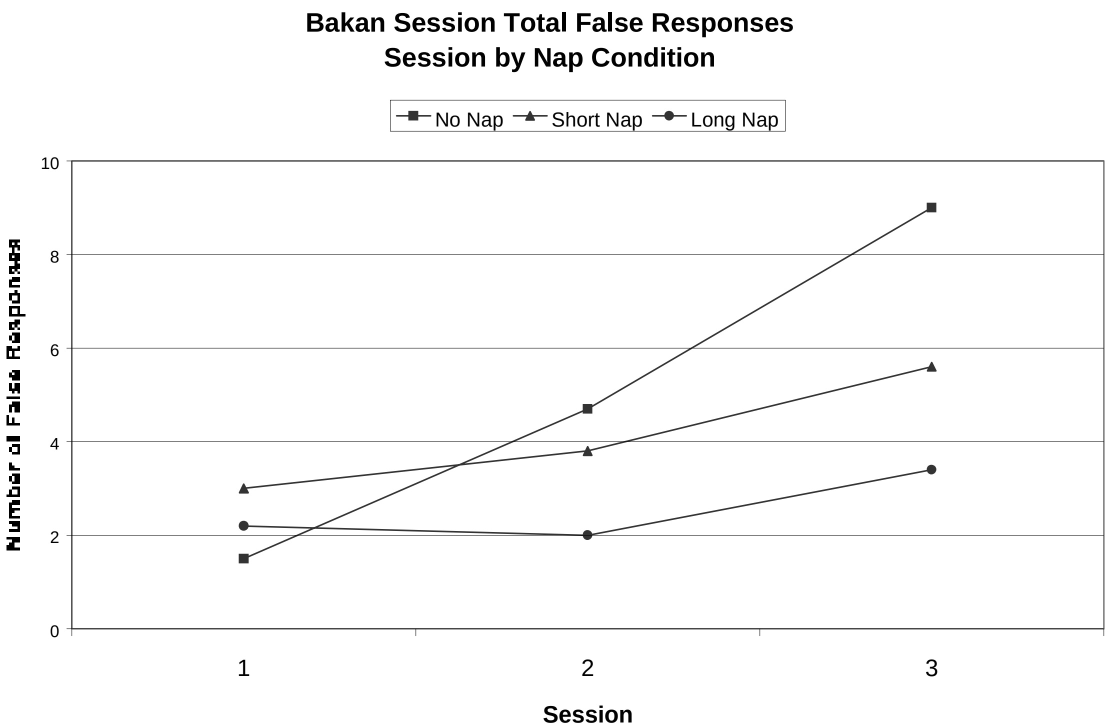

Figure 5. Bakan False Responses Nap Condition by Session.

False responses. Results of the analysis of false responses revealed a significant Session by Nap Condition interaction, F(4,106)=4.085, p=.004 and a significant Session by Gender interaction, F(2,52)=3.425, p=.04. Table 10 and Figure 5 present descriptive statistics for false responses by Session and Nap Condition.

Multiple comparison procedures to investigate cell mean comparisons within each level of Session and Nap Condition revealed the anticipated pattern of significant decrement in performance from session to session across the midnight shift for the No Nap condition. As with the data for the Short Nap group on correct responses, performance was protected during the session following the nap (Session 2), but some increases in false responses were observed by the final session of the shift (Session 3). For the SN group, mean false responses for the first two Sessions were 3.0 and 3.8, respectively. SN false responses increased to 5.6 by Session 3. There were no significant increases in false responses in the Long Nap group revealing protection of performance on false responses for the entire shift. The results of the multiple comparisons were as follows:

No Nap Group (CV(18,3)=2.64:
- Session 1 was significantly lower than Session 2, t(18)=3.68, p<.05
- Session 1 was significantly lower than Session 3, t(18)=5.85, p<.05
- Session 2 was significantly lower than Session 3, t(18)=4.49, p<.05

Short Nap Group (CV(19,3)=2.62:
- Session 1 was significantly lower than Session 3, t(19)=2.80, p<.05
- Session 2 was significantly lower than Session 3, t(19)=2.67, p<.05

Long Nap Group (CV(19,3)=2.62:
- No significant differences between Sessions.

Multiple comparisons between groups at each level of Session revealed significant protection of performance for both the Long Nap and Short Nap groups compared to the No Nap group. Multiple comparisons resulted in the following significant differences.
- LN Session 2 was significantly lower than NN Session 2, t=2.25, p<.05
- SN Session 3 was significantly lower than NN Session 3, t=2.81, p<.05
- LN Session 3 was significantly lower than NN Session 3, t=4.66, p<.05

Table 11 and Figure 6 present descriptive statistics for false responses related to the significant Session by Gender interaction.

Multiple comparison procedures to investigate cell mean comparisons within each level of Gender and Session revealed a pattern of declining performance across the midnight shift for both males and females. The females, however, did not show a significant decline until the final Session of the midnight shift.

Males (CV(27,3)=2.56:
- Session 1 was significantly lower than Session 2, t(27)=2.68, p<.05
- Session 1 was significantly lower than Session 3, t(27)=4.01, p<.05
- Session 2 was significantly lower than Session 3, t(27)=3.00, p<.05

Females (CV(30,3)=2.54:
- Session 1 was significantly lower than Session 3, t(30)=3.91, p<.05
- Session 2 was significantly lower than Session 3, t(30)=4.70, p<.05

Multiple comparisons between Gender at each level of Session revealed no significant differences.

Number/Letter Ratio Estimation. Analyses conducted on the Bakan number/letter ratio estimation task revealed no significant differences.

Table 11. False Responses on the Bakan by Gender and Session.

	Session 1	Session 2	Session 3
Males (n=28)			
mean	2.25	3.99	5.43
sd	2.24	3.67	4.09
Females (n=31)			
Mean	2.19	3.03	6.48
sd	2.10	3.34	6.29

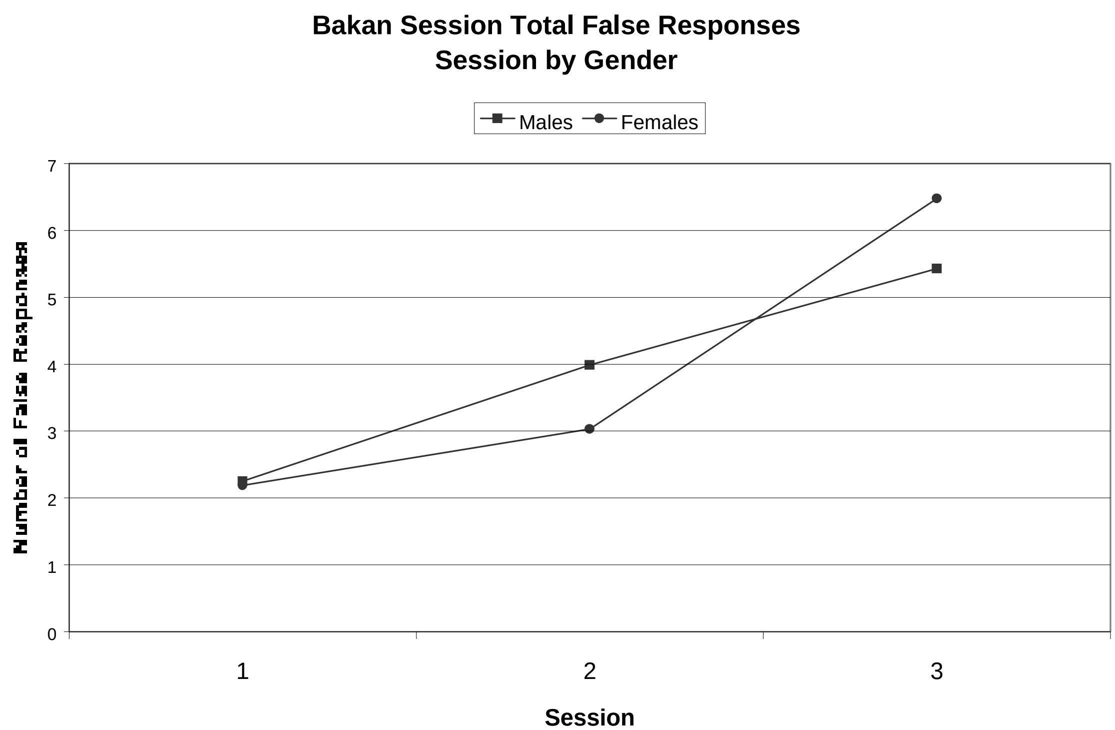

Figure 6. Bakan False Responses by Gender and Session.

Time on Task. To better understand the protective effects of naps revealed by the previous analyses, the Bakan data were examined for the changes in performance with time-on-task within each Bakan Session. Each 30-minute Bakan session was analyzed by the six 5-minute blocks for each of the three Bakan measures (Correct Responses, False Responses, and Number/Letter Ratio Estimation). The model included two between-subjects factors (Nap Condition and Session) and two within-subjects factors (Session and Block). Planned comparisons involved examining the changes within Session. Results of the analyses for False Responses and Number/Letter Ratio Estimation revealed no significant findings for Block.

Correct Responses

Results of this analysis revealed a significant three-way Nap Condition by Session by Block interaction, $F(20,90)=2.59$, $p=.001$. The following section presents results for each Session.

Table 12. Bakan Correct Responses for Session 1 by Nap Condition and 5-minute Block.

	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
No Nap						
mean	21.2	21.0	21.1	21.2	20.8	20.5
sd	1.0	1.1	1.1	1.5	1.4	1.7
Short Nap						
mean	20.8	20.9	19.6	19.7	19.1	18.8
sd	1.2	1.4	2.9	3.7	3.9	4.7
Long Nap						
mean	21.6	21.3	20.7	20.4	20.8	20.3
	0.6	1.1	3.1	2.1	1.5	1.9

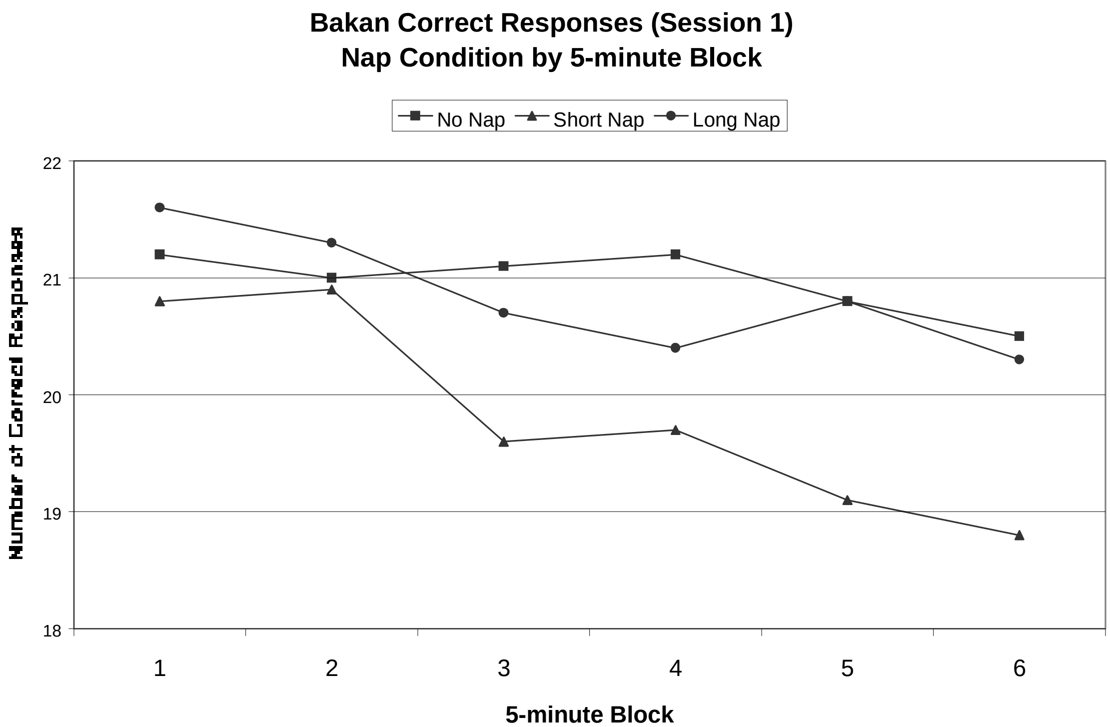

Figure 7. Bakan Correct Responses for Nap Condition by Block for Session 1.

Session 1 correct responses. Descriptive statistics for Session 1 correct responses on the Bakan test by Nap Condition and Block are presented in Table 12 and Figure 7.

Multiple comparisons within each group, based on Dunn (n-1, C) and a paired t-test, revealed no significant differences. Multiple comparisons between Nap Condition groups revealed that even though the Short Nap group did not show a significant decline on the within subject comparisons, they averaged significantly lower Correct Responses than both the Long Nap and No Nap groups on Block 5 and lower than the NN on Block 6. The following values were computed for the multiple comparisons:

- SN Block 5 was significantly lower than NN Block 5, t=2.08, p,.05
- SN Block 5 was significantly lower than LN Block 5, t=2.15, p<.05
- SN Block 6 was significantly lower than NN Block 6, t=2.06, p<.05

Table 13. Bakan Test Correct Responses for Session 2 by Nap Condition and 5-minute Block.

	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
No Nap						
Mean	20.2	19.3	17.5	17.7	17.4	17.0
sd	2.3	3.8	4.2	3.4	2.9	4.9
Short Nap						
Mean	21.1	20.8	20.35	19.3	18.3	18.5
sd	1.3	1.5	1.9	2.6	3.4	3.4
Long Nap						
Mean	21.2	20.5	20.6	20.6	20.4	20.2
sd	1.1	2.0	1.2	2.1	2.0	2.1

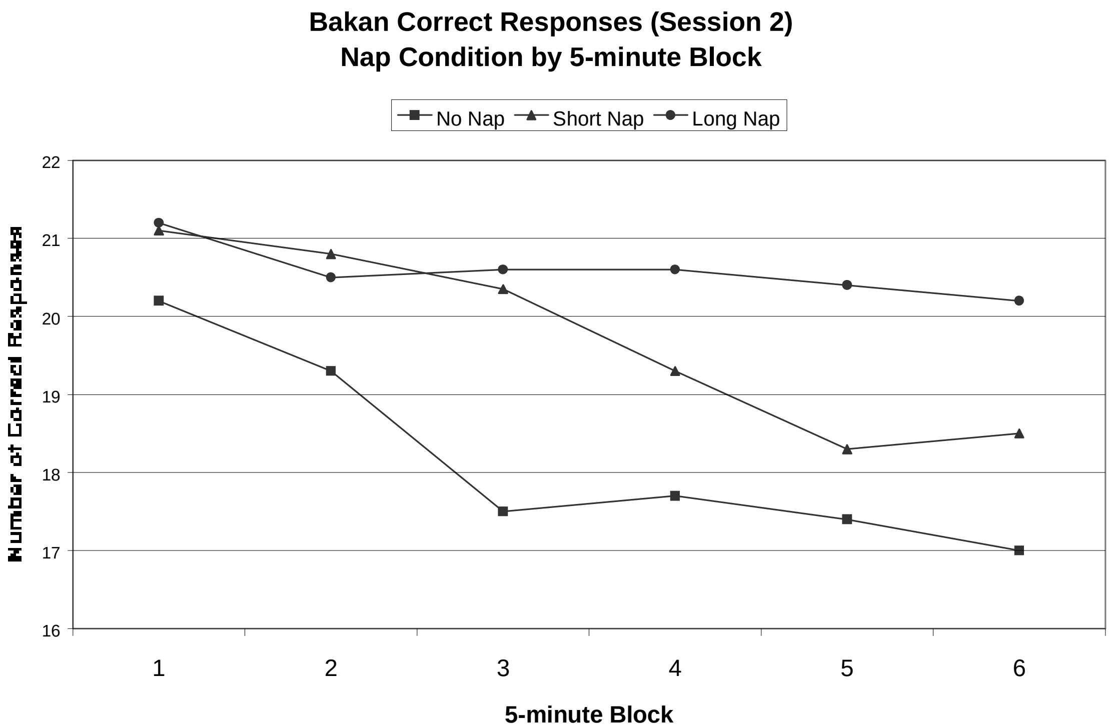

Figure 8. Bakan Correct Responses for Nap Condition by Block for Session 2.

Session 2 correct responses. Descriptive statistics for Session 2 correct responses on the Bakan test are presented in Table 13 and Figure 8.

Multiple comparison procedures to investigate within Nap Condition cell mean comparisons for each level of Block in Session 2 revealed the beginning of performance decrements by Block 5 across the session for the No Nap and Short Nap groups. No significant differences were found in the Long Nap group. The following significant differences were observed:

No Nap Group (CV(18,30)=3.69:

- Block 1 was significantly higher than Block 5, t(18)=4.35, p<.05

Short Nap Group (CV(19,30)=3.66:

- Block 1 was significantly higher than Block 5, t(19)=4.15, p,.05
- Block 1 was significantly higher than Block 6, t(19)=3.92, p<.05
- Block 2 was significantly higher than Block 5, t(19)=3.89, p<.05
- Block 2 was significantly higher than Block 6, t(19)=3.79, p<.05
- Block 3 was significantly higher than Block 5, t(19)=4.23, p<.05
- Block 3 was significantly higher than Block 6, t(19)=3.75, p<.05

Long Nap Group (CV(19,30)=3.66:

- No significant differences between Blocks.

Multiple comparisons between Nap Conditions revealed that although the Short Nap group's performance demonstrated a significant decline across the Session, they performed better than the NN group at Block 3. The Long Nap protected performance compared to both the Short Nap and No Nap groups in the last three blocks of the Session. The following significant differences were observed:

- SN Block 3 was significantly higher than NN Block 3, t=3.46, p<.05
- LN Block 3 was significantly higher than NN Block 3, t=3.70, p<.05
- LN Block 4 was significantly higher than SN Block 4, t=2.21, p<.05
- LN Block 4 was significantly higher than NN Block 4, t=3.45, p<.05
- LN Block 5 was significantly higher than SN Block 5, t=2.65, p<.05
- LN Block 5 was significantly higher than NN Block 5, t=3.49, p<.05
- LN Block 6 was significantly higher than SN Block 6, t=2.15, p<.05
- LN Block 6 was significantly higher than NN Block 6, t=3.83, p<.05

Table 14. Bakan Correct Responses for Session 3 by Nap Condition and 5-minute Block.

	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
No Nap						
Mean	18.6	17.6	15.5	14.1	15.2	15.4
sd	4.0	4.5	5.9	6.5	4.7	5.4
Short Nap						
Mean	19.2	19.1	18.3	18.2	17.8	17.2
sd	3.6	2.9	3.8	3.9	3.7	4.5
Long Nap						
Mean	20.7	19.3	19.9	18.8	18.6	18.6
	1.8	3.5	3.2	3.6	4.0	3.7

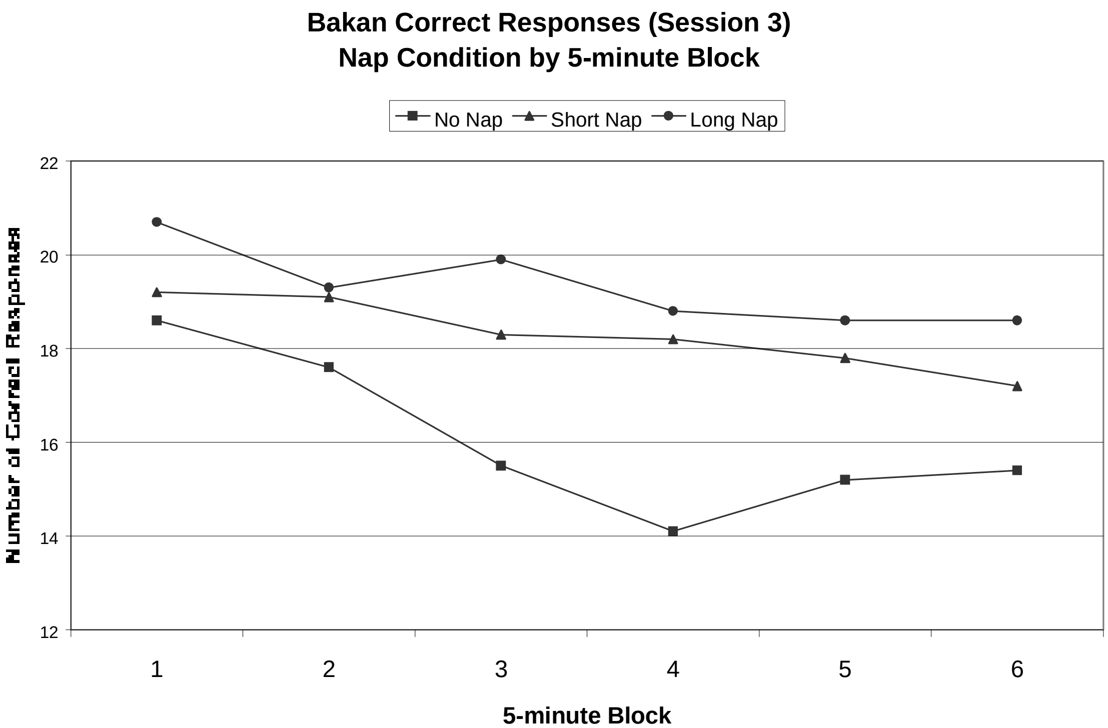

Figure 9. Bakan Correct Responses for Nap Condition by Block for Session 3.

Session 3 correct responses. Descriptive statistics for Session 3 correct responses on the Bakan test are presented in Table 14 and Figure 9.

Multiple comparisons for within Nap Condition for each level of Block, revealed a pattern suggesting that both the Long Nap and the Short Nap protected performance across the entire final session of the midnight shift. The following significant differences were found for the within group comparisons:

No Nap Group (CV(18,30)=3.69:

- Block 1 was significantly higher than Block 3, t(18)=3.76, p<.05
- Block 1 was significantly higher than Block 4, t(18)=4.62, p<.05
- Block 1 was significantly higher than Block 5, t(18)=4.32, p<.05
- Block 2 was significantly higher than Block 4, t(18)=4.51, p<.05
- Block 2 was significantly higher than Block 5, t(18)=3.83, p<.05

Short Nap Group (CV(19,30)=3.66):

No significant differences between Blocks.

Table 15. Means and standard deviations for sleep quality ratings by Nap Condition and Gender.

	Short Nap (45 min.)		Long Nap (120 min.)	
	male	female	male	female
Difficulty Falling Asleep				
mean	4.1	3.9	4.1	4.0
sd	1.5	1.1	1.0	0.8
Depth of Sleep				
mean	4.2	3.8	4.4	4.4
sd	1.3	0.8	1.0	0.7
Difficulty Arising From Sleep				
mean	3.1	2.5	2.6	3.5
sd	0.9	1.3	0.8	1.3
Level of Restedness				
mean	2.7	1.8	2.9	3.3
sd	1.2	0.8	0.7	0.9
Overall Sleep Quality Rating				
mean	14.1	12.0	14.0	15.2
sd	3.4	2.4	2.4	2.4

Long Nap Group (CV(19,30)=3.66):
No significant differences between Blocks.

Results of the multiple comparisons between Nap Conditions revealed the following significant differences:

- LN Block 1 was significantly higher than NN Block 1, t=2.48, p,.05
- LN Block 3 was significantly higher than NN Block 3, t=5.17, p<.05
- SN Block 3 was significantly higher than NN Block 3, t=3.32, p<.05
- LN Block 4 was significantly higher than NN Block 4, t=4.84, p<.05
- SN Block 4 was significantly higher than NN Block 4, t=5.56, p<.05
- LN Block 5 was significantly higher than NN Block 5, t=4.06, p<.05
- SN Block 5 was significantly higher than NN Block 5, t=3.04, p<.05
- LN Block 6 was significantly higher than NN Block 6, t=3.81, p<.05
- SN Block 6 was significantly higher than NN Block 6, t=2.07, p,.05

False responses and number/letter ratio estimation. Results of the analyses revealed no interactions or main effects of the Block factor.

Subjective Measures

The subjective measures included sleep quality, PANAS mood scale, and Stanford Sleepiness Scale ratings.

Sleep Quality Ratings

To assess the quality of the naps taken on the midnight shift, sleep quality ratings (SQR) were compared by Nap Condition and by Gender. Means and standard deviations for each SQR component and the overall SQR are presented in Table 15.

The two factor analysis of variance for Nap Condition and Gender revealed no significant effects for the overall SQR. The analysis resulted in significant Nap Condition by Gender interactions for two of the SQR components: 1) Difficulty Arising from Sleep F(1,36)=4.787, p=.035 and 2) Level of Restedness F(1,36)=4.954, p=.032.

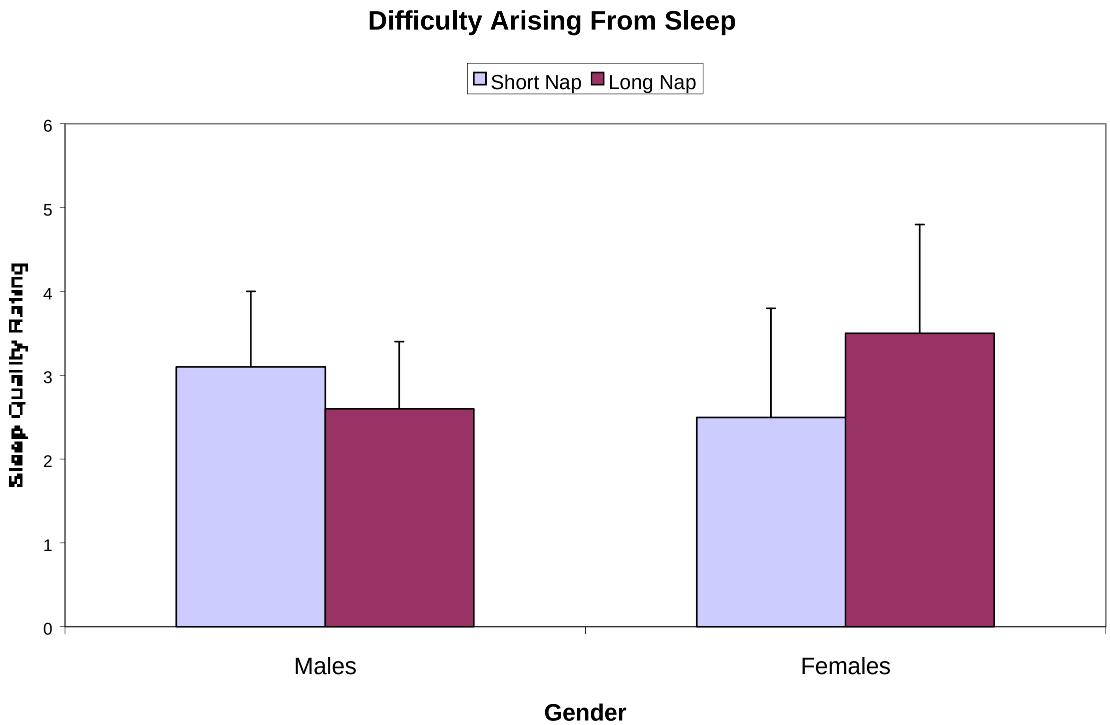

Figure 10. Sleep Quality Rating for Difficulty Arising by Nap Condition and Gender.

Figure 10 illustrates the Nap Condition by Gender interaction for the sleep quality item, Difficulty Arising from Sleep. The interaction indicates that females in the LN group reported greater difficulty arising than those in the SN group and that this pattern was reversed for males. Tests of simple effects, however, indicated that the differences between Nap Condition within Gender were not significant.

Figure 11 illustrates the Nap Condition by Gender interaction for the sleep quality item, Level of Restedness. Tests of simple effects indicated that the LN females reported feeling significantly more rested ($M=3.3$) than the SN females ($M=1.8$), $F(1,18)=14.78$, $p<.001$. No differences in restedness were found between Nap Conditions for the males.

Positive Affect and Negative Affect Scale (PANAS)

To assess the effect of Nap Condition and Gender on the positive (PA) and negative affect (NA) ratings on the PANAS, mood ratings were compared for the beginning and end of the midnight shift. Means and standard deviations for PA and NA are presented in Tables 16 and 17, respectively.

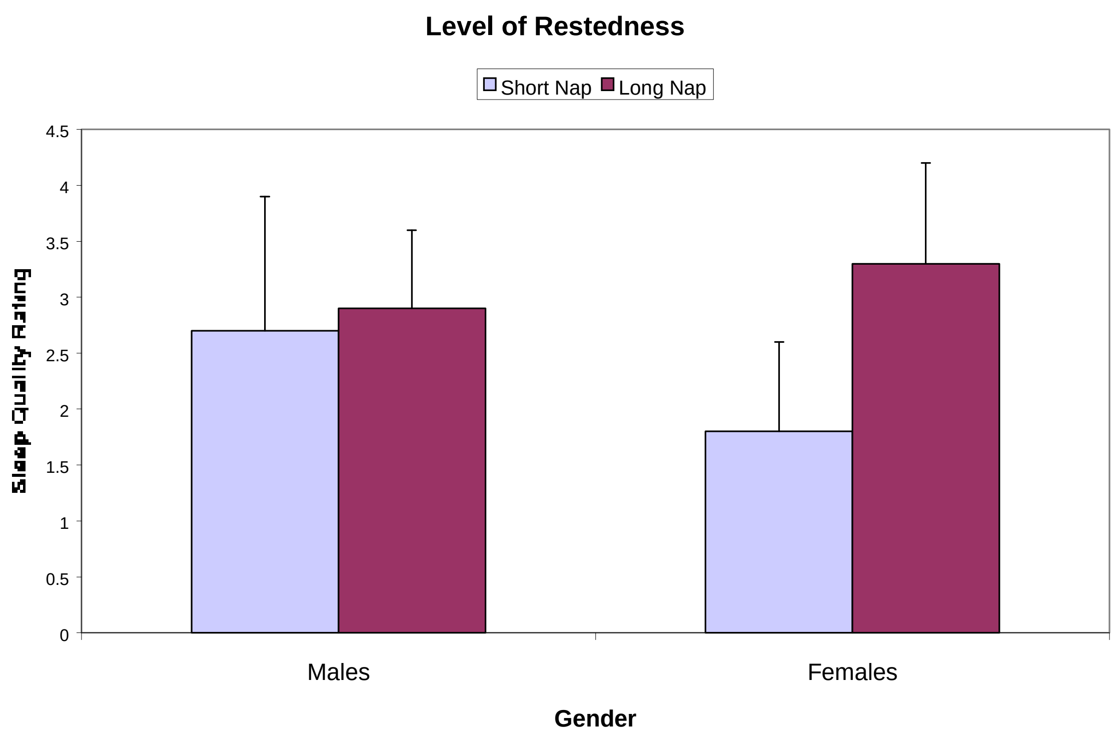

Figure 11. Sleep Quality Rating for Level of Restedness by Nap Condition and Gender.

Table 16. Means and standard deviations for Positive Affect (PA) ratings Before and After the Midnight Shift by Nap Condition and Gender.

	Before Midnight Shift		After Midnight Shift	
Nap Condition	**Males**	**Females**	**Males**	**Females**
No Nap				
mean	24.6	17.0	15.5	11.5
sd	8.8	5.8	8.8	3.1
Short Nap				
mean	22.6	16.2	14.6	12.0
sd	9.7	6.5	6.6	3.6
Long Nap				
mean	22.9	17.8	19.1	14.3
sd	9.9	6.1	8.4	4.4

Table 17. Means and standard deviations for Negative Affect (NA) ratings Before and After the Midnight Shift by Nap Condition and Gender.

	Before Midnight Shift		After Midnight Shift	
Nap Condition	**Males**	**Females**	**Males**	**Females**
No Nap				
mean	11.8	11.0	12.4	12.5
sd	1.8	2.1	1.9	2.4
Short Nap				
mean	10.3	10.8	12.3	13.6
sd	0.7	0.9	2.8	3.6
Long Nap				
mean	11.9	10.9	13.0	11.9
sd	3.0	1.6	3.7	2.5

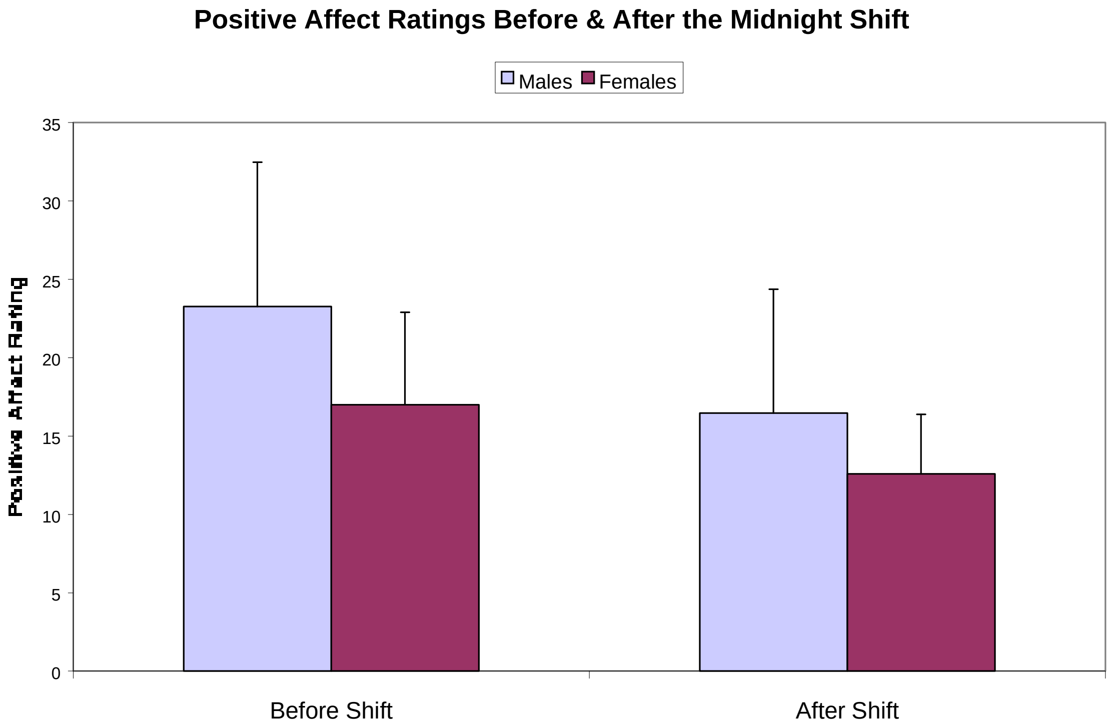

Figure 12. PANAS Positive Affect before and after the midnight shift.

A three-factor analysis of variance, with two between-subjects factors (Nap Condition and Gender) and one within-subjects factor (Time) revealed a significant main effect for Time on NA, $F(1,53)=24.3$, $p<.001$. Ratings of NA were higher at the end of the midnight shift (M=12.6) than at the beginning of the midnight shift (M=11.1). The analysis revealed a significant Gender by Time interaction for PA, $F(1,53)=4.1$, $p=.048$. Figure 12 illustrates the Gender by Time interaction for PA.

The interaction was further investigated for simple effects. Results revealed that males rated PA higher than females both before the midnight shift, $t(45.4)=3.07$, $p=.004$ and after the midnight shift, $t(37.8)=2.37$, $p=.018$. In addition, both males and females rated PA higher at the beginning of the midnight shift than at the end of the midnight shift, $t(27)=6.153$, $p<.001$ and $t(30)=5.982$, $p<.001$, respectively.

Stanford Sleepiness Scale

A four-factor analysis of variance, with two between-subjects factors (Nap Condition and Gender) and two within-subjects factors (Session and Pre-post Session) revealed a significant three-way interaction for Nap Condition by Session by Pre-post Session, $F(4,106)=4.077$, $p=.004$ and a significant Nap Condition by Gender interaction, $F(2,53)=6.801$, $p=.002$. Table 18 and Figure 13 present descriptive statistics for SSS.

Multiple comparisons to investigate differences between ratings within Nap and Gender groups were conducted in three ways: between all Pre-session ratings, between all Post-session ratings, and between Pre and Post ratings for each session. This resulted in a total of 9 comparisons within each group. Results of the comparisons were as follows:

No Nap Males (CV(7, 9)=3.95):

- Session 2 Pre was significantly higher than Session 1 Pre, $t(7)=5.02$, $p<.05$
- Session 3 Pre was significantly higher than Session 1 Pre, $t(7)=8.10$, $p<.05$
- Session 3 Pre was significantly higher than Session 2 Pre, $t(7)=5.29$, $p<.05$
- Session 2 Post was significantly higher than Session 1 Post, $t(7)=5.29$, $p<.05$

Table 18. Means and Standard Deviations for Stanford Sleepiness Scale Scores on the Midnight Shift by Nap Condition and Gender.

	Session 1		Session 2		Session 3	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
NNM						
mean	2.75	3.62	4.38	5.62	5.38	6.38
sd	1.04	0.74	1.19	1.06	0.92	0.92
NNF						
mean	2.64	3.36	4.00	5.18	5.09	6.00
sd	0.67	0.92	1.18	1.47	1.14	1.10
SNM						
mean	2.50	2.80	3.80	3.30	3.50	4.11
sd	1.35	1.03	1.48	1.34	1.27	1.79
SNF						
mean	3.90	4.60	4.90	5.10	4.90	5.89
sd	0.99	0.97	1.10	0.99	1.20	0.99
LNM						
mean	2.90	3.30	4.10	3.80	3.40	4.63
sd	1.29	1.49	1.29	1.32	1.35	1.15
LNF						
mean	2.80	3.40	3.20	3.80	3.40	5.00
sd	0.63	0.70	0.79	1.14	0.84	1.05

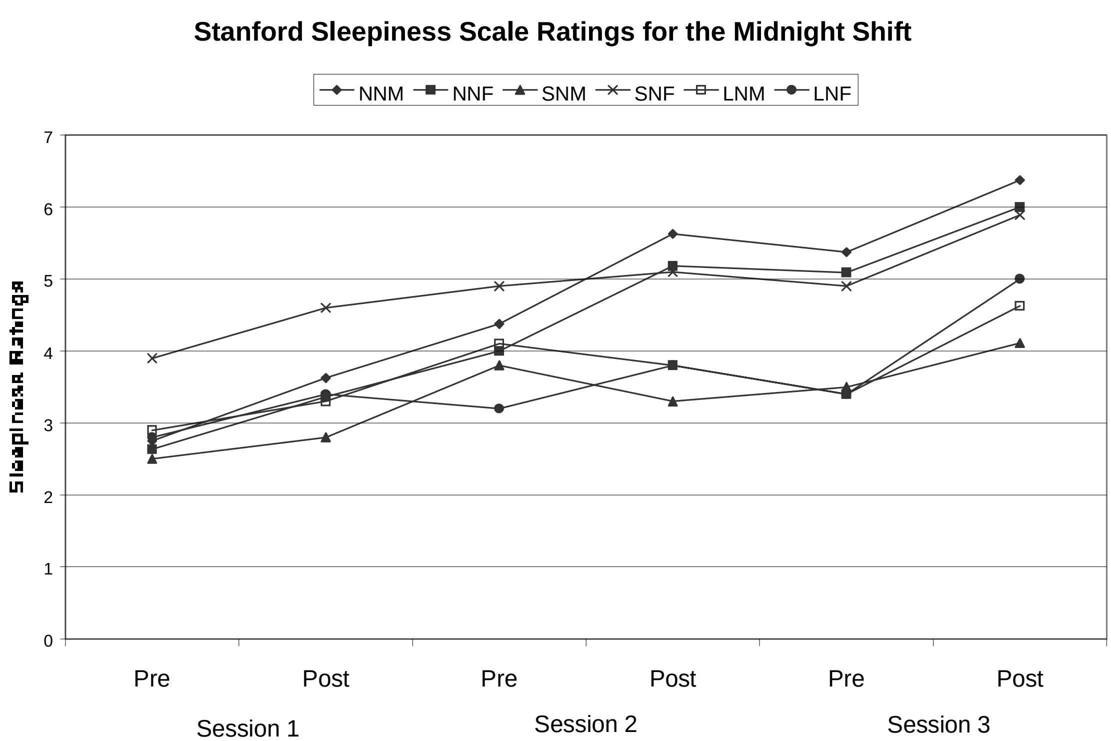

Figure 13. Stanford Sleepiness Scale by Nap Condition, Session and Pre-Post.

- Session 3 Post was significantly higher than Session 1 Post, $t(7)=6.67$, $p<.05$
- Session 3 Post was significantly higher than Session 2 Post, $t(7)=4.58$, $p<.05$
- Pre and Post comparisons were not significantly different for any Session.

No Nap Females (CV(10, 9)=3.52):

- Session 2 Pre was significantly higher than Session 1 Pre, $t(10)=4.89$, $p<.05$
- Session 3 Pre was significantly higher than Session 1 Pre, $t(10)=7.86$, $p<.05$
- Session 3 Pre was significantly higher than Session 2 Pre, $t(10)=5.16$, $p<.05$
- Session 2 Post was significantly higher than Session 1 Post, $t(10)=4.54$, $p<.05$
- Session 3 Post was significantly higher than Session 1 Post, $t(10)=7.25$, $p<.05$
- Session 1 Post was significantly higher than Session 1 Pre, $t(10)=3.73$, $p<.05$
- Session 2 Post was significantly higher than Session 2 Pre, $t(10)=3.99$, $p<.05$
- Session 3 Post was significantly higher than Session 3 Pre, $t(10)=3.63$, $p<.05$

Short Nap Males (CV(9, 9)=3.63:

- No significant differences.

Short Nap Females (CV(9, 9)=3.63:

- Pre-session ratings were not significantly different.
- Session 3 Post was significantly higher than Session 1 Post, $t(9)=4.84$, $p<.05$
- Session 3 Post was significantly higher than Session 2 Post, $t(9)=3.85$, $p<.05$
- Session 1 Post was significantly higher than Session 1 Pre, $t(9)=4.58$, $p<.05$

Long Nap Males (CV(9, 9)=3.63:

- Session 2 Pre was significantly higher than Session 1 Pre, $t(9)=3.67$, $p<.05$
- Post-session ratings were not significantly different.
- Pre and Post comparisons were not significantly different for any Session.

Long Nap Females (CV(9, 9)=3.63:

- Pre-session ratings were not significantly different.
- Session 3 Post was significantly higher than Session 1 Post, $t(9)=4.31$, $p<.05$
- Session 3 Post was significantly higher than Session 2 Post, $t(9)=6.00$, $p<.05$
- Session 3 Post was significantly higher than Session 3 Pre, $t(9)=4.71$, $p<.05$

Multiple comparisons to investigate differences between Nap and Gender groups within ratings were conducted on three rating times (Session 1 Pre, Session 2 Pre, and Session 3 Post) to determine if differences existed between groups at the beginning of the shift, immediately following the nap/break, and at the end of the shift. Results of the comparisons were as follows:

Session 1 Pre (Beginning of Shift):

- SNF were significantly higher than NNM, $t=2.20$, $p<.05$
- SNF were significantly higher than NNF, $t=3.06$, $p<.05$
- SNF were significantly higher than SNM, $t=3.40$, $p<.05$
- SNF were significantly higher than LNM, $t=2.43$, $p<.05$
- SNF were significantly higher than LNF, $t=2.67$, $p<.05$

Session 2 Pre (Immediately after nap/break):

- SNF were significantly higher than NNF, $t=2.18$, $p<.05$
- SNF were significantly higher than SNM, $t=2.67$, $p<.05$
- SNF were significantly higher than LNF, $t=4.12$, $p<.05$
- LNM were significantly higher than LNF, $t=2.18$, $p<.05$
- NNM were significantly higher than LNF, $t=2.26$, $p<.05$

Session 3 Post (End of Shift):

- NNM were significantly higher than SNM, $t=4.34$, $p<.05$
- NNM were significantly higher than LNM, $t=3.35$, $p<.05$
- NNM were significantly higher than LNF, $t=2.64$, $p<.05$
- NNF were significantly higher than SNM, $t=4.58$, $p<.05$
- NNF were significantly higher than LNM, $t=3.32$, $p<.05$

- NNF were significantly higher than LNF, $t=2.43$, $p<.05$
- SNF were significantly higher than SNM, $t=4.32$, $p<.05$
- SNF were significantly higher than LNM, $t=3.06$, $p<.05$
- SNF were significantly higher than LNF, $t=2.16$, $p<.05$
- LNF were significantly higher than SNM, $t=2.16$, $p<.05$

DISCUSSION

The findings from this study revealed that both a long nap of 2 hours duration and a shorter nap of 45 minutes duration can significantly protect performance during a midnight shift. The long nap, however, resulted in more consistent findings. The results in this study were most evident in the Bakan vigilance task and subjective ratings. The findings were important in demonstrating the effectiveness of napping as a countermeasure to performance decrement and sleepiness on the midnight shift on tasks requiring skills and abilities similar to those required in safety critical jobs such as Air Traffic Control Specialist.

The ATST and Bakan were selected because they assessed different abilities. The ATST simulated ATC tasks. The workload was high to simulate a scenario in which a napping ATCS would be asked to resume air traffic control duties during high workload condition. The Bakan was selected because it imposed a boring, low workload, vigilance condition. The Bakan had been demonstrated to be sensitive to variations in alertness and sleepiness (Dollins et al., 1993).

The findings from the Bakan revealed the anticipated performance decrement across the midnight shift in the No Nap group in both Correct Responses and False Responses. The decrements in the No Nap group between the first and last Session represented a decrease of 23% in Correct Responses and an increase in false responding of 600% from an average of 1.5 in Session 1 to 9.0 in Session 3. 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 in this study. Performance on both Correct Responses and False Responses was better for the Long Nap group than the No Nap group for both sessions after the nap. The Long Nap group performed better than the Short Nap group for Correct Responses in the final Session of the midnight shift. Examination of the 5-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 midnight shift. This difference was revealed by the analysis of Blocks where the final 3 Blocks were significantly better for the Short Nap group. A significant decrement in performance in the final session of the midnight shift was observed for both the Long Nap and Short Nap on Correct Responses and for the Short Nap on False Responses. However, these decrements represented an 8% decline in Correct Responses for both groups and less than double the number of False Responses from an average of 3.0 to an average of 5.6 for the Short Nap group when Session 1 is compared to Session 3. This represented substantial protection compared to the No Nap group.

Results from the ATST revealed that the test was less sensitive than the Bakan 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 Enroute Delay time for the Short Nap compared to the No Nap group on the last scenario. There are a number of factors which may have contributed to the ATST's lack of sensitivity to the factors which frequently induce decrements in performance. First, the ATST was selected as a quasi-work sample. All of the subjects 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 participants were or had been required to work midnight shifts during their careers and many may have brought coping strategies to this study. Second, the ATST scenarios were designed to present a fairly high workload. The high workload may have had an alerting effect for all groups and maintained performance. Third, participants were selected from all types of facilities, from Level 1 FAA Towers to Level 3 Enroute Centers. Because of differences in job duties and traffic workload at their facilities, participants came to the study with a wide variation of skill levels within the air traffic control occupation. Participants from the Level 1 Towers, for example, did not use radar separation on their job; and they were probably not trained in radar procedures. In contrast, Enroute controllers use radar separation procedures daily in their jobs. This difference in skills may have introduced extraneous variability into these analyses. Four, the within group comparisons were confounded with the scenarios. Different problems were administered for each test scenario. 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 was unavailable. Therefore, the degree to which scenario complexity and experimental factors were confounded was not adequately assessed. Finally, 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 which 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. The ATST with high workload scenarios was selected for the study to simulate a situation where an ATST who was napping would be required to arise and immediately return to the radar to work traffic.

As with the cognitive findings, results of the subjective measures supported the use of naps during the midnight shift. Specifically, the analysis of sleepiness ratings across the midnight 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 (M=3.9), sleepiness was rated similarly by each of the other groups at the beginning of the shift (M=2.5 to 2.9). Over the course of the midnight shift, however, both the males and females in the no nap conditions rated their sleepiness increasingly higher so that by the end of the midnight 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 the other napping condition 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 sleep quality ratings revealed that participants felt that naps were fairly easy to obtain. They also indicated that sleep during the naps was deep. All participants 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.

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 could only be implied to result from the sleep/wake cycle and subsequent exposure to daylight imposed by the experimental schedule. The Bakan 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.

The present study would tend to support the work of Matsumoto and Harada (1994), which indicated that a nap taken during a night work period can alleviate fatigue. Rogers, Spencer, Stone, & Nicholson (1989), however, found that a 1-hour nap taken at 0200 during a work period had limited beneficial effects on performance compared to a no nap condition. Dinges and associates (1985) indicated that naps taken during the circadian troughs led to greater performance decrements than did naps taken during the circadian peaks. This study showed post-nap sleepiness was higher and performance was lower when subjects were awakened from a nap during the circadian trough as compared to a nap taken during the circadian peak. Dinges advocates prophylactic napping and taking naps before a person's sleep loss extends beyond 36 hours. This advice is also applicable for ATCSs or other personnel in safety critical or aviation-related jobs. These work forces should be advised to nap prior to arriving at work for a midnight shift.

The protection of performance on the Bakan suggests that naps during the midnight shift would be useful as a countermeasure to performance decrement and sleepiness on the midnight shift during low workload conditions. From these data, the 2-hour nap appeared to be more protective. Future studies should examine a comparison between a prophylactic nap and a nap during the midnight shift.

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