# The Short-Term Benefits of Brief and Long Naps Following Nocturnal Sleep Restriction

Amber J. Tietzel BSc (Hons.) and Leon C. Lack PhD

*Flinders University, Adelaide, S.A., Australia*

**Study Objectives:** The purpose was to remedy the lack of experimental studies directly comparing the effects of brief and long daytime naps following nocturnal sleep restriction.

**Design:** Twelve young adult healthy sleepers participated in a repeated measures design comparing the effects of no nap, a 10-minute nap, and a 30-minute afternoon nap in each case following a night of 4.7 hours of total sleep time. Objective and subjective alertness measures and cognitive performance measures were taken before, then 5, 35, and 60 minutes after the termination of the nap.

**Setting:** N/A

**Participants:** N/A

**Interventions:** N/A

**Measurements and Results:** In the no nap condition measures showed either no change or a decreases of alertness and performance across the testing period. Following the 10-minute nap there was an immediate improvement in subjective alertness and cognitive performance which was sustained for the hour of post nap testing. Immediately following the 30 minute nap most measures of alertness and performance declined but showed some recovery by the end of testing.

**Conclusions:** Because the delayed benefits following the 30-minute nap may be due to sleep inertia, longer post-nap testing periods should be investigated. However, we conclude that the detrimental effects of sleep restriction were more rapidly and significantly ameliorated, at least within the hour following the nap, by a 10-minute afternoon nap.

**Key words:** Sleep deprivation; cognition; drowsiness; fatigue; napping; brief naps; sleep onset latency; subjective sleepiness

## INTRODUCTION

DAYTIME SLEEPINESS IS A WIDESPREAD PROBLEM IN THE INDUSTRIALIZED WORLD, with many people compromising their physiological sleep need with work or social pursuits. Indeed, there is emerging recognition among researchers and industry alike that daytime sleepiness impedes human neurobehavioral functioning thereby increasing vulnerability to workplace incidents and accidents.[1]

Considerable attention has been given to napping as a means of increasing alertness. In general, researchers report benefits from napping in terms of: 1) improved subjective alertness;[2-10] 2) EEG activity indicating increased alertness;[2-7] 3) increased sleep latency;[11,16,17] 4) improved reaction time performance;[8-10,12,13] 5) improved short-term memory performance;[8,10] 6) improved vigilance performance;[2,4,7,8] and 7) improved performance on a simulated driving task.[5]

Recently, brief naps have been promoted as solutions to daytime sleepiness.[14,15] Brief naps are more practical than long naps in workplace environments. In addition, there is anecdotal evidence that brief naps may be more rejuvenating than long naps, at least in the period immediately following the nap. However, only three experimental studies have compared brief naps with long naps in the same study. Lumley et al.[16] compared naps of 0, 15, 30, 60, and 120 minutes duration, permitted at 09:00 hrs, following a night with no sleep. Multiple sleep latency tests (MSLTs) were employed two hourly for eight hours following the nap. Naps of 30, 60, and 120 minutes improved alertness, with such improvements emerging four hours after the naps. The 15-minute nap in the morning did not significantly improve alertness following total sleep deprivation in this study.

Helmus et al.[17] compared a brief nap of 15 minutes duration with a longer nap of two hours duration in the middle of the day also following a night of total sleep deprivation. Following the termination of naps at 12:00 hours, MSLTs were performed at 25-minute intervals (12:15, 12:40, 13:05, 13:30 and 13:55 hours) and then later at 15:00 hours. These sleep-deprived subjects obtained greater improvements in alertness from the two-hour nap, relative to the 15-minute nap, but only at 15:00 hours after a three-hour post-nap delay.

Takahashi et al.[18] investigated the effects of brief and long naps scheduled after lunch (12:30 hours), but in their case, following a night with more than seven hours sleep. Thirty subjects were randomly assigned to one of three groups: a no nap control group, a 15-minute nap opportunity (mean sleep duration=7.3 minutes), and a 45-minute nap opportunity (mean sleep duration=30.1 minutes). There was improved subjective alertness at 30 minutes and three hours after the 15-minute nap opportunity. After the 45-minute nap opportunity improved subjective alertness was shown only at three hours. Thus in the middle of the day after a normal night of sleep, a brief nap seems to produce more immediate improvement in alertness than a longer nap. However, more than seven hours of nocturnal sleep would not be considered sleep restriction conditions.

In brief, it has been shown that after total sleep deprivation long naps are more beneficial than brief naps but that following normal sleep brief naps produce comparable and perhaps more immediate benefits. Between the conditions of total sleep deprivation and normal sleep is the very common experience of some degree of restricted sleep with its frequent contribution to daytime sleepiness. A direct comparison of the effects of brief and long naps under these conditions has not been studied. Therefore, the present study addressed this deficiency.

**Accepted for publication December 2000**

Address correspondence to: Dr. Leon Lack, School of Psychology, Flinders University, GPO Box 2100, Adelaide, S.A. 5001, Australia; Tel: 618 8201 2391; Fax: 618 8201 3877; E-mail: leon.lack@flinders.edu.au

## METHOD

### Participants

The sample consisted of six males (Mean age=21.83 yrs, SD=4.17) and six females (Mean age =20.00 yrs, SD=1.67) from a university population. Participants were required to be self-reported good sleepers and were therefore excluded if they reported a history of sleep complaints or sleep onset latency greater than 30 minutes and more than three days a week of nocturnal awakenings greater than 30 minutes. Also excluded from the study were habitual nappers, users of benzodiazapines or other drugs affecting sleep architecture, and excessive consumers of caffeine, nicotine, or alcohol. The study received approval from the Flinders University Social and Behavioural Research Ethics Committee. Informed consent was given by all participants.

### Design

Subjects participated in three separate afternoon laboratory sessions, approximately one week apart, each comprising one of three experimental conditions: (1 a no nap control condition; (2 a 10-minute nap condition; and (3 a 30-minute nap condition. Conditions were administered in a Latin squares counterbalanced order for males and females separately. Female subjects were scheduled during the first two weeks of their menstrual cycle to avoid circadian and temperature differences that occur between ovulation and menstruation in ovulating females.

### Prior to Laboratory Sessions

Participants were instructed to maintain adequate total sleep with regular bedtimes and wake up times for the entire week prior to the first laboratory session and henceforth for the remainder of their participation in the study except for the night immediately preceding each of the three experimental sessions. On the evening prior to a laboratory session, subjects were required to limit their nocturnal sleep to the hours between 24:00 and 05:00 hours. Compliance to these instructions was confirmed with sleep/wake diaries and wrist activity monitors throughout the experimental period and with check-in telephone calls at 24:00 and 05:00 hours on the night and morning immediately prior to each laboratory session. In addition, during the period three days prior to and including the laboratory sessions, subjects were asked to refrain from consuming alcohol and caffeine. Participants were instructed to eat their usual size lunch during the hour prior to their arrival at the sleep laboratory and refrain from vigorous mental or physical activity and smoking for 30 minutes prior to the session.

### The Laboratory Session

Upon arriving at the laboratory at 13:00 hours, EEG electrodes were applied for standard bipolar recording between Cz and Oz sites in the EEG 10/20 system. EOG electrodes were applied to the nasion and the outer canthus of the right eye for eye movement recording. Participants were then confined to bed for the duration of each laboratory session, which consisted of nap and testing periods.

Apart from nap and testing periods, the bedroom environment was kept quiet and free from interruptions and was consistently illuminated by a 75W light globe producing 50 lx illuminance at the participant's head. External time cues, including daylight, clocks and watches, were eliminated for the duration of the laboratory session.

### Test Instruments

The test battery comprised the Stanford Sleepiness Scale[19], the fatigue and vigor sub-scales of the Profile of Mood States[20] and two cognitive performance tests. The first cognitive performance task, the Symbol-Digit Substitution Task (SDST), involved showing the participant a series of nine novel shapes paired with digits between one and nine. The participant was then given a worksheet with a long random sequence of shapes and was required to copy the corresponding digits as quickly and accurately as possible using the originally dispayed pairings at the top of the worksheet as a key guide. The dependent measure was the number of correct digit substitutions within a period of 90 seconds. A number of parallel forms of the SDST task were constructed using different symbols matched with the digits in order to provide a novel task for all test periods in all three conditions. Pre-testing showed them all to be of equal difficulty. The second cognitive performance task, the Letter Cancellation Task (LCT), required participants to search for two target letters in a matrix of alphanumeric stimuli, with the dependent measure being the number of correct identifications in a four-minute period. Again, parallel equally difficult forms of the task were constructed to provide novel forms for each testing occasion.

### Assessment of Objective Alertness

Objective alertness, measured as sleep onset latency (SOL), was measured on two occasions, the first at the beginning of the 10-or 30-minute nap and the second occasion one hour from the termination of the nap or no nap condition. In the 10-minute and 30-minute napping conditions subjects were awoken only when they had slept for precisely 10 minutes or 30 minutes respectively. In the no nap condition a similar SOL procedure was followed except that the trial was terminated prior to sleep onset to avoid the participant obtaining any sleep. This precluded an initial SOL measure for this condition. The decision to terminate the SOL procedure in this case was taken at the first indication of stage 1 sleep (slow rolling eye movements and/or some decrease of alpha power) but before a single 30-second epoch of S1 sleep was completed. The second SOL trial was conducted at approximately 16:15 hours, one hour from the termination of the first SOL trial.

A three-epoch criterion was employed in the present study to determine the SOL measure for the 10-minute and 30-minute conditions and final SOLs for all three conditions. An alpha baseline level was determined during each sleep trial, by averaging the amount of alpha for the two epochs with the highest amount of alpha, then dividing by two. The criterion of sleep was reached when three consecutive epochs below this baseline alpha level were obtained. The sleep latency score for each sleep onset trial was the latency from lights out to the first of three consecutive 30-second epochs identified as sleep.

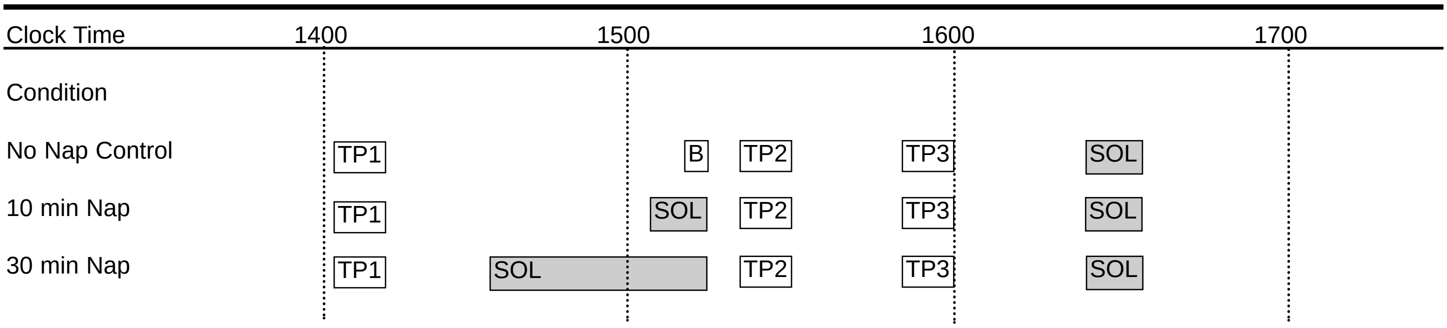


**Figure 1—**Summary of the experimental protocol. The timing of Test Periods (TP), and sleep onset latency trials (shaded horizontal bars) are indicated by clock time. In the no nap control the sleep onset trial terminated before sleep onset is indicated as a B for bedtime. TP1, 2, and 3 included testing of all subjective alertness and objective performance measures. Stanford sleepiness was also measured just before the final SOL trial at 16:20 hours.

## Procedure

Each laboratory session comprised four periods of testing and two SOL trials. The first SOL trial extended into a 10-minute or 30-minute nap for the two napping conditions. To equate clock time for all post-nap testing periods, the time at which subjects attempted to initiate sleep was staggered for the three nap conditions. This is illustrated in the summary of the experimental protocol in Figure 1. Lights were turned out for the no-nap, 10-minute nap, and 30-minute nap conditions at 15:10, 15:00 and 14:40 hours respectively, with the target time for awakening from the nap or termination of the trial to be about 15:15 hours. In fact, the SOL trial termination mean time for all conditions combined was 15:13 hours with a standard deviation of only 1.5 minutes.

The first test period was scheduled prior to the first SOL trial from 14:05 to 14:20 hours and included all dependent measures. This left an interval of at least 20 minutes between the first test period and the first SOL trial. This buffer interval was used before the initial and final SOL trials to avoid interference of performance testing with the SOL measurement. The second test period was initiated five minutes after the termination of the SOL trial to measure the immediate effects on subjective sleepiness and performance. The third testing period began 35 minutes after the SOL trial to test the longer term effects on subjective sleepiness and performance. The fourth began one hour after the first SOL trial and only tested subjective sleepiness and SOL.

## RESULTS

### Baseline Measures

The mean (SD) total sleep times as indicated by wrist actigraphic data on the night before the no nap laboratory session, 4.71(.24) hours, the 10-minute nap session, 4.72(.17) hours, and the 30-minute nap session, 4.69(.41) hours were no different as indicated by a one-way repeated measures ANOVA, $F(1,14)=.05$, $p>.05$. Thus the same degree of sleep restriction applied to all three nap conditions.

Baseline pre-nap scores were examined for the six dependent variables using one-way repeated measures ANOVA. No condition differences were evident. Therefore, all dependent measures were comparable prior to the naps or no nap condition.

### Order Effects

Despite the use of a Latin squares design to balance any possible order effects and the use of parallel forms of the cognitive performance measures to minimize practice order effects we examined possible order effects in the SDST and LCT measures. One-way repeated measure ANOVAs applied to the pre-nap scores across the first, second, and third order of administration showed no significant variation for either the SDST measure ($F(1,11)=0.30$, $p>0.05$) nor the LCT measure ($F(1,11)=0.68$, $p>0.05$).

### Objective Alertness

Figure 2 illustrates the measure of objective alertness, SOL, in the three conditions. A lengthening of SOL, indicating increased alertness, followed both the 10-minute and 30-minute naps. A two-way repeated measures ANOVA for the 10-and 30-minute conditions revealed significant increases of SOL following napping ($F(1,11)=20.32$, $p<0.01$) and no significant interaction between conditions ($F(1,11)= 0.17$, $p>.05$) indicating comparable benefits from the two nap lengths.

A one-way repeated measures ANOVA, applied only to the three post nap SOL values, showed a significant effect of nap condition, $F(1,11)=10.09$, $p<.01$. A paired samples t-test indicated that the final SOL for the no nap condition (M=3.83 min,

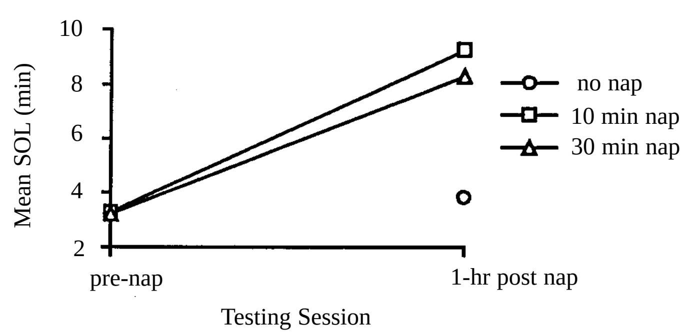


**Figure 2—**Change in objective alertness, as indexed by mean sleep onset latency (SOL), produced by the 10-minute nap and the 30-minute nap as compared with SOL following no nap.

**Table 1—**Means (M) and standard deviations (SD) of subjective sleepiness (SSS). Simple ANOVA main effects across time (horizontal) are at each level of nap condition and simple ANOVA main effects across nap condition (vertical) are at each point of time.

| Nap condition | F | df | p | | Pre-nap | 5 minutes post-nap | 35 minutes post-nap | 1 hour post-nap |
|---|---|---|---|---|---|---|---|---|
| No nap | 9.35 | 3,33 | <.0071 | M | 3.33[b] | 4.50[a,x] | 4.33[a,b] | 4.75[a,x] |
| | | | | SD | 1.15 | 0.90 | 1.23 | 1.36 |
| 10 minute | 2.87 | 3,33 | >.0071 | M | 4.17 | 3.50[y] | 3.58 | 3.58[y] |
| | | | | SD | 1.19 | 1.17 | 1.08 | 2.56 |
| 30 minute | 2.94 | 3,33 | >.0071 | M | 3.50 | 4.25[x,y] | 3.50 | 3.25[y] |
| | | | | SD | 1.51 | 1.66 | 1.68 | 1.36 |
| | | | | F | 3.67 | 6.22 | 2.94 | 13.16 |
| | | | | df | 2,22 | 2,22 | 2,22 | 2,22 |
| | | | | p | >.0071 | <.0071 | >.0071 | <.0071 |

Note: Different superscripts represent a significant difference between means (e.g., a>b, x>y). Means sharing a common superscript were not significantly different. Superscripts a and b were horizontal comparisons and x and y were vertical comparisons. Bonferroni correction applied to all p-values.

SD=3.05) was significantly shorter than the average of the two other nap conditions (M=8.77 min, SD=7.87), t(11)=2.99, p<.05, further indicating that napping improves objective alertness.

## Subjective Alertness

Table 1 shows the means and standard deviations of Stanford Sleepiness Scores for each of the three conditions across the four testing periods. An overall two-way repeated measures ANOVA examining the relationship between the three nap conditions at four testing periods showed no significant main effects but indicated a significant interaction (F(6,66)=6.27, p<.001). To determine the contributions to this interaction a series of repeated measures simple ANOVAs and post-hoc t-tests was conducted for each condition across time periods and at each time period across conditions. Table 1 shows these post-hoc analyses with Bonferroni corrected probabilities. The no-nap control condition showed a significant increase in sleepiness from pre-nap to "post-nap" testing periods. Although the 10-minute nap appeared to decrease Stanford Sleepiness Score, this change did not reach the corrected significance level. Although the 30-minute nap seemed to result in an immediate increase in sleepiness followed by an improvement later, this variation was not significant. However, across conditions there was less sleepiness immediately following the 10-minute nap than the other two conditions and less sleepiness one hour after both naps than without a nap.

## Fatigue and Vigor

The means and standard deviations for the fatigue and vigor scales are shown in Table 2. Both the POMS fatigue and vigor scales appeared to show immediate improvement in mood following the 10-minute nap compared to decreases for both the no-nap and 30-minute nap conditions with the 30-minute nap condition then improving to the same level as the 10-minute condition by 35 minutes after the naps. Only the vigor scale showed this interaction to be significant (F(2,22)=3.18, p<0.05). However, there were no significant simple main effects across testing periods or conditions (Table 2).

**Table 2—**Mean (SD) fatigue and vigor POMS scales for the three nap conditions pre- and post-nap

| POMS scale | Nap condition | Pre-nap | 5 min Post-nap | 35 min Post-nap |
|---|---|---|---|---|
| Fatigue | No nap | 2.71(.96) | 2.89(.96) | 2.87(.90) |
| | 10-min nap | 2.81(1.06) | 2.57(.92) | 2.69(.79) |
| | 30-min nap | 2.58(1.08) | 2.85(1.18) | 2.58(1.14) |
| Vigor | No nap | 2.35(.75) | 2.09(.55) | 2.00(.58) |
| | 10-min nap | 2.08(.51) | 2.23(.57) | 2.29(.60) |
| | 30-min nap | 2.39(.73) | 2.01(.46) | 2.29(.79) |

**Table 3—**Means (M) and standard deviations (SD) of correct digit substitutions in the symbol-digit substitution task(SDST). Simple ANOVA main effects across time (horizontal) are at each level of nap condition and simple ANOVA main effects across nap condition (vertical) are at each point of time.

| Nap condition | F | p | | Pre-nap | 5 minutes post-nap | 35 minutes post-nap |
|---|---|---|---|---|---|---|
| No nap | 8.12 | <.0083 | M | 59.17[a] | 55.00[b,y] | 54.42[b,y] |
| | | | SD | 6.93 | 8.73 | 8.30 |
| 10 minute | 14.03 | <.0083 | M | 58.75[b] | 65.25[a,x] | 66.92[a,x] |
| | | | SD | 6.80 | 7.58 | 9.62 |
| 30 minute | 11.01 | <.0083 | M | 58.08[a] | 50.58[b,z] | 60.75[a,x,y] |
| | | | SD | 6.69 | 7.86 | 10.65 |
| | | | F | 0.77 | 42.39 | 10.71 |
| | | | p | >.0083 | <.0083 | <.0083 |

Note: Superscripts a and b were horizontal comparisons and x and y were vertical comparisons. Different superscripts represent a significant difference between means (e.g., a>b, x>y). Means sharing a common superscript were not significantly different. Degrees of freedom for all ANOVAs were 2,22. Bonferroni correction applied to all p values.

### Symbol-Digit Substitution Task

Table 3 shows the means and standard deviations of performance on the symbol-digit substitution task (SDST) for each of the three conditions across the three testing periods along. A two-way repeated measures ANOVA examining the relationship between the three nap conditions at three time periods showed no significant main effects but revealed a significant interaction between conditions and time periods ($F(4,44)=14.74$, $p<.001$). To determine the contributions to this interaction a series of repeated measures simple ANOVAs and post-hoc t-tests were conducted for each condition across time periods and at each time period across conditions. These analyses are also indicated in Table 3. The no nap condition showed a significant decline from the pre nap period. The 10-minute nap was followed by a signficant immediate and sustained improvement in SDST performance. The 30-minute nap was followed by a significant decline in performance with a return to pre-nap levels 35 minutes after the nap.

### Letter Cancellation Task

The changes of performance on the letter-cancellation task (LCT) were very similar to those of the SDST . An overall two-way repeated measures ANOVA between the three nap conditions at three testing periods revealed a significant interaction ($F(4,44)=14.87$, $p<.001$). Table 4 shows the means and standard deviations of each of the three conditions across the three testing periods along with separate analyses using Bonferroni corrected significance levels. As with SDST, the LCT performance showed an immediate and sustained improvement following the 10-minute nap. Immediately following the 30-minute nap there was a decline in LCT performance. However, 35 minutes after the longer nap there was a return to pre-nap levels which was significantly greater than the no nap condition.

## DISCUSSION

### Objective Alertness

The 10-minute and 30-minute naps produced significantly improved objective alertness one-hour after napping. These findings are consistent with Carskadon and Dement[11] who demonstrated that a daily afternoon nap (mean 33.7 minutes) incorporated into an experimental protocol of 5 hours sleep per night for seven nights, sustained a high level of objective alertness for two to six hours after the nap.

The present findings appear not to be consistent with Lumley et al.[16] who found that after total sleep deprivation a 15-minute nap at 09:00 hours did not significantly improve objective alertness. However, in the present study after nocturnal sleep of 4.7 hours a brief nap of 10 minutes at 15:00 hours significantly lengthened sleep latency as much as from a 30-minute nap. Therefore, the recuperative value of naps may well be influenced by the circadian timing of the nap[21] and prior wake time.[21,22]

### Subjective Alertness

When compared with the no nap condition, the 10-minute nap significantly improved subjective alertness (SSS) five minutes after the nap and henceforth for the following hour, while the 30-minute nap showed no improvement over the no-nap condition until one hour after napping.

Horne and Reyner[5] also revealed immediate and sustained improvements in subjective alertness following a brief nap of up to 15 minutes (mean total sleep=10.8 minutes) in a sample of sleep restricted adults. Takahashi et al.[18] also observed improved subjective alertness, relative to a no-nap condition, 30 minutes after a 15-minute nap opportunity (mean total sleep = 7.3 minutes). Recently Takahashi et al.[6] have confirmed an increased subjective alertness at 30 and 120 minutes after a brief nap (mean total sleep=10.2 minutes).

**Table 4—**Means (M) and standard deviations (SD) of correct letter cancellations in the LCT. Simple ANOVA main effects across time (horizontal) are at each level of nap condition and simple ANOVA main effects across nap condition (vertical) are at each point of time.

| Nap condition | F | p | | Pre-nap | 5 minutes post-nap | 35 minutes post-nap |
|---|---|---|---|---|---|---|
| No nap | 6.81 | <.0083 | M | 104.33[a] | 100.58[y] | 96.50[b,z] |
| | | | SD | 6.57 | 6.36 | 6.24 |
| 10 minute | 16.13 | <.0083 | M | 101.75[b] | 110.33[a,x] | 118.58[a,x] |
| | | | SD | 6.71 | 6.99 | 7.95 |
| 30 minute | 6.98 | <.0083 | M | 106.83[a] | 93.00[b,y] | 105.92[a,y] |
| | | | SD | 7.22 | 5.16 | 7.11 |
| | | | F | 2.93 | 21.84 | 17.86 |
| | | | p | >.0083 | <.0083 | <.0083 |

Note: Superscripts a and b were horizontal comparisons and x and y were vertical comparisons. Different superscripts represent a significant difference between means (e.g., a>b, x>y). Means sharing a common superscript were not significantly different. Degrees of freedom for all ANOVAs were 2,22. Bonferroni correction applied to all p-values.

## Fatigue and Vigor

Although the changes in fatigue and vigor were in the same directions as the other measures they were generally not significant in this study. These findings are not consistent with Taub et al.[9] who observed that a 30-minute nap scheduled at 16:35 hours improved fatigue within 35 minutes of napping. However, the present findings are consistent with Hayashi et al.[4] who also observed no significant change in subjective fatigue subsequent to a 20-minute midafternoon nap.

## Cognitive Performance

The 10-minute nap produced an immediate and sustained improvement in performance on the SDST and LCT. These findings concur with Horne and Reyner[5] who observed that a midafternoon nap of up to 15 minutes (mean = 10.8 minutes) improved performance on a one-hour simulated driving task that began five minutes after napping. Hayashi et al.[4] also demonstrated improved performance on a vigilance task assessed approximately 45 minutes after a 20-minute midafternoon nap.

In contrast, the 30-minute nap did not significantly improve SDST performance within 35 minutes of the nap, while it did improve LCT performance 35 minutes after napping. Taub et al.[9] also observed improved auditory reaction time performance within 35 minutes of a 30-minute nap scheduled at 16:35 hours.

## General Discussion

The primary purpose of this investigation was to compare the recuperative value of the 10-minute and 30-minute naps. Immediately after the 10-minute nap there was more improvement of subjective alertness, and SDST and LCT performance than after the 30-minute nap. However, at 35 minutes post-nap there was only a significant advantage for the 10-minute nap on the LCT measure. One hour after napping, objective and subjective alertness were comparable for the two napping conditions and significantly greater than without a nap.

Although Takahashi et al.[18] did not measure immediately after napping, our 35-minute post-nap effects were consistent with their 30-minute post-nap effects in which they observed comparable improvements in subjective alertness for both 15-minute and 45-minute nap opportunities. Their finding of superior objective alertness following the 15-minute nap opportunity was consistent only with our results of superior LCT performance 35 minutes after the 10-minute nap.

The findings from the present study suggest that, following restricted nocturnal sleep, a 10-minute nap produces an immediate improvement of subjective and objective alertness and cognitive performance which is sustained for at least an hour following the nap. On the other hand, a 30-minute nap produces an immediate decrease of subjective alertness and impaired cognitive performance. Some researchers attribute this paradoxical suppression of performance immediately after napping to a phenomenon called sleep inertia.[21,23-26] The 30-minute nap would have incurred more sleep inertia than the 10-minute condition because sleep inertia appears to be related to duration of delta wave sleep[1,27,28] and the 30-minute nap in our study comprised 7.5 times more delta wave activity than the 10-minute nap.

Although not statistically significant, the overall directions of changes in subjective fatigue and vigor from pre-nap to post-nap were the same as those of objective and subjective alertness and cognitive performance. While a sample of 12 subjects was sufficient to demonstrate marked improvements in the latter measures, a larger sample may have also shown significant changes for fatigue and vigor. The non-significant improvements for these subjective measures may also be due to the sole inclusion of non-nappers in the sample. Evans et al.,[29] for example, found that, in contrast to habitual nappers, non-nappers reported no significant subjective benefits from a 60-minute nap opportunity (mean=33 minutes sleep). Recently Tamaki et al.[7] found that in regular nappers subjective fatigue and sleepiness was decreased for two hours following a 30-minute nap. It, therefore, seems possible that the subjective fatigue and vigor measures may have shown more reliable improvement had the sample comprised habitual nappers instead of non-nappers.

Another noteworthy finding of this study was the decline in alertness and performance across testing periods for the no nap condition. The experimental protocol for the no nap condition may have contributed to this decline. Subjects were given conditions to facilitate sleep onset including comfortable, dark, and quiet bed rest. It would seem reasonable to suggest that this procedure may have induced lower arousal, without any of the benefits obtained from sleeping, thereby leaving subjects in a relatively deactivated state. As a consequence of this lowered state of arousal, alertness and performance may have declined in the manner observed.

Alternatively, the decline in the no nap condition may reflect a circadian rhythm effect. The post-nap testing periods may have fallen within the midafternoon sleepy period or "post-lunch dip" in alertness. The existence of the "post-lunch dip" has been documented extensively in the research literature[30-33] and has been previously named by researchers as being responsible for subjective alertness and cognitive performance decrements.[30,34] It should be noted that if the decline in subjective alertness for the no nap condition indeed reflects a circadian rhythm process, then improved subjective alertness following the 10-minute nap compared to no nap represents a real nap effect. That is, while in some cases the 10-minute nap may not significantly improve subjective alertness compared to pre-nap levels, it does appear to reverse the detrimental circadian effect at that time in the afternoon as indicated by significant interaction effects.

The improvement of alertness and performance following a brief nap has important practical implications for individuals and industry alike. A brief daytime nap may not only be an effective and practical countermeasure for sleep restricted students, but also partially sleep deprived transport workers, nurses, doctors, process operators, shift workers, soldiers in sustained operations, and various other sub-populations of our community. With particular regard to industry, management may reduce the adverse effects of impaired performance, productivity, and workplace safety that accompanies daytime sleepiness[1] by providing an opportunity for employees to interject a brief nap into their daily work routines.

It may be that these recommendations are premature, given that the present study did not examine post-nap effects for more than one hour after napping. It remains possible that long naps may show greater benefits over brief naps, given adequate time for sleep inertia to dissipate. Further research is therefore required to extend post-nap testing for several hours in order to plot the time course of sleep inertia and nap benefits. Do the effects of the 30-minute nap surpass the 10-minute nap? If so, how long does it take for this to occur? It is important that researchers continue to address issues of nap length and persistence of post-nap effects in order to evaluate the relative cost/benefit of different nap lengths.

## REFERENCES


1. Rosekind MR, Smith RM, Miller DL, Co EL, Gregory KB, Webbon LL, Gander PH, Lebacqz JV. Alertness management: strategic naps in operational settings. J Sleep Res 1995;4(2):62-66.

2. Gillberg M, Kecklund G, Axelsson J, Åkerstedt T. The effects of a short daytime nap after restricted night sleep. Sleep 1996;19:570-575.

3. Hayashi M, Ito S, Hori T. The effects of a 20-min nap at noon on sleepiness, performance and EEG activity. Inter J Psychophysiol 1999;32:173-180.

4. Hayashi M, Watanabe M, Hori T. The effects of a 20 min nap in the mid-afternoon on mood, performance and EEG activity. Clin Neurophysiol 1999;110:272-279.

5. Horne JA, Reyner LA. Counteracting driver sleepiness: effects of napping, caffeine, and placebo. Psychophysiol 1996;33:306-309.

6. Takahashi M, Arito H. Maintenance of alertness and performance by a brief nap after lunch under prior sleep deficit. Sleep 2000;23:813-819.

7. Tamaki M, Shirota A, Hayashi M, Hori T. Restorative effects of a short afternoon nap (<30min) in the elderly on subjective mood, performance and EEG activity. Sleep Research Online 2000;3:131-139.

8. Taub JM. Effects of scheduled afternoon naps and bedrest on daytime alertness. Inter J Neurosci 1982;16:107-127.

9. Taub JM, Tanguay PE, Clarkson D. Effects of daytime naps on performance and mood in a college student population. J Ab Psychol 1976;85:210-217.

10. Taub JM, Hawkins DR, Van de Castle RL. Temporal relationships of napping behavior to performance, mood states and sleep physiology. Sleep Res 1978;7:164.

11. Carskadon MA, Dement WC. Effects of a daytime nap on sleepiness during sleep restriction. Sleep Res 1986;15:69.

12. Dinges DF, Orne MT, Whitehouse WG, Orne EC. Temporal placement of a nap for alertness: contributions of circadian phase and prior wakefulness. Sleep 1987;10:313-329.

13. Naitoh P, Kelly TL, Babkoff H. Napping, stimulant, and four-choice performance. In: Broughton RJ, Ogilvie RD. eds. Sleep, arousal, and performance. Boston, MA: Birkhäuser, 1992:198-219.

14. DeLuca T. Power napping. World Wide Web 1999; tomdeluca.com/nap/index.htlm

15. Mandell M. Fighting off sleep at the office. Retrieved April 10, 1999 from the World Wide Web: http://www.cnn.com

16. Lumley M, Roehrs T, Zorick F, Lamphere J, Roth T. The alerting effects of naps in sleep-deprived subjects. Psychophysiol 1986;23:403-408.

17. Helmus T, Rosenthal L, Bishop C, Roehrs T, Syron ML, Roth T. The alerting effects of short and long naps in narcoleptic, sleep-deprived, and alert individuals. Sleep 1997;20:251-257.

18. Takahashi M, Fukuda H, Arito H. Brief naps during post-lunch rest: effects on alertness, performance, and autonomic balance. Eur J Appl Physiol 1998;78:93-98.

19.Hoddes E, Zarcone V, Smythe H, Phillips R, Dement WC. Quantification of sleepiness: a new approach. Psychophysiol 1973;10:431-436.

20.McNair DM, Lorr M, Droppleman LF. Manual for the POMS. San Diego, CA: Educational and Industrial Testing Service, 1971.

21. Naitoh P. Circadian cycles and restorative power of naps. In: Johnson LC, Tepas DI, Colquhoun WP, Colligan MJ, eds. Biological rhythms, sleep and shift work. New York: Spectrum, 1981:553-580.

22. Broughton R, Dunham W, Krupa S, Mullington J. Timing of midday nap is closely coupled with morning wake-up time. Sleep Res 1995;24:513.

23. Bruck D, Pisani DL. The effects of sleep inertia on decision-making performance. J Sleep Res 1999;8:95-103.

24. Dinges DF. Are you awake? Cognitive performance and reverie during the hypnopompic state. In: Bootzin R, Kihlström J Schacter D, eds. Sleep and cognition. Washington, DC: American Psychological Association, 1990:159-175.

25. Dinges DF. Adult napping and its effects on ability to function. In: Stampi C, ed. Why we nap: evolution, chronobiology, and functions of polyphasic and ultrashort sleep. Boston, MA: Birkhäuser, 1992:118-134.

26. Naitoh P. Minimal sleep to maintain performance: the search for quantum in sustained operations. In: Stampi C, ed. Why we nap: Evolution, chronobiology, and functions of polyphasic and ultrashort sleep. Boston, MA: Birkhäuser, 1992:199-216.
27. Dinges DF, Orne MT, Orne EC. Sleep depth and other factors associated with performance upon abrupt awakening. Sleep Res 1985;14:92.
28. Muzet A, Nicolas A, Tassi P, Dewasmes G, Bonneau A. Implementation of napping in industry and the problem of sleep inertia. J Sleep Res 1995;4:67-69.
29. Evans FJ, Cook MR, Cohen HD, Orne EC, Orne MT. Appetitive and replacement naps: EEG and behavior. Science 1977;197:687-688.
30. Broughton R. Performance and evoked potential measures of various states of daytime sleepiness. Sleep 1982;5:S135-146.
31. Broughton RJ. Chronobiological aspects and models of sleep and napping. In: Dinges DF, Broughton RJ, eds. Sleep and alertness: Chronobiological, behavioral, and medical aspects of napping. New York: Raven Press, 1989:71-98.
32. Campbell SS, Zulley J. Napping in time-free environments. In: Dinges DF, Broughton RJ, eds. Sleep and alertness: chronobiological, behavioral, and medical aspects of napping. New York: Raven Press, 1989:121-138.
33. Lack L, Patrick S. Evidence of a "post-lunch dip" in the circadian system. Sleep Res Online 1999;2(1):613.
34. Babkoff H, Caspy T, Mikulincer M. Subjective sleepiness ratings: the effects of sleep deprivation, circadian rhythmicity and cognitive performance. Sleep 1991;14:534-539.