The Use of Caffeine Versus Prophylactic Naps in Sustained Performance

*†Michael H. Bonnet, ‡Steven Gomez, *Oliver Wirth and $Donna L. Arand

*Dayton Veterans Affairs Medical Center, Dayton, Ohio, U.S.A.; †Wright State University, Dayton, Ohio, U.S.A.; ‡San Diego Naval Health Research, San Diego, California, U.S.A.; and $Kettering Medical Center, Kettering, Ohio, U.S.A.

Summary: Previous studies have shown that performance during sleep loss is improved by prophylactic naps as a function of varying nap length. Based on single-dose caffeine studies, a similar dose-response effect has been hypothesized on performance, alertness and mood during sleep loss. The present study compared the effects of repeated versus single-dose administration of caffeine and varying amounts of sleep taken prior to sleep loss on performance, mood and physiological measures during 2 nights and days of sleep loss. A total of 140 normal, young male adults participated at one of two study sites. Ninety-eight subjects at one site were randomly assigned to one of four nap conditions (0, 2, 4 or 8 hours) and 42 subjects at the second site were assigned to one of four caffeine conditions. After a normal baseline night of sleep and morning baseline tests of performance, mood and nap latency, subjects in the nap groups returned to bed at noon, 1600 hours, 1800 hours or not at all. Bedtimes were varied so that all naps ended at 2000 hours. Subjects in the caffeine groups received either a single 400-mg dose of caffeine at 0130 hours each night or repeated doses of 150 or 300 mg every 6 hours starting at 0130 hours on the 1st night of sleep loss. A placebo control group (no nap and placebo administered every 6 hours on the repeated caffeine schedule) was run at both sites. Subjects remained awake and followed the same schedule of computer-administered performance tests, mood scales, multiple sleep latency test observations and meals/breaks for 52 hours before being allowed a recovery night of sleep at their normal sleep time. Results are consistent with previous findings and suggest that performance, mood and alertness are directly proportional to prophylactic nap length. Furthermore, an 8-hour nap is superior in maintaining performance, mood and alertness to either single or repeated caffeine administrations. Naps, in general, provided longer and less graded changes in performance, mood and alertness than did caffeine, which displayed peak effectiveness and loss of effect within about 6 hours. Shorter prophylactic naps and small repetitive doses of caffeine, however, did maintain performance, mood and alertness during sleep loss significantly better than no naps or large single doses of caffeine. Neither nap nor caffeine conditions could preserve performance, mood and alertness near baseline levels beyond 24 hours, after which levels approached those of placebo. Key Words: Sleep deprivation—Nap—Caffeine—Work schedules—Continuous performance—Prophylactic sleep.

Several studies have documented the fact that additional prophylactic sleep taken prior to a period of sleep loss helps maintain alertness and performance during the sleep loss (1–5). The beneficial effect of a prophylactic nap during sleep loss appears to be related to the amount of prior additional sleep in an approximately linear manner, with increasing sleep resulting in higher alertness (1).

Separate studies have shown that the acute use of caffeine improves alertness across an all-night work period (6). Sugerman and Walsh (7) concluded that the increase in alertness after 4.0 mg/kg (body weight) of caffeine was similar to the increase in alertness seen after a 3.5-hour afternoon nap. However, despite this conclusion, the effects of various doses of caffeine and prophylactic naps have never been directly compared in a single study.

In the current dual-center study, the effects of four levels of prophylactic naps (0, 2, 4 and 8 hours) and three levels of caffeine (placebo, 150–300 mg and 400

---

Accepted for publication September 1994.

Address correspondence and reprint requests to Michael H. Bonnet, Ph.D. (151N), VA Hospital, 4100 W. Third Street, Dayton, OH 45428, U.S.A.

1 This work was performed at the Long Beach Veterans Administration Medical Center and the San Diego Naval Health Research Center supported by a Merit Review Grant from the Department of Veterans Affairs, the Sleep-Wake Disorders Research Institute, and the Naval Medical Research and Development Command, Department of the Navy, Bethesda, Maryland under Research Work Unit 61153N MR 04101.03-6003. The views presented in this paper are those of the authors. No endorsement by the Department of the Navy has been given or should be inferred.
mg) were compared over a 2-night period of sleep loss. It was hypothesized that both caffeine and prophylactic naps would improve alertness and performance and that the improvements would be related to the dose and time course of the caffeine or nap. The prophylactic nap data presented in this paper have been previously published (1).

METHODS

The present study represents the combined results from a two-center study. The data were obtained at the VA Hospital in Long Beach, California, and at the San Diego Naval Health Research Center. Subjects at both sites followed the same schedule of multiple sleep latency tests (MSLTs), performance tests, and caffeine or placebo administration. The study sites differed in that a normal Navy work day begins at 0600 hours compared to 0800 hours at the Long Beach site, so the protocol at the San Diego site was started 2 hours earlier. All San Diego data and times presented, therefore, have been shifted 2 hours to match the Long Beach circadian day. Also, subjects at the Long Beach center were usually sleep deprived Friday and Saturday nights, whereas those at the San Diego center were sleep deprived on Tuesday and Wednesday.

Subjects

Subjects at both study centers were required to be healthy, 18- to 30-year-old males without significant history of sleeping problems, shift work, frequent naps or benzodiazepine use. Potential subjects using more than 250 mg of caffeine or the equivalent were excluded. Selected subjects took infrequent naps. All subjects completed an informed consent and a 4-hour session of practice on study tests before being scheduled for the study.

Design

All selected subjects were scheduled for a laboratory adaptation night, which was preceded by additional test practice. Following the adaptation night, a final 90-minute test practice session was followed by an adaptation nap latency test. The study proper involved spending 4 consecutive nights and 3 days in the laboratory. The initial night was a baseline sleep night. On the following morning, subjects completed baseline testing on all performance and mood measures and had their baseline nap latency test between 0800 and 1200 hours (see Table 1).

Subjects at the Long Beach center (university students) were randomly assigned to one of four nap conditions. Depending upon random assignment, all subjects received either no afternoon nap or an available nap time of 2, 4 or 8 hours. Bedtimes were varied so that all naps ended at 2000 hours. Subjects not sleeping between 1200 and 2000 hours were allowed to work on homework or perform recreational activities such as playing pool, taking a walk, or watching television. Beginning at 2000 hours, all subjects followed the same schedule of alternating performance test blocks, MSLT observations and meals/breaks for 52 hours before being allowed a night of recovery sleep scheduled at their normal sleep time. During the sleep-loss period, all subjects were administered placebo capsules every 6 hours starting at 0130 hours.

Subjects at the San Diego center (naval recruits and university students) were randomly assigned to one of four placebo/caffeine conditions. Caffeine was administered in capsule form with matched placebo. One group received placebo throughout the study. This group was the primary control group, and data from the two centers were statistically compared with this group to insure compatibility. Caffeine conditions consisted of a single administration of 400 mg caffeine at 0130 hours each night or 150 mg or 300 mg caffeine administered every 6 hours starting at 0130 hours on the first night of sleep loss. As with the Long Beach site, beginning at 2000 hours, all subjects followed the same schedule of alternating performance test blocks, MSLT observations and meals/breaks for 52 hours before being allowed a night of recovery sleep scheduled at their normal sleep time.

All subjects at both centers were assigned their own room for the course of the study. Each room contained a standard hospital bed and furniture including a desk with an Apple IIe or IIGS computer. Subjects participated in the study in groups of 1–4 individuals. Subjects completed all tests and questionnaires at their individual computer workstation in their room under technician observation. Nonstartling procedures, such as calling the subject’s name, were used by the technicians to awaken faltering subjects. Meals and breaks were scheduled in another area of the laboratory, which was also within technician observation. Caffeinated beverages were not available.

Tests

Performance and mood were assessed with the same battery of measures including logical reasoning [1-minute and 30-minute versions of the modified Baddeley task (8)], hand tremor (2-minute insertion of a stylus into a 4-mm opening with percent of side touching time measured), the digit symbol substitution task from the WAIS [5 minutes (9)], tapping (preferred rate for 10 minutes), computer modified Williams Word Memory Test of immediate free recall (10), computer mod-

Sleep, Vol. 18, No. 2, 1995
ified Wilkinson Addition [60 minutes (11)], visual vigilance [60 minutes (12)], subjective sleepiness (10-point visual analog scale), Profile of Mood States (POMS) and oral temperature. The tests were administered in repeated batteries (see Table 1 for the schedule and battery contents). Results from the MSLT, oral temperature, POMS vigor and fatigue subscales, subjective sleepiness, vigilance, logical reasoning, digit symbol substitution, and addition tests will be reported in this paper.

For all subjects on all measures except MSLT, performance during continuous operations was automatically scored by the computer and output in a format suitable for statistical analysis. To help reduce between-subject variance, scores on all measures were calculated as percentage changes from performance levels attained on the baseline day in the laboratory (preceding the prophylactic nap when given). The MSLT was scored for the latency to stage 2 sleep to maximize the sensitivity of the test during prolonged sleep loss.

**Electroencephalographic recordings**

Four-channel sleep recordings (LE-A2, RE-A2, C3-A2, OZ-A1) were made during nocturnal sleep periods, naps and MSLT evaluations. Seventeen MSLT evaluations were made during the study proper. The first occurred at 1000 hours on the baseline day. The remaining 16 MSLT tests began at 2200 hours that night and continued at 3-hour intervals until 1900 hours 2 days later.

**RESULTS**

**Data analysis**

One hundred forty subjects participated in the studies. Initial analyses by ANOVA were performed on subject variables across placebo and treatment groups to insure comparability. No overall differences were found among groups for age and weight (see Table 2). However, to establish comparability between the placebo groups across both centers, separate comparisons of age, weight and performance for placebo groups were conducted. These ANOVAs revealed no significant main or interaction differences between placebo groups across study center for age and all but two dependent measures. Significant interaction differences between placebo groups emerged on the POMS fatigue scale and on subjective alertness as measured by the visual analog scale (VAS). Scaling differences between the two measures resulting in a restriction in range of scores at the San Diego center accounted for most of these differences. When controlled through statistical manipulation, these scaling differences disappeared and no change in the trend of the performance data across groups or in the overall interpretation resulted. Thus with comparability established, the placebo groups were combined (total n = 27) for subsequent analyses. Similarly, performance, mood and sleepiness did not differ significantly between the 2- and 4-hour nap groups and between the caffeine 150- and 300-mg repetitive-dose groups. Therefore, in order to simplify interpretation and maximize group differences, these groups were combined for subsequent analyses yielding a 2-4-hour nap group (total n = 60) and a 150-300 mg of caffeine group (total n = 17). There were 24 subjects in the 8-hour nap group and 12 subjects in the single-dose 400 mg caffeine group.

Baseline performance, mood and MSLT data are presented in Table 3. These data were collected be-

<table>
<thead>
<tr>
<th>Time</th>
<th>Tests</th>
<th>Test number</th>
<th>Medication</th>
</tr>
</thead>
<tbody>
<tr>
<td>0800</td>
<td>Battery 1*</td>
<td>Baseline</td>
<td></td>
</tr>
<tr>
<td>0930</td>
<td>Battery 2*</td>
<td>Baseline</td>
<td></td>
</tr>
<tr>
<td>2200</td>
<td>Battery 2</td>
<td>Repetition 1</td>
<td></td>
</tr>
<tr>
<td>2300</td>
<td>Battery 1</td>
<td>Repetition 1</td>
<td></td>
</tr>
<tr>
<td>0130</td>
<td>Battery 1</td>
<td>Repetition 2</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>0430</td>
<td>Battery 2</td>
<td>Repetition 2</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>0730</td>
<td>Battery 1</td>
<td>Repetition 3</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>1030</td>
<td>Battery 2</td>
<td>Repetition 3</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>1330</td>
<td>Battery 1</td>
<td>Repetition 4</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>1630</td>
<td>Battery 2</td>
<td>Repetition 4</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>1930</td>
<td>Battery 1</td>
<td>Repetition 5</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>2230</td>
<td>Battery 2</td>
<td>Repetition 5</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>0130</td>
<td>Battery 1</td>
<td>Repetition 6</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>0430</td>
<td>Battery 2</td>
<td>Repetition 6</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>0730</td>
<td>Battery 1</td>
<td>Repetition 7</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>1030</td>
<td>Battery 2</td>
<td>Repetition 7</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>1330</td>
<td>Battery 1</td>
<td>Repetition 8</td>
<td>Caffeine/placebo, meal</td>
</tr>
<tr>
<td>1630</td>
<td>Battery 2</td>
<td>Repetition 8</td>
<td>Caffeine/placebo, meal</td>
</tr>
</tbody>
</table>

* Test battery 1: logical reasoning (30 minutes), tremor (2 minutes), sleepiness scale (VAS), digit symbol substitution (5 minutes), oral temperature, tapping (10 minutes), Williams word memory, POMS, MSLT.

**Test battery 2: Sleepiness scale (VAS), digit symbol substitution (5 minutes), oral temperature, Wilkinson addition (60 minutes), visual vigilance (60 minutes) MSLT.**

Note. Tests in each battery are listed in the order they are administered. Times appearing in this table refer to approximate starting times for each test battery, whereas times reported in the text and figures refer to the starting times of individual tests.
between 0800 and 1200 hours following the baseline sleep night. All performance, mood and MSLT variables were expressed as the proportion of change from baseline (i.e., observation divided by baseline score) to help control for individual differences in performance ability. Data for these variables were analyzed by ANOVA with terms for group (4 df), time of test (df dependent upon number of administrations of a given test) and interaction. Pairwise comparisons were performed with the Neuman–Keuls test at the 0.05 significance level, using the Greenhouse-Geisser corrected degrees of freedom. All reported results in the text will refer to statistically significant differences except where noted otherwise.

Performance variables

Results from the visual vigilance P(A) observations are presented in Fig. 1. A significant group by time interaction was found \[ F(21,1699) = 2.78, p < 0.001 \]. Neuman–Keuls pairwise comparisons revealed group differences throughout most of the study period. Vigilance observations for the 8-hour nap group diverged most and were significantly improved as compared to the shorter nap and caffeine groups until 1130 hours following night 2. Performance for the 400 mg caffeine group peaked at 0530 hours during the 1st night but then decreased to below placebo levels. Performance for the 150–300 mg caffeine group peaked twice at 0530 hours during the 1st night and also at 2330 hours on the 2nd night before declining to placebo levels. The 2-4-hour nap groups and repeated caffeine groups demonstrated intermediate performance, which was generally maintained until night 2. Performance then decreased for all groups and converged during night 2. At the 0530 test point on night 2, performance was improved in the 8-hour nap and 400 mg caffeine groups compared with that of the other groups, but no significant differences were seen at 1130 hours.

Similar performance patterns to vigilance were seen on the digit symbol substitution test. A significant group by time interaction was found \[ F(37,1247) = 2.05, p < 0.001 \]. Pairwise comparisons revealed less variability between nap and caffeine groups compared with that seen with the vigilance observations. However, significant group differences were found after 0730 hours on the first morning and continuing throughout the duration of the study period, with a pattern of performance similar to that of vigilance. The proportion of correct substitutions to baseline was significantly higher for the 8-hour nap group compared with the 400 mg caffeine group, with the placebo, 2–4-hour nap and 150–300 mg caffeine groups generally performing within intermediate levels. Performance for the single-dose 400 mg caffeine group was consistently lower than that of other groups and troughed at 0400 hours on the 2nd night after a slight improvement in correct substitutions at 0130 hours following caffeine.

### TABLE 2. Study groups

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age (years)</th>
<th>Weight (kg)</th>
<th>Nap (hours)</th>
<th>Medication</th>
<th>Dose/schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (control)</td>
<td>27</td>
<td>20.6</td>
<td>160.1</td>
<td>0</td>
<td>Placebo</td>
<td>7 administrations</td>
</tr>
<tr>
<td>Group 2</td>
<td>60</td>
<td>20.3</td>
<td>165.3</td>
<td>2–4</td>
<td>Placebo</td>
<td>7 administrations</td>
</tr>
<tr>
<td>Group 3</td>
<td>24</td>
<td>20.3</td>
<td>169.7</td>
<td>8</td>
<td>Placebo</td>
<td>7 administrations</td>
</tr>
<tr>
<td>Group 4</td>
<td>17</td>
<td>20.0</td>
<td>171.0</td>
<td>0</td>
<td>Caffeine</td>
<td>150 or 300 mg × 7 administrations</td>
</tr>
<tr>
<td>Group 5</td>
<td>12</td>
<td>19.6</td>
<td>150.3</td>
<td>0</td>
<td>Caffeine</td>
<td>400 mg × 2 administrations and placebo × 5 administrations</td>
</tr>
</tbody>
</table>

### TABLE 3. Baseline data for performance, mood and physiological variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>PLACEBO (n = 27)</th>
<th>NAP2-4HR (n = 60)</th>
<th>NAP8HR (n = 24)</th>
<th>CAF150–300 (n = 17)</th>
<th>CAF400 (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nap total sleep (minutes)</td>
<td>0 (0)</td>
<td>157 (88)</td>
<td>375 (51)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Vigilance P(A)</td>
<td>0.91 (0.08)</td>
<td>0.91 (0.08)</td>
<td>0.90 (0.07)</td>
<td>0.86 (0.10)</td>
<td>0.86 (0.14)</td>
</tr>
<tr>
<td>Digit symbol correct</td>
<td>125.0 (15.6)</td>
<td>123.2 (23.1)</td>
<td>132.5 (26.5)</td>
<td>129.1 (23.5)</td>
<td>140.3 (16.7)</td>
</tr>
<tr>
<td>Addition correct</td>
<td>133.7 (59.9)</td>
<td>150.8 (56.4)</td>
<td>170.9 (52.8)</td>
<td>86.5 (33.7)</td>
<td>99.9 (30.2)</td>
</tr>
<tr>
<td>POMS fatigue</td>
<td>4.9 (5.4)</td>
<td>7.2 (5.4)</td>
<td>9.1 (5.8)</td>
<td>4.2 (3.6)</td>
<td>4.6 (4.2)</td>
</tr>
<tr>
<td>Sleepiness (VAS 1–10)</td>
<td>6.1 (1.9)</td>
<td>5.1 (2.3)</td>
<td>4.9 (2.0)</td>
<td>7.8 (1.5)</td>
<td>8.3 (1.0)</td>
</tr>
<tr>
<td>Sleep latency (minutes)</td>
<td>14.3 (5.8)</td>
<td>16.0 (4.8)</td>
<td>14.3 (5.4)</td>
<td>13.0 (5.7)</td>
<td>11.7 (4.8)</td>
</tr>
<tr>
<td>Body temperature (F)</td>
<td>98.4 (0.8)</td>
<td>98.4 (0.8)</td>
<td>98.5 (0.6)</td>
<td>98.2 (0.5)</td>
<td>98.3 (0.6)</td>
</tr>
</tbody>
</table>

*PLACEBO = no nap and no caffeine; NAP2-4HR = 2- or 4-hour nap; NAP8HR = 8-hour nap; CAF150–300 = repeated 150 or 300 mg caffeine dose; CAF400 = single 400 mg caffeine dose. Data are represented as means within each group; standard deviations appear in parentheses.

Sleep, Vol. 18, No. 2, 1995
administration. Only the 8-hour nap group maintained performance near or above baseline levels during the same period. A similar decrease in performance after 24 hours was seen in all groups.

The results of the Wilkinson addition test were similar to those seen for vigilance and digit symbol substitution, and a significant group by time interaction was found \( F(25,838) = 2.47, p < 0.001 \). Performance in all groups was close to baseline until 1030 hours following the 1st night of sleep loss. During the day, performance was improved in the 8-hour nap group compared with the other groups until 2230 hours. At 2230 hours performance improved significantly in the 150–300 mg caffeine group, but this was followed by a rapid return to baseline at 0430 hours during the 2nd night of sleep loss. At the 0430 hours point, however, performance remained significantly improved in the 400 mg caffeine group (caffeine administered at 0130 hours) and in the 8-hour nap group. Group differences were not found at the final two test administrations (1030 and 1630 hours) following the 2nd night of deprivation.

A significant group by time interaction was also found for logical reasoning \( F(21,704) = 1.632, p = 0.035 \). As with the other performance tests, logical reasoning for all groups declined rapidly after 24 hours of wakefulness. Compared with the placebo and 2–4-hour nap groups, however, performance for the 8-hour nap and both caffeine groups was significantly improved between 0730 and 1330 hours on the 1st day of sleep loss. In the 150–300 mg caffeine group, logical reasoning performance was sustained longer and was most improved compared with all other groups from 1330 hours on the 1st day through 0130 hours on the 2nd day of sleep loss.

![FIG. 1. Visual vigilance P(A) for nap and caffeine groups during period of sleep loss. The presence of brackets indicates overall statistically significant differences between groups at that time point. Data points within brackets indicate nonsignificant differences.](image)

with the highest vigor scores being reported by the 8-hour nap group most frequently.

A significant group by time interaction was found for subjective alertness, as measured by VAS \( F(37,1266) = 2.21, p < 0.001 \). Pairwise comparisons revealed significant group differences during most of the sleep-loss period, particularly on the 1st night. As shown in Fig. 3, subjective alertness of both nap groups was significantly higher than that of placebo and caffeine groups between 2230 and 0830 hours on the 1st night of sleep deprivation. During the 2nd night of sleep deprivation between 0430 and 0645 hours, however, the subjective alertness rating for the single-dose 400 mg caffeine group was generally higher compared with that of the 8-hour nap group.

### Mood variables

The data from the POMS fatigue and vigor scales were analyzed. A significant group by time interaction was found for fatigue \( F(17,564) = 4.58, p < 0.001 \). Pairwise comparisons revealed significant group differences during most of the sleep-loss period (see Fig. 2). In general, the fatigue scores for the both nap groups gradually increased during the sleep-loss period, whereas those for the caffeine groups showed incremental increases in fatigue, with a gradual decline in fatigue after peaking on the 2nd night. The fatigue scores for the 8-hour nap group were significantly lower than those of both caffeine conditions during the 1st and 2nd nights of sleep loss. There were no significant differences between fatigue scores for the 150–300 mg caffeine and 400 mg caffeine groups. For POMS vigor, results were generally consistent with those for fatigue.

### Physiological measures

Multiple sleep latency observations were analyzed and a significant group by time interaction was found \( F(24,812) = 3.18, p < 0.001 \). Pairwise comparisons (see Fig. 4) revealed significant group differences through 0100 hours on the 2nd night of sleep loss and at 1600 and 2200 hours on the final evening. Latency values for the 8-hour nap group diverged most and were generally longer than those for other groups, except between 2200 and 1600 hours on the 2nd night and day of sleep loss. For subjects who received a single 400-mg dose of caffeine, mean sleep latency values initially increased significantly (equal to that of the 8-hour nap group) at 0400 hours but then returned to placebo levels at 0700 hours. Results for the 2–4-hour nap group and 150–300 mg caffeine group were intermediate. Although the 150–300 mg caffeine group was significantly sleepier than the placebo group prior to the initial caffeine administration, alertness was greater.
than placebo at 0400 hours (after caffeine) and re- 
mained improved (compared to placebo) until 0400 
hours on the 2nd night of sleep loss with one excep-
tion. Similarly, MSLT latencies were longer than placebo in 
the 2–4-hour nap group from 0400 hours on the 1st 
night of sleep loss until 1600 hours on the 1st day of 
sleep deprivation. The 150–300 mg caffeine group and 
the 2–4-hour nap group differed significantly at only 
three points during the study, with the nap group hav-
ing longer latencies than the caffeine group at 0100 
(prior to caffeine use) and 1900 hours of the 1st night 
and day of sleep loss, and the 150–300 mg caffeine 
group having longer latencies at 0100 hours on the 2nd 
night of sleep loss.

A significant group by time interaction effect on oral 
temperature was found \( F(42,1428) = 1.98, p < 0.0001 \). Oral temperature recordings for the nap groups 
were significantly higher than those of caffeine groups 
throughout the sleep-loss period, whereas temperature 
for the placebo groups varied within intermediate lev-
els. In general, oral temperature for the caffeine groups 
peaked and troughed approximately 3 hours earlier 
than that of the placebo and nap groups. The largest 
difference was found consistently between the 8-hour 
nap group, whose average oral temperature was main-
tained above placebo levels, and the 400 mg caffeine 
group, whose temperature averaged below placebo.

**DISCUSSION**

As hypothesized, both prophylactic naps and caff-
eine improved alertness and performance across the 
sleep-deprivation period. The improvements seen were 
relatively consistent across performance, physiological 
and mood measures and can be summarized in three 
points:

1. There is a dose-related increase in alertness and 
performance for both prophylactic sleep and dose of 
cafeine. As a rough generalization, 2–4 hours of pro-
phylactic nap was similar to 150–300 mg of caffeine 
in the magnitude of improvement. The 8-hour pro-
phylactic nap seemed to provide increased alertness 
and performance compared with all other nap and caff-
eine conditions. The dose-response effect of caffeine 
was most evident at the 0400 MSLT on the 1st night 
of sleep loss. At that point, latency was equal in the 
2–4-hour nap group and the 150–300 mg caffeine groups 
and equal in the 8-hour nap group and 400 mg caffeine 
group. Latencies were significantly longer in the higher 
"dose" conditions than in the lower "dose" conditions 
and all groups differed from placebo.
2. The beneficial effect of both naps and caffeine seemed most predominant during the 1st night of deprivation. Occasional improvement as compared with placebo was seen on a few measures at a few time points on the 2nd night, but differentiation of conditions was much less apparent. Subjects in all conditions were relatively incapacitated.

3. Time-course effects of caffeine are clearly evident in the data (see particularly the MSLT and vigilance figures). Because tests were given 3–6 hours apart and were differentially placed with respect to time of caffeine administration (0130 hours only for 400 mg and 0130 hours and each 6 hours following for 150–300 mg), the magnitude and placement of the apparent caffeine effect is somewhat variable. However, in general, 400 mg caffeine caused a clear spike in performance and alertness for about 6 hours following the initial administration. This period of action corresponds roughly with the work schedule period in a previous study showing the beneficial impact of caffeine on an all-night work shift (7). As one might expect, there was a return to baseline level of function, usually without dropping below placebo levels, as the caffeine action diminished. However, these caffeine time-course effects help illustrate the relative lack of time-course effects from the prophylactic naps, which seemed to show relatively little decay effect (i.e. if the naps were a drug, they would have a long half-life).

There was some task-to-task variability in group response on the various tasks. Many of these differences may be due to the relatively few subjects in the caffeine conditions and variance in the baseline observations. For example, on the POMS vigor and fatigue subscales and the logical reasoning test, performance in the 150–300 mg caffeine group improved markedly during the day after the 1st night of sleep loss, but these effects were not pronounced in other measures. The 400 mg caffeine group displayed poor performance as compared with their baseline throughout the study on the digit symbol substitution test only. Such differences, although statistically significant in this study, probably represent chance findings and should not cloud the major conclusions. In another sense of variability, the MSLT and mood scales seemed most responsive to the sleep deprivation manipulation. The sensitivity of the MSLT to sleep loss has been frequently reported and is assumed to reflect its direct relationship to the sleep process. The sensitivity of all of the dependent measures used in this study was increased by basing them on each subject’s baseline level of performance.

The results for the prophylactic nap data in this report are slightly different from an earlier publication, which included only prophylactic nap data (1). In that study, no significant group difference was found from the placebo no-nap condition at any point during the 2nd night of sleep deprivation. In the analyses included in the present report, performance and alertness were significantly improved in the 8-hour nap condition compared with the placebo condition until 1130 hours following the 2nd night of sleep deprivation on the vigilance task and throughout the entire study on the POMS fatigue scale. These significant differences shown in the current study probably reflect the increased statistical power associated with 27 subjects in the placebo group in these combined data.

As previously reported, both prophylactic naps and caffeine will help maintain alertness and performance. In the real world, both naps and caffeine have separate advantages and disadvantages, which will help dictate their use. Prophylactic naps clearly have the advantage of long-lasting effect and probably can be used with some frequency without the development of tolerance, dependency, withdrawal or side effects. On the other hand, naps must be planned and may consume a substantial amount of time. Caffeine clearly can be used when time is insufficient for a nap, but it carries the potential risks of most pharmacological interventions. One strategy which may be superior to either the use of caffeine or prophylactic naps may be the use of both. In an initial study, it has been found that the effects of prophylactic naps and caffeine are additive, so that shorter naps may combine with lower doses of caffeine to maintain alertness at a high level (13). Such a strategy is certainly a common sense approach when faced with the demand to work all night, at least on an acute basis.

In summary, the data in the current study are consistent with previous reports that both caffeine and naps can help alleviate some of the sleepiness that accompanies a substantial period of sleep loss. The effects of 400 mg caffeine dissipated after about 6 hours, and a more evenly graded increase in alertness was found after naps. Both strategies may help deal with some aspects of sleep loss, but the use of caffeine somewhat later during sleep loss and in conjunction with prophylactic naps might offer the strongest combination of benefits.

REFERENCES


Sleep, Vol. 18, No. 2, 1995


