The Effect of Varying Prophylactic Naps on Performance, Alertness and Mood throughout a 52-Hour Continuous Operation

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Summary: The current study reports the effect of 0–8-hr naps placed prior to two consecutive nights of total sleep deprivation. A total of 104 young adult male subjects were randomly assigned to one of four prophylactic nap conditions (0, 2, 4 or 8 hr). After a normal baseline night of sleep and a morning of baseline test performance, subjects returned to bed at 1200, 1600 or 1800 hr or not at all prior to a continuous operation that extended until each subject's normal bedtime on the third following night. All subjects who napped arose at 2000 hr, and all subjects maintained the same schedule of computer-administered performance tests throughout the sleep-loss period. Results indicated that performance and alertness in all nap conditions were improved in a dose–response fashion compared to a no-nap control throughout the first 24 hr of sleep loss. However, significant improvement in nap conditions compared to the no-nap condition was not seen in many variables during the second night of sleep loss. Whereas an 8-hr nap prior to an operation maintained performance at a high level for 24–30 hr, significant improvement in alertness and performance as compared to the no-nap control was also documented by shorter naps. No nap could reverse the profound loss of alertness seen during the second night of sleep loss. **Key Words**: Sleep—Sleep deprivation—Continuous operations—Prophylactic nap—Psychomotor performance—Work schedule tolerance.

In operational settings, performance declines as a function of work load and sleep loss (1). Several experiments have placed naps, ranging from 60 to 240 min, at varying points during sleep loss in an attempt to reverse the accumulating fatigue. Conclusions that can be drawn from the studies (1–16) include the following:

1) Naps generally reduce but do not reverse the effects of sleep loss. For example, Dinges et al. (16) found that a 2-hr nap after 42 hr of sleep loss did not improve simple reaction time (which was 25% longer than baseline at that point), but did prevent an additional lengthening in reaction time (to 54% longer than baseline) that occurred in the no-sleep control group during the following 3 hr. Other studies concluded that daily 4–6-hr sleep periods are required to maintain performance at near-baseline levels (15,17,18) during periods of continuous operations.

2) Naps, particularly during the circadian trough, may result in significantly *decreased* performance

("sleep inertia") shortly after awakening (1,8,10,19). This inertia is probably secondary to arousal from slow-wave sleep (8,10,20,21).

3) The relative value of a 1-hr versus 2-hr versus 3-hr nap cannot be readily determined from the studies that have been performed to date due to interacting methodological problems such as lack of control of circadian effects (4,5).

4) There is evidence that a nap taken early in a continuous operation will continue to provide benefits, perhaps for as long as 54 hr (2,14,16,22,23). Earlier naps may also result in less total sleep compared to those after greater sleep loss because sleep efficiency is lower.

5) Data (summarized in Table 1) from four studies that have allowed subjects to take a nap during the day *before* an all-night work shift (no prior sleep loss) show that there was a consistent substantial decrease in performance following the night of total sleep loss. Morning performance following 1–4-hr naps on the preceding day was clearly improved compared to the total-sleep-loss condition in each experiment. Four hours of sleep apparently left performance near pre-study morning baseline levels (14,22). Unfortunately, response time improvement after the 1-hr nap (23)

TABLE 1. *Decline in nocturnal performance with and without preceding sleep*

Task	Nap length (hr)	% Decline sleep loss	% Decline post-nap
10-min RT (23): long response	1	47	8
10-min RT (16)	2	30	20
10-min add (14): correct additions	4	31	5
30-min add (22): correct additions	4	33	5

appears greater than the improvement in response time after the 2-hr nap (16). This may be accounted for by the fact that the Gilberg study (23) was conducted with four subjects and is therefore based on a very small data set.

The total length and efficiency of sleep are related to how long the individual has been awake (18), the circadian placement of the sleep period (24–26) and the length of the prior sleep period (27). Prophylactic naps all occur when prior wakefulness is short (4–13 hr), at a poor circadian time for naps (midday or evening) and following a normal night of sleep. As a result, sleep efficiency is low. For example, in the Bonnet et al. study (22), subjects slept for 234 min in the placebo condition, but these 234 min came in a 7.8-hr sleep period (sleep efficiency = 50%). It may be impractical in applied settings for busy individuals to spend 8 hr in bed to sleep 4 hr and maintain nocturnal performance. Triazolam has been used to boost sleep efficiency in prophylactic naps, and was successful in increasing sleep efficiency to 80% in one study (22). However, the increase in sleep efficiency must be balanced against the possibility of carryover sedation.

Previous studies have suggested that prophylactic naps may have superior efficacy in maintaining performance during long work periods containing sleep loss. However, prior studies have not attempted to determine the extent of the dose–response relationship between length of prophylactic nap and amount or duration of performance improvement during work shifts that follow. The current study was therefore designed to examine the effect of 2-, 4- and 8-hr prophylactic naps on performance and alertness over an extended operation. Separate groups were given triazolam for the prophylactic nap to determine the effect of that medication in increasing sleep, producing hangover and altering performance and mood during measurements that extended continuously for about 50 hr after the nap.

METHODS

Subjects

Subjects were required to be healthy, 18–30-yr-old males without significant history of sleeping problems,

shiftwork or benzodiazepine use. Potential subjects using more than 250 mg of caffeine equivalent were excluded. Selected subjects were infrequent nappers. All subjects completed an informed consent and a 4-hr session of practice on tests to be used in the study before being scheduled for the study. In the initial condition randomization, 96 subjects were planned (12 per group). However, additional subjects were planned into the total-sleep-loss group because it was anticipated that the dropout rate might be higher in that condition.

Design

Subjects were scheduled for a laboratory adaptation night, which was preceded by additional test practice. Following the adaptation night, a final 90-min test practice session was followed by an adaptation nap latency test. The study proper involved spending four consecutive nights and 3 days in the laboratory (usually Thursday night through Monday morning). The initial night was a baseline sleep night scheduled according to the subject's habitual sleep/wake time. 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 hr. Subjects were randomly assigned to one of eight nap conditions (summarized in Table 2). Depending upon random assignment, all subjects received either no afternoon nap or an available nap time of 2, 4, or 8 hr. Bedtimes were varied so that all naps ended at 2000 hr. Subjects not sleeping between 1200 and 2000 hr were allowed to work on homework or perform recreational activities such as playing pool, taking a walk or watching television. Beginning at 2000 hr, all subjects followed the same schedule of alternating performance test blocks, MSLT observations and meals/breaks for 52 hr before being allowed a night of recovery sleep scheduled at their normal sleep time.

All subjects 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 IIGS computer. Subjects participated in the study in groups of one to four 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 a battery of measures including logical reasoning [1- and 30-min

TABLE 2. *Study groups*

Group	Nap time in bed (hr)	Medication
1	0	None
2	2	Placebo
3	4	Placebo
4	8	Placebo
5	2	Triazolam, 0.125 mg
6	4	Triazolam, 0.125 mg
7	8	Triazolam, 0.50 mg
8	8	Triazolam, 0.125 mg/0.125 mg divided dose after 2–6 hr of sleep

TABLE 3. *Study performance schedule*

Time (hr)	Tests[a]	Test number
1. 0800	Battery 1	Baseline
2. 0930	Battery 2	Baseline
3. 2000	Battery 1	Repetition 1
4. 2230	Battery 2	Repetition 1
5. 0300	Battery 1	Repetition 2
6. 0430	Battery 2	Repetition 2
7. 0900	Battery 1	Repetition 3
8. 1030	Battery 2	Repetition 3
9. 1500	Battery 1	Repetition 4
10. 1630	Battery 2	Repetition 4
11. 2100	Battery 1	Repetition 5
12. 2230	Battery 2	Repetition 5
13. 0300	Battery 1	Repetition 6
14. 0430	Battery 2	Repetition 6
15. 0900	Battery 1	Repetition 7
16. 1030	Battery 2	Repetition 7
17. 1500	Battery 1	Repetition 8
18. 1630	Battery 2	Repetition 8

[a] *Test Battery 1:* logical reasoning (30 min), tremor (2 min), sleepiness scale, digit symbol substitution (5 min), oral temperature, tapping (10 min), Williams Word Memory, POMS, MSLT. *Test Battery 2:* sleepiness scale, digit symbol substitution (5 min), oral temperature, Wilkinson Addition (60 min), visual vigilance (60 min), MSLT.

versions of the modified Baddeley task (28)], digit span task from the WAIS (29), hand tremor (2-min insertion of a stylus into a 4-mm opening with percentage of side-touching time measured), the digit symbol substitution task from the WAIS [5 min (29)], tapping (preferred rate for 10 min), computer-modified Williams Word Memory Test of immediate free recall (30), computer-modified Wilkinson Addition [60 min (31)], visual vigilance [60 min (32)], subjective sleepiness (10-point analog scale), Profile of Mood States (POMS) and oral temperature. The tests were administered in repeated batteries; the scheduling and contents of batteries are summarized in Table 3.

It was not possible to blind subjects or experimenters from nap length, but all subjects taking a nap received a placebo or triazolam in a double-blind manner 30 min before the nap. Subjects in Group 8 received 0.125 mg triazolam before their nap and a second capsule containing 0.125 mg triazolam at their first awakening of 10+ min during their nap (2–6 hr into the nap).

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 nap). The MSLT was scored for the latency to stage 2 sleep to maximize the sensitivity of the test during prolonged sleep loss.

EEG recordings

Four-channel sleep recordings (LE—A_2, RE—A_2, C_3—A_2, OZ—A_1) were made during nocturnal sleep periods, naps and MSLT evaluations. Seventeen MSLT evaluations were made during the study proper. The first occurred at 1000 hr on the baseline day. The remaining 16 MSLT tests began at 2200 hr that night (following the prophylactic nap) and continued at 3-hr intervals until 1900 hr 2 days later.

RESULTS

Data analyses

One hundred four subjects completed the study. There were 12 subjects in each group except the total-sleep-loss group, which had 20 subjects. The data for MSLT and visual vigilance were analyzed intitially, and the group combinations and analysis format resulting from the MSLT and vigilance data analyses were then applied for the remaining performance and mood variables. Initially, Groups 2 and 5 (both having 2 hr in bed for their nap) were compared in a standard ANOVA to determine whether medication effects existed. No significant differences were found for MSLT and vigilance comparisons, and the groups were combined for further analyses. Similarly, Groups 3 and 6 (in bed for 4 hr for naps) and Groups 7 and 8 (in bed for 8 hr for naps) were combined. The 8-hr-in-bed placebo group (Group 4) was found to differ from Groups 7 and 8 but not from Groups 3 and 6, and was therefore combined with Groups 3 and 6. This combination was consistent with the total nap sleep time of Group 6 (260 min), which was closer than that of Groups 3 and 6 than to that of Groups 7 and 8. Groups will therefore be referred to as "No Sleep", "90-Min Nap", "201-Min Nap", and "375-Min Nap".

Analyses of nocturnal sleep

Nocturnal sleep variables on baseline and recovery nights were compared using a four-group (3 df) by two-night (1 df) ANOVA with repeated measures on the night variable. Results can be seen in Table 4. A sig-

TABLE 4. *Nocturnal baseline and recovery sleep mean values for No Nap, 90-Min Nap, 201-Min Nap and 375-Min Nap conditions[a]*

	Baseline				Recovery				F inter-action	p
	No Nap	90 Min	201 Min	375 Min	No Nap	90 Min	201 Min	375 Min		
Total sleep time	418 (63)	420 (44)	433 (37)	400 (70)	452 (46)	460 (51)	459 (36)	447 (51)	1.75	0.16
% Stage 1	8.3 (3)	8.9 (5)	9.3 (4)	7.4 (3)	2.6 (2)	3.1 (2)	3.0 (2)	2.6 (2)	0.85	0.46
% Stage 2	50 (6)	46 (8)	51 (8)	47 (7)	45 (9)	46 (9)	47 (8)	43 (8)	2.45	0.06
% Stage 3	5.4 (3)	5.1 (3)	5.6 (5)	5.9 (3)	7.1 (5)	6.8 (3)	6.6 (4)	7.3 (4)	0.58	0.62
% Stage 4	10.4 (4)	10.5 (6)	9.0 (6)	12.4 (8)	24.7 (8)	22.3 (8)	20.6 (8)	25.0 (9)	0.67	0.57
% REM	16 (6)	23 (6)	20 (6)	20 (5)	17 (6)	19 (6)	20 (6)	20 (5)	2.23	0.09
Sleep latency, Stage 2	13 (11)	15 (15)	11 (8)	26 (35)	4.6 (5)	4.6 (5)	4.2 (3)	3.6 (2)	3.11	0.03
Wake time (min)	38 (32)	26 (23)	20 (19)	22 (20)	11 (14)	4.7 (6)	5.7 (7)	3.7 (6)	1.28	0.28
Stage changes	159 (29)	131 (35)	133 (27)	131 (42)	128 (41)	115 (30)	112 (22)	110 (30)	2.07	0.10
Time in bed (min)	470 (49)	461 (54)	465 (38)	448 (45)	468 (43)	470 (50)	469 (35)	454 (41)	0.64	0.58
Sleep efficiency	91 (7)	94 (4)	96 (4)	95 (5)	98 (3)	99 (1)	99 (2)	100 (0.4)	1.39	0.25
Awakenings	2.6 (2)	1.6 (1.4)	1.6 (1.4)	1.2 (1.2)	0.9 (1)	0.3 (0.4)	0.4 (0.6)	0.4 (0.4)	1.26	0.29
Latency to REM (min)	125 (40)	90 (52)	109 (64)	106 (40)	98 (66)	90 (68)	80 (42)	86 (55)	1.11	0.34
EEG arousals	100 (52)	73 (26)	82 (24)	76 (33)	44 (37)	53 (25)	48 (21)	54 (26)	6.12	0.001

[a] Standard deviations are in parentheses.

nificant main effect for the night comparison, indicating that sleep values were significantly different on the recovery night as compared to the baseline night, was found for all variables in Table 4 except for percent REM. Significant nap group by night interactions were found for sleep latency and number of EEG arousals (these *F* values are designated in the table as "*F* interaction"). Pairwise comparisons for the sleep latency variable indicated that the baseline but not the recovery sleep latency in the 375-Min Nap condition was longer than in the other groups. For EEG arousals, the baseline but not the recovery night number of arousals in the No Nap condition was increased compared to all other groups.

Prophylactic nap data

Prophylactic nap data are presented in Table 5. Because naps were designed to differ significantly in length, statistical analyses were not performed on the data. Data from all seven groups given a nap opportunity are presented in the table for comparative purposes. Again, because nap lengths differed, minutes of sleep stages rather than percentage values are presented. It can be seen from the table that, due to individual variability, 0.125 mg triazolam was ineffective in increasing total sleep time in the 2-hr nap. However, the medication increased total sleep time by 1–2 hr in the 201- and 375-Min Nap groups. This additional sleep

TABLE 5. *Prophylactic nap values[a]*

	2-hr naps		4-hr naps		8-hr naps		
	Placebo: Group 2	Triazolam (0.125 mg): Group 5	Placebo: Group 3	Triazolam (0.125 mg): Group 6	Placebo: Group 4	Triazolam (0.5 mg): Group 7	Triazolam (0.125 mg × 2): Group 8
Total sleep time	90 (29)	92 (33)	143 (67)	200 (28)	260 (105)	397 (42)	354 (52)
Stage 1	11 (6)	9.4 (6)	20 (13)	19 (9)	42 (24)	42 (18)	34 (9)
Stage 2	37 (19)	44 (17)	74 (36)	111 (31)	121 (54)	222 (58)	163 (46)
Stage 3	7.2 (6)	6.9 (5)	7 (6)	11 (10)	12 (9)	20 (17)	18 (11)
Stage 4	23 (20)	24 (15)	19 (13)	22 (16)	24 (24)	34 (26)	52 (27)
Stage REM	11 (9)	7.4 (7)	22 (16)	35 (19)	57 (31)	73 (31)	82 (33)
Sleep latency	10 (10)	18 (27)	28 (67)	5.8 (3)	12 (8)	8.4 (3)	12.2 (6)
Wake time	22 (29)	8.6 (16)	67 (50)	34 (28)	203 (98)	72 (40)	106 (53)
No. stage changes	30 (11)	29 (14)	56 (23)	64 (12)	96 (41)	107 (28)	105 (28)
Time in bed	122 (2)	119 (2)	238 (3)	239 (3)	476 (11)	477 (4)	472 (12)
Sleep efficiency	81 (25)	86 (30)	62 (28)	86 (12)	56 (22)	84 (8)	77 (11)
No. awakenings	0.3 (0.2)	0.2 (0.2)	1.2 (1)	1.2 (1)	1.8 (1)	1.4 (0.8)	1.8 (1)
Latency to REM	81 (24)	67 (43)	100 (84)	75 (36)	85 (127)	108 (62)	61 (29)
No. EEG arousals	16 (11)	12 (9)	34 (22)	28 (17)	50 (29)	63 (20)	51 (31)

[a] Standard deviations are in parentheses. All values are in minutes except stage changes, sleep efficiency, awakenings and EEG arousals.

TABLE 6. *Baseline mean data for prophylactic nap sleep time, MSLT and performance variables*

Test	Group			
	No Nap (n = 20)	90-Min Nap (n = 24)	201-Min Nap (n = 36)	375-Min Nap (n = 24)
Nap total sleep (min)	0 (0)	90 (31)	201 (86)	375 (51)
MSLT latency	15.7 (5.8)	15.3 (5.2)	16.5 (4.4)	14.3 (5.3)
Vigilance P(A)	0.92 (0.071)	0.89 (0.098)	0.91 (0.069)	0.89 (0.076)
Adds correct	146 (61)	149 (65)	152 (51)	171 (53)
POMS fatigue	4.3 (5.8)	6.2 (5.0)	7.8 (5.7)	9.1 (5.7)
POMS vigor	20 (6.6)	21 (6.0)	20 (5.2)	20 (5.6)
Logical reasoning correct (30 min)	226 (52)	179 (76)	213 (86)	223 (78)

a Standard deviations are in parentheses.

was made up of stage 2 (58%), SWS (20%) and REM (19%).

Analyses of performance data

Mean baseline performance and MSLT data are presented in Table 6. These data were collected between 0800 and 1200 hr following the baseline sleep night (see Table 3). All performance and MSLT variables were analyzed and are 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 (3 df), time of test (df dependent upon number of administrations of a given test) and interaction. Pairwise comparisons were performed with the Newman-Keuls test at the 0.05 level using the Greenhouse-Geisser degrees of freedom. All reported results in the text will refer to statistically significant differences unless noted otherwise. Results on the many performance tests were similar. Therefore, only data from MSLT, vigilance, additions, logical reasoning, POMS subjective fatigue and POMS subjective vigor will be presented in this report.

Performance variables. Results from the vigilance test can be seen in Fig. 1. In the ANOVA, a significant time by group interaction was found ($F_{21,525} = 1.91$, p < 0.01). Pairwise comparisons indicated a general dose-response function with performance significantly improved in the 375-Min Nap condition as compared to the No Nap condition and 90-Min Nap condition until the middle of the second sleep loss night. Performance in the 201-Min Nap condition was better than performance in the No Nap condition during the first 18 hr of sleep loss. Performance in the 90-Min Nap condition was improved compared to the No Nap condition only at 1730 hr following the first night of sleep loss. Performance did not differ as a function of group following the second night of sleep loss.

Results on the addition test were similar to those seen for vigilance. Again, a significant group by time interaction was found ($F_{21,576} = 1.57$, p = 0.05). The pairwise comparisons indicated improved perfor-

mance in the 375-Min Nap condition compared with the other conditions. For correct additions, the overall proportions of baseline scores were 0.82, 0.83, 0.87 and 0.95 of baseline values, respectively, for the four groups. Performance in the 375-Min Nap condition remained improved compared to all the other groups until 1030 hr following the second night of total sleep loss.

For logical reasoning (30-min version), the group by time interaction was not significant, so error was pooled to test the main effects. The main effects for group ($F_{3,592} = 3.63$, p < 0.05) and time ($F_{7,533} = 81.54$, p < 0.001) were both significant. Pairwise comparisons indicated that performance was decreased throughout sleep loss in the No Nap condition (overall proportion of baseline was 0.72) compared to the 201-Min Nap condition (mean was 0.82) and 375-Min Nap condition (mean was 0.82). Overall performance in the 90-Min Nap condition (mean was 0.75) was worse than in the 201-Min Nap condition but not worse than in the 375 Min-Nap condition.

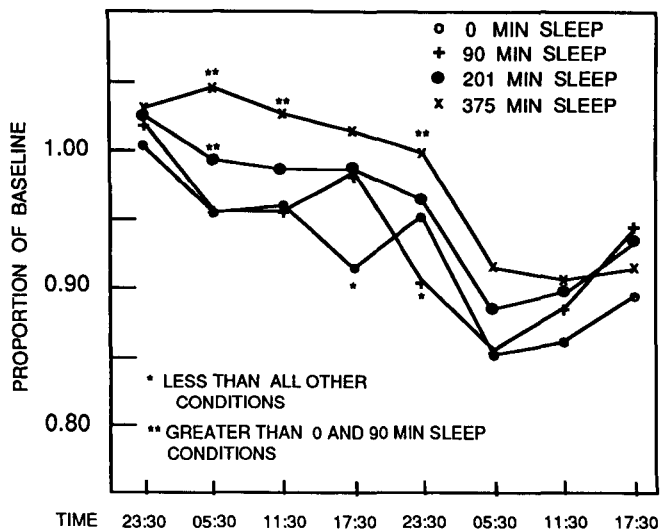*Mood variables.* The data from the POMS fatigue

FIG. 1. Vigilance P(A) for the four prophylactic nap groups during the course of the continuous operation. Statistically significant differences are noted in the figure and in the text.
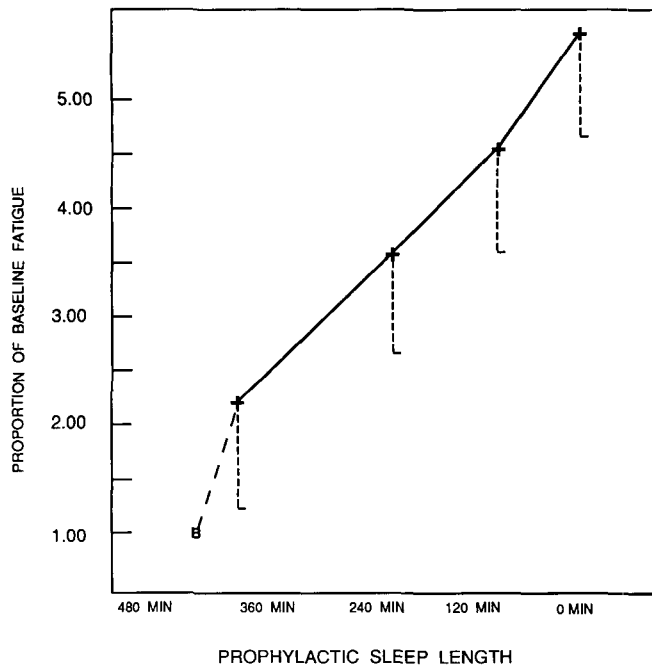
FIG. 2. POMS fatigue averaged across the continuous operation for the four prophylactic nap sleep lengths. The group mean values differ significantly (see text). The baseline level is indicated by a "B", and the vertical lines are Newman-Keuls confidence error bars for consecutive means.
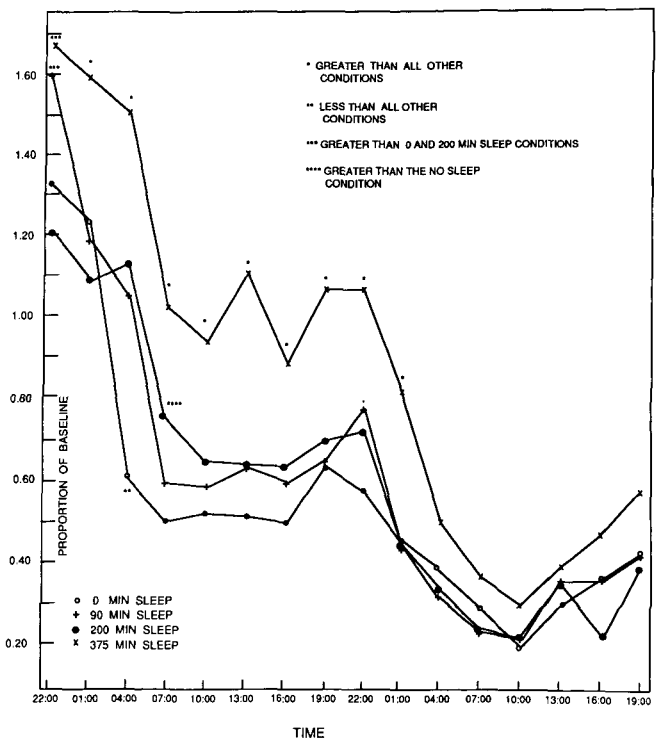

FIG. 3. MSLT data for the four prophylactic nap groups during the course of the continuous operation. Statistically significant differences are noted in the figure and in the text.

and vigor mood scales were analyzed. For POMS fatigue, a significant group by time interaction was not found. Therefore, the interaction variance was pooled to test for main effects for group and time. Both main effects were significant. For the group difference ($F_{3,256}$ = 12.69, p = 0.001), each group mean value differed from all other mean values except for the 90-Min Nap condition mean, which differed from all other means except the 201-Min Nap condition mean. The group mean data are plotted in Fig. 2. A striking linear relationship was found between overall POMS fatigue rating and nap length: the POMS fatigue levels of the 90-Min Nap condition, 201-Min Nap condition and 375-Min Nap condition were approximately 80, 60 and 40% of the No Nap condition.

For POMS vigor, there was a significant group by time interaction ($F_{21,476}$ = 1.78, p < 0.02). Pairwise comparisons revealed significant group differences only through the fourth test point (the first 24 study hours). POMS vigor was increased in the 201-Min Nap condition and in the 375-Min Nap condition as compared to the other conditions at 0530 and 1130 hr following the first night. POMS vigor was higher in all three nap conditions than in the No Nap condition at 1730 hr following the first night of deprivation.

MSLT. MSLT data are presented in Fig. 3. A significant group by time interaction was found for the MSLT data ($F_{45,466}$ = 1.94, p < 0.01). As with perfor-

mance data, pairwise comparisons revealed a dose-response relationship that resulted in significant group differences through 0100 hr on the second night of sleep loss. As with other measures, MSLT values in the 375-Min Nap condition diverged most and were significantly longer than for all other conditions from 0100 hr on the first sleep-loss night until 0100 hr on the second sleep-loss night. MSLT latencies in the No Nap condition at 0400 hr on the first night of sleep loss were significantly less than in all other conditions. MSLT values in the 375-Min Nap condition and 90-Min Nap condition were greater than values in the 201-Min Nap condition and No Nap condition at the initial 2200 hr MSLT test. MSLT values were greater in the 201-Min Nap condition than in the No Nap condition at 0400 and 0700 hr on the first night of sleep loss.

Triazolam hangover effects. Specific triazolam hangover effects were examined by evaluating performance and mood shortly after the 2000 hr wake time. Four comparisons were made. Sleepiness and mood were evaluated during the first hours after arising by directly comparing sleepiness ratings and logical reasoning (1- and 30-min tasks) between (a) 90-Min Nap with and without traizolam groups; (b) 201-Min Nap with and without triazolam groups; (c) 375-Min Nap with and without triazolam (0.5 mg) groups and (d) all triazolam subjects (n = 48) versus all placebo nap subjects (n =

36). Significant differences were found only for comparison "a". In the 90-Min Nap condition, subjects in the triazolam group received triazolam at 1730 hr and began testing at 2000 hr. Although subjective sleepiness and performance on the 30-min logical reasoning task were not different in any of the drug–placebo comparisons at 2000 hr [1.48 and 1.31 times baseline for subjective sleepiness, $F_{1,22} = 0.14$; 0.83 and 0.72 times baseline for logical reasoning (30 min), $F_{1,22} = 0.07$], significant differences were seen in the 1-min logical reasoning task when given immediately after awakening and again about 8 hr later in the "a" comparison. Drug and placebo proportions of baseline values for the two administrations were, respectively, 0.82 (first drug) and 0.86 (second drug) versus 1.19 and 1.05 ($F_{1,22} = 6.21$, p = 0.02).

DISCUSSION

The results of this study support a general dose–response relationship between the length of a prophylactic nap and measures of alertness, performance and mood during the first 24–30 hr of an extended continuous operation. The current data, in contrast to those reported by Dinges (16), indicate that the effects of the prophylactic nap were essentially eliminated by 0400–1000 hr on the second night of total sleep loss. The ANOVA interactions between length of prophylactic nap and time, which were found in several variables in the current study, may have been found because of the relatively large numbers of subjects in each group in the current study or may be representative of a floor effect. For example, on the MSLT, very little circadian variation was found in the final 14 hr of the study in the No Nap condition, and mean values ranged from 20 to 40% of baseline (3–6 min). It is unlikely that means could drop much below these values, whereas continued decreases in MSLT values in the nap conditions were more likely. Conversely, POMS fatigue, which started near zero and did not approach a maximum value, was less limited (and showed a simple ANOVA main effect) than the vigor mood scale, which quickly declined to zero values in some subjects. Regardless, performance and alertness were severely limited in all groups during the second night of sleep loss.

The group results for POMS fatigue (Fig. 2) strongly support a linear increase in sleepiness as a function of prior sleep allowed. Although the correlation between individual nap sleep length and fatigue rating (individual subject data, $r_{102} = 0.28$, p < 0.01) was not as robust as the group mean data appear (they would give a correlation of $r = 1.00$), the clear incremental increases in overall fatigue do suggest an orderly dose effect of prior sleep length, at least as measured by fatigue.

The magnitude of effects found in the current study compares reasonably with the magnitude of effects found in a similar study of prophylactic naps and nocturnal performance with and without 0.5 mg triazolam (22). On two measures that were directly comparable between the two studies, MSLT changes across the first night of sleep loss were somewhat larger in the current study than in the previous study (with differences between triazolam 8-hr nap conditions and placebo 8-hr nap conditions being about 6 versus about 2.5 min) and addition differences were somewhat smaller (with differences betwen triazolam 8-hr nap conditions and placebo 8-hr nap conditions being about 9 additional correct addition problems per half hour versus about 7.5 additional correct addition problems per hour). Although these data show some expected variability, they lead one to conclude that the effects of prophylactic naps are simple and reproducible.

The major applied questions addressed by the current study were, "If I must begin a work period X hours in length this evening, should I take a nap this afternoon; if I take a nap, how long should I sleep; and, if I take a nap, should I use medication to help me sleep?" Many interacting factors clearly modify any direct answer to such questions. However, based entirely upon the data reported in this study, some rough figures are possible. For example, over the first 24 hr of the study (2000 hr to 2000 hr), there was an overall 4, 10 and 18% improvement in the number of correct addition problems done in the 90-Min Nap condition, 201-Min Nap condition and 375-Min Nap condition compared to the No Nap condition. These improvements can translate into increased productivity. By only considering increased productivity, subjects in the nap conditions completed sufficient additional correct addition problems to compensate for 1 hr, 2.3 hr and 4.3 hr of their respective 2-, 4- or 8-hr naps. If a similar change ratio is applied to the MSLT (alertness) and POMS fatigue data, the increases in alertness translate into 3.7, 7 and 13.7. Although it does not make complete sense to call these latter numbers "savings" or "compensation", these figures do illustrate that the magnitude of change for objective alertness and subjective mood is three times greater than that seen for specific performance variables. If these changes indeed could be interpreted as the increase in addition performance was interpreted above, it would imply that any prophylactic nap period would result in alertness benefits roughly double the length of the nap taken, and that benefits would continue to accumulate at the same rate for naps as long as 8 hr. Although the exact operational consequence of decreased alertness is unclear, it is clear that a single missed signal by an impaired operator can have devastating consequences. The additive effect of increasing the lengths of prophylactic naps up to 8 hr

to increase alertness and performance may almost mandate the use of extended prophylactic naps in situations requiring nocturnal work or extended work in many sensitive work situations. The answers to the first two applied questions are clearly that one should take a prophylactic nap before an all-night work shift and that the nap should be as long as practically possible to maximize performance.

In the current study, approximately half of the participants received triazolam to increase their sleep efficiency during their prophylactic nap. The triazolam did not increase total sleep in the 90-Min Nap condition, probably because the subjects slept well even without the medication, and the immediate logical reasoning task indicated the possibility of triazolam hangover (about 3 hr post-drug ingestion). On the other hand, triazolam had significant effects in increasing total sleep time in the 4- and 8-hr naps. The increased sleep time was large enough that the 8-hr placebo nap group was more similar to the 201-Min Nap group than it was to the 8-hr triazolam nap group. Significant hangover effects were not found for any variable for the 4- or 8-hr triazolam groups. The figures are consistent in showing that the 375-Min Nap condition, which included two groups that received triazolam, had increased performance and alertness compared to all the other groups at many time points. Examination of the figures does reveal that the 375-Min Nap condition generally was not superior to all other conditions at the first test point, and it is possible that triazolam activity limited performance and alertness at this test point. However, the initial dip in performance (see particularly vigilance, Fig. 1) still left the 375-Min Nap condition superior to the conditions that accumulated less total nap sleep. As such, hangover must be considered a relative term. The use of triazolam for a prophylactic nap may provide positive benefits if it is known that the nap will be 4-hr or longer and that sleep difficulty is possible. However, in some troop deployment settings, it has been shown that 0.5 mg triazolam was not effective in increasing sleep time, but it did decrease memory performance (33,34). Some hangover from triazolam can be counteracted by caffeine (35).

The present study and several previous laboratory studies (14,16,22,23) have shown that prophylactic naps can benefit nocturnal performance and that the extent of improvement is dependent upon the length of the nap. Real-world conditions, however, differ significantly from the laboratory. Subjects in laboratory studies are screened for normal sleep habits (including no recent history of shiftwork) and have one or more normal nights of sleep scheduled in the sleep laboratory to rule out sleep pathologies and preexisting sleep deprivation. Laboratory subjects sleep in conditions where they will not be disturbed, and are usually not allowed to arise even if they have been awake for a considerable amount of time. In the real world, shiftworkers usually have a history of shiftwork and variable amounts of sleep deprivation before a night shift or extended work period. Prophylactic naps will not be beneficial if they are not really prophylactic naps. Taking a nap will not replace a lost night of sleep and will not rectify a circadian rhythm abnormality. Previous work has suggested that a primary advantage of taking a nap before sleep loss is avoiding sleep inertia. This means that if a proposed prophylactic nap is not really additional sleep, one primary advantage of the nap is lost, and the empirical data presented here no longer apply.

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