Perceptual and Motor Skills, 1979, 48, 495-506. © Perceptual and Motor Skills 1979

EFFECTS OF TOTAL SLEEP LOSS ON SLEEP TENDENCY[1]

MARY A. CARSKADON AND WILLIAM C. DEMENT

Stanford University School of Medicine

Summary.—Effects of two nights of sleep loss were assessed in six young adult (18—21 yr.) volunteers (2 women, 4 men). Performance on the Wilkinson Addition Test fell significantly below baseline values during the sleep-loss procedure and recovered after one or two full nights of sleep. Performance on a Serial Alternation Task also declined during sleep loss. Mood and sleepiness, assessed by subjective self-rating scales, showed a significantly less positive mood and a greater degree of sleepiness during sleep loss, with a recovery to baseline levels after one full night of sleep. Sleep tendency, measured at 2-hr. intervals during all waking periods, was assessed using an objective measure of latency to sleep onset, the Sleep Latency Test. The scores fell to about 1 min. at 0600 on the first night of sleep loss and remained at similarly low values throughout the sleep loss period. After one night of recovery sleep the scores remained significantly below baseline levels, which were not achieved until after the second recovery night. The multiple sleep latency test appears to be a valuable operationally defined tool for measuring daytime sleepiness.

In studies of sleep loss a tacit assumption is made that subjects will become very sleepy and tend to fall asleep very rapidly if not actively prevented from doing so. Although most experiments on sleep loss incorporate a procedure for preventing subjects from falling asleep, the tendency to fall asleep *per se* has not received attention as a dependent variable. Subjective assessment of sleepiness/fatigue has been evaluated in several sleep loss studies (Murray, 1968; Kollar, *et al.*, 1969; Hoddes, *et al.*, 1973), all demonstrating an increase in feelings of sleepiness/fatigue with sleep loss that appears to overlay a diurnal fluctuation. Murray (1968), however, cautions that such subjective ratings during sleep deprivation may be distorted by "repression." We have also found certain inconsistencies among patients using a subjective rating of sleepiness (the Stanford Sleepiness Scale) in a non-sleep deprivation setting (Dement, *et al.*, 1978).

Our observations during a study of a 90-min. schedule of sleep and wakefulness (Carskadon & Dement, 1975, 1977), in which subjects had 16 opportunities to fall asleep every 24 hr., suggested that measuring sleep latency periodically throughout the day might be an effective objective measure of sleep tendency. Combining this measure with a subjective sleepiness scale and several more traditional measures of performance, the present study is an attempt

---

[1] Supported by National Institute of Mental Health Research Scientist Award MH 05804 to WCD and National Institute of Mental Health Grant MH 28461. Send requests for reprints to Mary A. Carskadon, Sleep Research Center, Dept. Psychiatry and Behavioral Sciences, Stanford University, School of Medicine, Stanford, CA 94305.

to validate the multiple sleep latency approach to measuring daytime function and to demonstrate the relative sensitivity of sleep tendency to sleep loss.

METHOD

Subjects

Subjects were six undergraduate volunteers, two women and four men, ages 18 to 21 yr. Physical examination 1 wk. before the study showed that all subjects were in good health. On sleep habits questionnaires, four subjects reported habitually sleeping 6.5 to 7.0 hr. per night, and two subjects stated they slept 8.5 hr. each night. No subject showed any evidence of drug or alcohol abuse and all agreed to refrain from alcohol, drugs (for 1 wk. before the study), and caffein throughout the study. The experiment was performed during the break between winter and spring quarters, and subjects were asked to maintain their habitual sleep patterns during the week before the study. Although volunteers with relatively light academic loads were chosen, one subject was unable to comply with this restriction, sacrificing sleep to study for quarter-end examinations. Table 1 summarizes relevant information about the subjects, including average nightly sleep time estimates given on sleep logs for 10 days before the study began.

TABLE 1

PRELIMINARY INFORMATION ON SUBJECTS

Subject	Sex	Age (yr.)	Habitual Sleep Time (hr.)	Sleep Log Sleep Time (hr.)	Total Dark Time (hr.) (B-1, B-2, R-1, R-2)	Study Run
DP	M	20	7.0	6.7	7.0	2
BW	M	18	6.5	8.2	7.0	2
MR	F	21	6.5	5.5	7.0	1
AM	M	18	6.5	6.9	7.0	1
CW	M	19	8.5	*	9.0	2
LS	F	19	8.5	6.8	9.0	1

*Sleep log data from CW were not available.

Procedure

The study was performed in two six-day runs of three subjects. Assignment to either run was based solely on subject availability. Before the experiment, five subjects slept for one night in the laboratory to accommodate to the setting and to wearing electrodes. The study consisted of three, two-day conditions: baseline-1, baseline-2, sleep-deprivation-1, sleep-deprivation-2, and recovery-1, recovery-2.

Tests were performed in individual, sound-attenuated rooms. Each room contained a bed, desk, chair, night table, and closet. Environmental time cues, e.g., daylight and clocks, were excluded from the rooms.

On baseline-1, baseline-2, recovery-1, and recovery-2 bedtimes were set according to the habitual sleeping hours reported by the subjects: two subjects went to bed at 2300 and four at 0100. All were awakened at 0800. Volunteers arrived at the sleep laboratory approximately two hours before bedtime on the first night of the study. A brief orientation was given and electrodes were applied in the standard manner (Rechtschaffen & Kales, 1968) for recording sleep. (Electrodes remained on the subjects throughout the study; individual electrodes were replaced as necessary to maintain the quality of the recording.) Electroencephalogram (EEG) was recorded monopolarly from electrodes placed at C_3 or C_4 and referenced to the opposite ear lobe or mastoid. In two subjects the EEG was also recorded monopolarly from 0_1 and 0_2 (Jasper, 1958) to give a better determination of alpha rhythm. Electro-oculogram (EOG) was recorded monopolarly on two channels from the right and left outer canthi. Electromyogram (EMG) was recorded from two of three surface electrodes placed on the chin. All sleep periods and performance tests were monitored using Grass 7B polygraphs at a paper speed of 10 mm per second. During performance tests, the EMG channel was sacrificed to allow for a microswitch signal. Sleep recordings were scored in 30-sec. epochs using the criteria of Rechtschaffen and Kales (1968).

Two tests of performance were used. The first was the Wilkinson Addition Test (Wilkinson, *et al.*, 1966), which was administered for 60 min. at 4-hr. intervals. On every day, the test was given at 0845, 1245, 1645, and 2045; on sleep-deprivation-1 and sleep-deprivation-2, it was also administered at 0045 and 0445. The Wilkinson Addition Test consists of columns of five, two-digit numbers which subjects are instructed to add "as quickly and accurately as possible." In addition, subjects were asked to tap a microswitch as they completed each problem. During the test, subjects were aroused and urged to continue working if there was a gap of one minute between microswitch signals. The Wilkinson Addition Test was scored for the number of problems completed and for the percentage of correct responses.

The second performance measure, the Serial Alternation Task (Billiard, 1976), was administered for 30 min. at 1445 each day and also at 0245 on the deprivation days. The Serial Alternation Task is a modified serial counting task (Lubin, *et al.*, 1974) in which subjects are asked to depress two microswitches "regularly and alternately at a steady pace." Subjects were aroused and urged to continue tapping if they stopped for 60 sec. Performance on this task was measured as the percentage of the task spent tapping with all gaps $\geq$ 2 sec. subtracted.

A mood scale that is sensitive to sleep loss was adapted from Lubin, *et al.* (1974). The scale has 19 positive items, e.g., able to work hard, happy, alert, carefree, on which the subject describes himself as "not at all" (zero points), "a little" (1 point), "quite a bit" (2 points), or "extremely" (3 points). The maximum positive mood score is 57 points and the minimum is zero. The mood scale was administered 5 min. before each sleep period (sleep latency test or all night sleep).

The Stanford Sleepiness Scale is a 7-point Likert rating scale shown by Hoddes, *et al.* (1973) to be sensitive to sleep loss. The scale was administered at 15 min. intervals during all waking periods, including immediately before each sleep period and performance test. On this scale, a score of 1 indicates maximum alertness and a score of 7, maximum sleepiness.

Sleep tendency was measured using multiple sleep latency tests during the day. The sleep latency test was given at 2-hr. intervals beginning at 1000 each day. For Subjects CW and LS, the last sleep latency test on baseline and recovery days was 2200; for the other four subjects, the last sleep latency test was at midnight (except on recovery-2, when the 2200 test terminated the study). During the deprivation condition, the sleep latency test was repeated every 2 hr. until 0200. All vigorous activity was suspended at least 15 min. before each test. Five minutes before the sleep latency test, subjects were asked to lie in bed and perform several simple calibrating maneuvers (open eyes, close eyes, look right, look left, clench teeth) to ensure that the electrode hook-up was functioning well. Each sleep latency test began with instructions to "please close your eyes, lie quietly, and try to fall asleep," after which the lights were extinguished and the bedroom door closed. The sleep latency test was terminated after 1 min. of stage 1 sleep or after 20 min. had elapsed.

One of the most difficult problems in this study was setting the criterion for judging sleep onset. Johnson (1975) states that "the appearance of the first sleep spindle should be used to identify sleep onset," because stage 1 is a transition state between waking and sleeping. Agnew and Webb (1972) concluded that there was very little difference in the accuracy of judging sleep onset between a stage 1 and a stage 2 (the first sleep spindle) criterion. In addition, they showed that the criteria were highly correlated, with a mean difference of roughly 4 min. (stage 1 preceding stage 2). Agnew and Webb (1972) noted, however, that neither measure was consistently related to perceived sleep onset. Dement (1965), on the other hand, found that the presence of slow eye movements (SEMs), even when accompanied by EEG alpha rhythm, was sufficient to determine the onset of NREM sleep as defined by a shut-down of peripheral sensory awareness. Rechtschaffen and Foulkes (1965) also found that SEMs on a background of EEG alpha rhythm in certain subjects denoted an absence of recall for visual stimuli.

The decision to use the onset of the first 30-sec. epoch scored as stage 1 sleep as the criterion value for the sleep latency test was based on several factors. First, a stage 2 criterion would permit an accrual of sleep that might affect subsequent tests. Second, the variable of interest was the *tendency* to fall asleep, which Agnew and Webb (1972) confirm can be reliably assessed by a stage 1 criterion. Third, an epoch of stage 1 sleep was the first clearly established sign of the cessation of wakefulness. Finally, we wished to have a measure with which to compare various clinical populations, some of whom, most notably sleep apnea patients, have difficulty maintaining a clear-cut sleep pattern for longer than 20 to 30 sec.

RESULTS

Selected sleep parameters from baseline and recovery nights were compared using matched-pair *t* tests. Wilkinson Addition Test, Stanford Sleepiness Scale, mood scale, and sleep latency test results were analyzed using a condition by days by tests (for only the test given on all 6 days) repeated measures analysis of variance with six subjects having repeated measures across all factors. A pooled within-subjects error value was used for computing *F* ratios. Significance levels were determined using the conservative Greenhouse-Geiser (Winer, 1962) approach in which the second member of the degrees of freedom expression was always $N - 1$, i.e., 5. Finally, relationships between performance measures, Stanford Sleepiness Scales, mood scales, and sleep latency tests were examined using within-subsets Pearson product-moment correlation coefficients. Significance of the average correlations was determined by zero μ *t* tests. The .05 rejection region (two-tailed) was adopted in all statistical tests.

All Night Sleep Recordings

The first night was not included in the analysis because of the "first night effect" (Agnew, *et al.*, 1966; Mendels & Hawkins, 1967) that may distort the sleep recording, even if there has been a previous adaptation period (Scharf, *et al.*, 1975). Table 2 lists the means and standard deviations of selected sleep parameters from baseline-2, recovery-1, and recovery-2. These results are consistent with other sleep loss studies (Berger & Oswald, 1962; Williams, *et al.*, 1964), showing a significant increase in slow wave sleep (stages 3 and 4) on

TABLE 2

ALL-NIGHT RECORDING DATA

		Total Sleep Time (min.)	Stage 1		Stage 2		Stage 3 & 4		REM	
			min.	%	min.	%	min.	%	min.	%
B-2	*M*	443.8	33.4	7.1	177.0	39.9	126.1	29.1	107.3	23.9
	SD	62.6	21.3	3.5	55.0	10.7	44.8	12.0	31.6	4.3
R-1	*M*	455.8*	8.3*	1.8*	169.5	37.0	190.8*	43.0*	87.2	18.2
	SD	62.8	3.7	0.6	48.6	8.4	39.1	12.4	52.4	8.3
R-2	*M*	442.0	20.6*	4.4*	166.2	34.9	140.8	32.7	114.4	25.8
	SD	61.2	12.9	2.1	52.0	13.3	37.2	10.5	23.6	2.6

*Significant difference from B-2.

recovery-1, a decrease in stage 1 sleep on recovery-1, and a non-significant tendency for REM to be reduced on recovery-1 and to rebound on recovery-2.

Performance

Both scores on the Wilkinson Addition Test (number completed and percentage correct) showed a significant decrement during the deprivation period. Fig. 1 summarizes the results. Analysis of variance that included only the tests given every day showed significant effects across conditions, a reduction in the number of problems completed ($F = 129.4$, $df = 2/5$; baseline mean = 334.1; deprivation mean = 233.9; recovery mean = 360.4) and in the percentage of problems completed correctly ($F = 62.2$, $df = 2/5$; baseline mean = 96.0%; deprivation mean = 88.3%; recovery mean = 94.2%). A significant interaction (conditions and days) was also found for the percentage of correct answers ($F = 9.5$, $df = 5/5$; baseline-1 mean = 96.5%, baseline-2 mean = 95.4%; sleep-deprivation-1 mean = 90.1%; sleep-deprivation-2 mean = 86.6%; recovery-1 mean = 92.8%; recovery-2 mean = 95.6%). This finding reflects a decline in accuracy during the deprivation period and

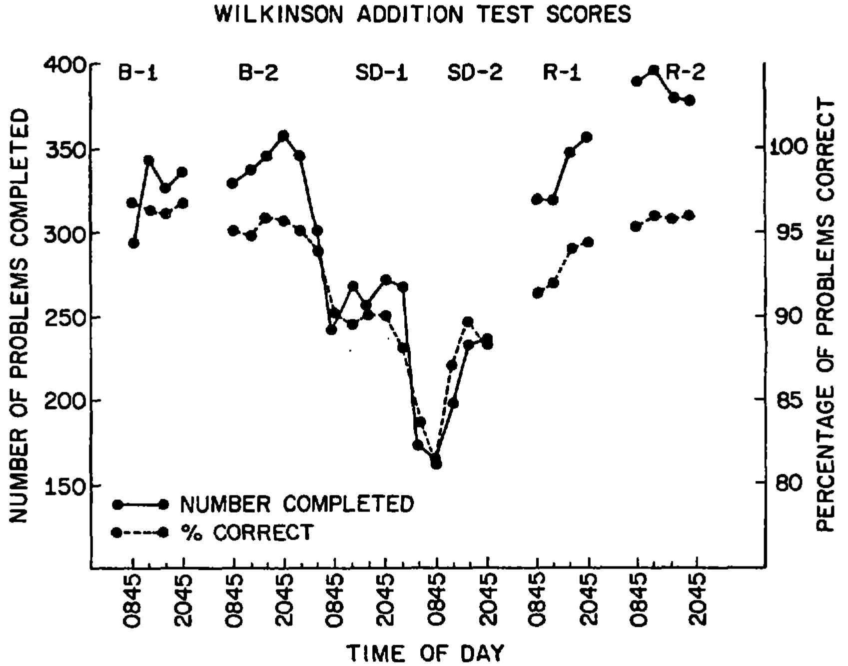

FIG. 1. Performance on the Wilkinson Addition Test. Performance on both measures declined on the first (SD-1) and second (SD-2) deprivation days. During the recovery period, the number of problems completed attained baseline values on R-1, but the percentage of correct responses did not reach baseline levels until after two nights of recovery sleep.

progressive improvements in accuracy from recovery-1 to recovery-2. The reduction in the number of problems completed appeared to be related to the fact that the subjects fell asleep during the tests on the deprivation period. During baseline only one arousal was needed for any of the subjects (MR). In the deprivation period, however, as many as 18 arousals were needed in one test. The highest average number of arousals was 7.0 on the 0845 test of sleep-deprivation-2.

On the Serial Alternation Task, performance decrements were even more clearly related to falling asleep during the task (Fig. 2). During baseline, only 1 subject (MR) fell asleep during this task; on the second baseline day, MR appeared to be very sleepy, and performed only 81.2% of the time. All other subjects were able to perform at virtually 100% effectiveness. During the deprivation period, the scores decreased progressively from an average of 98.9% at 0245 on sleep-deprivation-1 to 71.6% at 1445 on sleep-deprivation-2. The scores returned to baseline values on recovery-1.

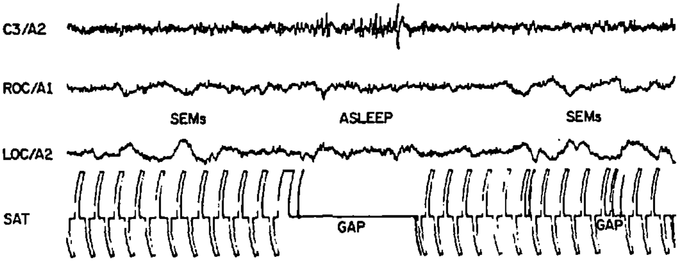

FIG. 2. Performance on the Serial Alternation Task (SAT) during sleep loss. At a paper speed of 10 mm/sec., EEG was recorded from C3/A2 on the top tracing, EOG from right (ROC/A1) and left (LOC/A2) outer canthi on the second and third tracings, and SAT microswitch signals on the bottom tracing. On the left of the figure, the subject was able to perform the SAT with no gaps with alpha rhythm in the EEG and slow eye movements (SEMs) in the EOG. When the EEG changed to stage 1 sleep, however, the subject was unable to tap the switches.

Mood and Stanford Sleepiness Scales

The mood scales (analyzed only for scales given on each of the six days) showed a significant main effect due to condition ($F = 64.82$, $df = 2/5$; baseline mean = 32.4; deprivation mean = 25.0; recovery mean = 35.4). Throughout the deprivation period, subjects had fewer positive responses than on baseline and during recovery.

Stanford Sleepiness Scale scores were averaged for each hour and repeated-measures analysis of variance applied for those hours when the scales were given each day in each subject, i.e., 0800—2200. A significant condition effect showed an increase of reported sleepiness during deprivation with a return to baseline values on recovery ($F = 203.8$, $df = 2/5$; baseline mean = 2.3; deprivation mean = 3.4; recovery mean = 2.2). In addition, there was a significant time of day effect ($F = 10.8$, $df = 13/5$) in which scores were higher in the first two morning hours and lowest from about 1900 until 2300. The Stanford Sleepiness Scale also showed a significant interaction (condition and days) reflecting a progressive increase in sleepiness from sleep-deprivation-1 to sleep-deprivation-2 and a decrease in sleepiness from recovery-1 to recovery-2. There was also a significant correlation (average $r = -.73$) between Stanford Sleepiness Scale scores given 5 min. after mood scales and the mood scale scores. This finding suggests that both scales reflect similar subjective feelings.

Sleep Latency Tests

Analysis of variance of the sleep latency test scores for tests at 1000, 1200, 1400, 1600, 1800, 2000, and 2200 yielded several significant main effects. First, there was a significant effect of conditions ($F = 98.6$, $df = 2/5$), in which the baseline average was 5.4 min., deprivation average was 0.5 min., and recovery average was 3.8 min. Time of day was also a significant factor ($F = 9.01$, $df = 6/5$), reflecting higher morning and evening latencies than those at midafternoon ($M_{1000} = 3.5$. min.; $M_{1200} = 3.0$ min.; $M_{1400} = 2.4$ min.; $M_{1600} = 2.3$ min.; $M_{1800} = 2.6$ min.; $M_{2000} = 3.2$ min.; $M_{2200} = 5.7$ min.). The significant effect of days ($F = 17.1$, $df = 5/5$) in which the sleep latency tests on the second day were longer than on the first day can be better described looking at the condition by day averages: baseline-1 mean = 5.8 min.; baseline-2 mean = 5.1 min.; sleep-deprivation-1 mean = 0.6 min.; sleep-deprivation-2 mean = 0.3 min.; recovery-1 mean = 1.5 min.; and recovery-2 mean = 6.1 min. It is clear that the main days effect reflects the lengthening of sleep latencies on recovery-2 relative to recovery-1. The condition by days interaction was also significant ($F = 33.6$, $df = 2/5$).

Fig. 3 illustrates the average latencies to stage 1 onset on each of the sleep latency tests. Several portions of this figure are of particular interest. First, the latencies on baseline days are generally quite low, but seem to be highest in the late evening hours (specifically 2200). Second, the latencies fell to very low values (< 2 min.) quite early in the deprivation period and remained low throughout. Third, the recovery process on recovery-1 seemed to be quite gradual, with sleep latencies reaching baseline values only in the evening. Finally, the recovery-2 pattern of sleep latencies was very similar to baseline, showing highest values at 2200.

Correlation coefficients were computed for sleep latency tests and Wilkinson Addition Test scores, corresponding to tests given after sleep latency tests. Significant correlations were found between sleep latency and number of problems completed (average $r = .56$) as well as number of correct answers (average $r = .57$). Therefore, the degree of sleepiness as measured by the sleep latency test is somewhat predictive of performance on the Wilkinson Addition Test. In addition, there was a smaller, but significant correlation between sleep

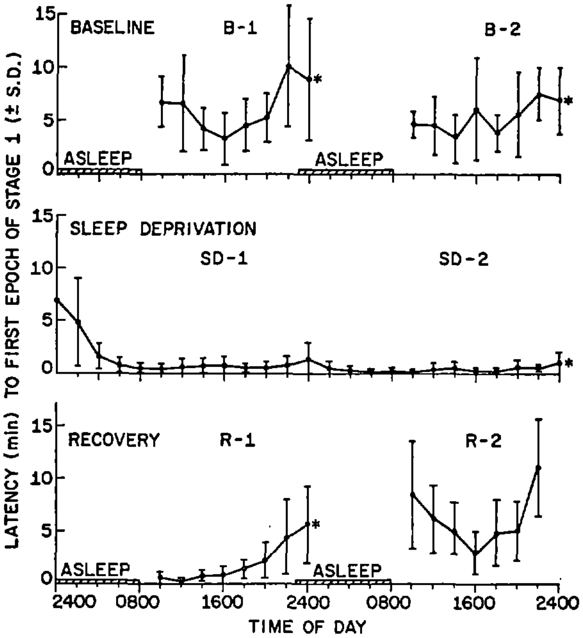

FIG. 3. Mean and standard deviations of sleep latency test scores. The sleep latencies fell to very low values early during the sleep loss period and did not reach the baseline level until after two full nights of sleep. The asterisks denote those tests which included only 4 subjects.

latency test scores and the immediately preceding Stanford Sleepiness Scale rating (average $r = -.47$) and mood scale scores (average $r = .47$).

DISCUSSION

The Sleep Latency Test appears to be a valuable, operationally defined tool for measuring daytime sleepiness. In a separate study (Carskadon, Harvey, Dement, & Anders, 1977), we have also shown that the Sleep Latency Test is sensitive to acute partial sleep loss in children, even when performance measures showed little or no change.

It is also of interest that the basal sleep tendencies of college students were very low throughout the day. One might predict that an optimum level of functioning would be accompanied by maximum daytime latencies. There is some indication from this study that chronic partial sleep loss on the student's normal schedules affected the sleep latency test scores. Subject MR, whose sleep logs revealed an average of only 5.5 hr. sleep on the 10 nights before the study, had the lowest baseline sleep latencies. In addition, a correlation coefficient computed between sleep log data and average baseline scores showed a significant relationship ($r = -.93$) between the two variables. We have also found that pre-adolescent children given 9 to 10 hr. of sleep each night do not tend to fall asleep as much on the sleep latency test during the day (Carskadon, Harvey, & Dement, 1977). More recent findings in our laboratory from eight college age subjects suggest that the sleep latencies can be lengthened by increasing nighttime sleep (unpublished results).

The mid-afternoon trough in sleep latency on baseline-1, baseline-2, and recovery-2 presents an intriguing problem. Kleitman (1963) has summarized a number of studies that show a plateau of performance and body temperature corresponding to the time of this dip in sleep latencies. It was noted by Kleitman, however, that there is occasionally a "let-down" experienced in certain subjects and related to the noontime meal. In the present study, luncheon occurred at about 1100 and would not, therefore, seem to be directly affecting the sleep latency test trough, which generally occurred at 1400 or 1600. We have seen a similar pattern in several patient groups and adult comparison groups (Dement, *et al.*, 1978; Richardson, *et al.*, 1978). In addition, Webb and Agnew (1975) found lower sleep latencies in morning and afternoon hours than in the evening hours on a 9-hr. schedule of sleep and wakefulness. Although the downward trend of sleep latency reverses spontaneously, it is a provocative speculation that an afternoon nap might accelerate the improvement and produce greater alertness in the evening. The U-shaped pattern of daytime sleep latency curves suggests, too, that the relationship between sleep latency and length of prior wakefulness may be more complex than the log linear relationship presented by Agnew and Webb (1971).

The rapidity with which sleep latencies declined to minimum values during deprivation suggests that some basic physiological process or sleep mechanism has reached a critical value at this time. If true, it is possible that biochemical and neurophysiological assessment of sleep loss might be able to measure the discrete effects of sleep loss early in a deprivation period before the influences of stress and fatigue become severe. Webb (1957) has found, however, that the sleep latency results may not be as clear-cut in animals (rats) as in humans.

The gradual recovery of sleep latency on recovery-1 is interesting in two respects. First, the performance, mood, and Stanford Sleeping Scale data showed nearly complete recovery to baseline values after a single night of sleep. Sleep latency test scores, on the other hand, suggest that the recovery is not complete on recovery-1. Second, the progressive lengthening of latencies on recovery-1 may indicate that both a night's sleep and an extended period of wakefulness are necessary to complete the recuperation process. It would be of interest to replicate the study allowing more sleep on recovery-1 and determine the recovery curve of sleep latency.

We feel that multiple sleep latency tests throughout the day offer a valuable addition to the experimental repertoire of researchers interested in daytime alertness/sleepiness. The sleep latency tests are fairly simple to administer and appear to be less liable to problems of changing motivation than performance measures. We have begun to utilize the approach clinically in diagnosing patients and assessing treatment (Dement, *et al.*, 1978; Richardson, *et al.*, 1978) and we are examining developmental changes of sleep latencies of adolescents (Carskadon, *et al.*, 1978). Application of the procedure to studies of selective and partial sleep loss may also result in a better understanding of the function of sleep.

REFERENCES

AGNEW, H. W., JR., & WEBB, W. B. Sleep latencies in human subjects: age, prior wakefulness, and reliability. *Psychonomic Science*, 1971, 24, 253-254.

AGNEW, H. W., JR., & WEBB, W. B. Measurement of sleep onset by EEG criteria. *American Journal of EEG Technology*, 1972, 12, 127-134.

AGNEW, H. W., WEBB, W. B., & WILLIAMS, R. L. The first night effect: an EEG study of sleep. *Psychophysiology*, 1966, 2, 263-266.

BERGER, R. J., & OSWALD, J. Effects of sleep deprivation in behavior, subsequent sleep, and dreaming. *Journal of Mental Science*, 1962, 108, 457-465.

BILLIARD, M. Competition between the two types of sleep, and the recuperative function of REM sleep versus NREM sleep in narcoleptics. In C. Guilleminault, W. C. Dement, & P. Passouant (Eds.), *Narcolepsy.* New York: Spectrum Publ., 1974. Pp. 77-96.

CARSKADON, M. A., & DEMENT, W. C. Sleep studies on a 90-minute day. *Electroencephalography and Clinical Neurophysiology*, 1975, 39, 145-155.

CARSKADON, M. A., & DEMENT, W. C. Sleepiness and sleep state on a 90-minute schedule. *Psychophysiology*, 1977, 14, 127-133.

CARSKADON, M. A., DEMENT, W C., HARVEY, K., & ANDERS, T. F. Adolescent maturation and changes in sleep tendency: preliminary report. Paper presented to the 18th annual meeting of the Association for the Psychophysiological Study of Sleep, Palo Alto, California, 1978. (abstract)

CARSKADON, M. A., HARVEY, K., & DEMENT, W. C. Sleep tendency in children. *Sleep Research*, 1977, 6, 91.

CARSKADON, M. A., HARVEY, K., DEMENT, W. C., & ANDERS, T. F. Acute partial sleep deprivation in children. *Sleep Research*, 1977, 6, 92.

DEMENT, W. C. Perception during sleep. In J. Aubin (Ed.), *Psychopathology of perception.* New York: Grune & Stratton, 1965. Pp. 247-270.

DEMENT, W. C., CARSKADON, M., & RICHARDSON, G. Excessive daytime sleepiness in the sleep apnea syndrome. In C. Giulleminault & W. C. Dement (Eds.), *Sleep apnea syndromes.* New York: Alan R. Liss, 1978. Pp. 23-46.

HODDES, E., ZARCONE, V., SMYTHE, H., PHILLIPS, R., & DEMENT, W. C. Quantification of sleepiness: a new approach. *Psychophysiology*, 1973, 10, 431-436.

JASPER, H. H. (Committee Chairman) The ten-twenty electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology*, 1958, 10, 371-375.

JOHNSON, L. C. The effect of total, partial, and stage sleep deprivation on EEG patterns and performance. In N. Burch & H. L. Altschuler (Eds.), *Behavior and brain electrical activity.* New York: Plenum, 1975. Pp. 1-30.

KLEITMAN, N. *Sleep and wakefulness.* Chicago: Univer. of Chicago Press, 1963.

KOLLAR, C. J., PASNAU, R. O., RUBIN, R. T., NAITOH, P., SLATER, G. G., & KALES, A. Psychological, psychophysiological and biochemical correlates of prolonged sleep deprivation. *American Journal of Psychiatry*, 1969, 126, 488-497.

LUBIN, A., MOSES, J. M., JOHNSON, L. C., & NAITOH, P. The recuperative effects of REM and stage 4 sleep on human performance after complete sleep loss: experiment 1. *Psychophysiology*, 1974, 11, 133-146.

MENDELS, J., & HAWKINS, D. R. Sleep laboratory adaptation in normal subjects and depressed patients ("first night effect"). *Electroencephalography and Clinical Neurophysiology*, 1967, 22, 556-558.

MURRAY, E. J Sleep deprivation and personality adjustment. In L. E. Abt & B. F. Riess (Eds), *Progress in clinical psychology.* Vol. 8. New York: Grune & Stratton, 1968. Pp. 44-62.

RECHTSCHAFFEN, A., & FOULKES, D. Effect of visual stimuli on dream content. *Perceptual and Motor Skills,* 1965, 20, 1149-1160.

RECHTSCHAFFEN, A., & KALES, A. *A manual of standardized terminology, techniques, and scoring system for sleep stages of human subjects.* Los Angeles: BIS/BRI, UCLA, 1968.

RICHARDSON, G., CARSKADON, M., FLAGG, W., VAN DEN HOED, J., DEMENT, W., & MITLER, M. Excessive daytime sleepiness in man: multiple sleep latency measurement in narcoleptic and control subjects. *Electroencephalography and Clinical Neurophysiology,* 1978, 45, 621-627.

SCHARF, M. B., BIXLER, E. O., & KALES, A. Readaptation to the sleep laboratory. *Psychophysiology,* 1975, 12, 412-415.

WEBB, W. B. Antecedents of sleep. *Journal of Experimental Psychology,* 1957, 53, 162-166.

WEBB, W. B., & AGNEW, H. W., JR. Sleep efficiency for sleep-wake cycles of varied length. *Psychophysiology,* 1975, 12, 637-641.

WILKINSON, R. T., EDWARDS, R. S., & HAINES, E. Performance following a night of reduced sleep. *Psychonomic Science,* 1966, 5, 471-472.

WILLIAMS, H. L., HAMMACK, J. T., DALY, R. L., DEMENT, W. C., & LUBIN, A. Responses to auditory stimulation, sleep loss and the EEG stages of sleep. *Electroencephalography and Clinical Neurophysiology,* 1964, 16, 269-279.

WINER, B. J. *Statistical principles in experimental design.* New York: McGraw-Hill, 1962.

Accepted February 8, 1979.