Report Number 55

RECOVERY FROM FATIGUE

Annual Summary Report

Mary R. Cook, Harvey Cohen, and Martin T. Orne

July 1972

(For the period 1 August 1971 to 31 July 1972)

Supported by
U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701

Contract No. DADA 17-71-C-1120

Contributors to the Pennsylvania Hospital
Philadelphia, Pennsylvania 19107
Martin T. Orne, M.D., Ph.D.
Principal Investigator

Report Number 55

RECOVERY FROM FATIGUE

Annual Summary Report

Mary R. Cook, Harvey Cohen, and Martin T. Orne

July 1972

(For the period 1 August 1971 to 31 July 1972)

Supported by
U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701

Contract No. DADA 17-71-C-1120

Contributors to the Pennsylvania Hospital
Philadelphia, Pennsylvania 19107
Martin T. Orne, M.D., Ph.D.
Principal Investigator

ACKNOWLEDGMENTS

The Unit for Experimental Psychiatry at the Institute of the Pennsylvania Hospital is fortunate in being composed of research colleagues with diverse backgrounds and interests; without such an unusual group this research could not have been undertaken. The research staff are Harvey D. Cohen, Mary R. Cook, Frederick J. Evans, Charles Graham, David A. Paskewitz, and Emily Carota Orne. The laboratory staff whose role is always a difficult and particularly invaluable one consists of Bette J. Newill, John Basinski, Cynthia Bendon, Virginia P. Derrickson, Elizabeth R. Gessner, Eileen F. Grabiec, John F. Kihlstrom, Barbara J. McCann, Maribeth A. Miller, Frank Mural, Donald E. Newman, Lani L. Pyles, David S. Roby, Deborah E. Seeley, Neal A. Shore, and Mae C. Weglarski.

SUMMARY

To study the effectiveness of daytime sleep (napping) in alleviating the subjective and objective consequences of fatigue, partially sleep-deprived subjects volunteered to take naps in a controlled laboratory setting. EEG and EOG records were obtained as well as a behavioral performance measure, reaction time measures, and subjective depth of sleep reports. Subjects carried out a serial subtraction task (a) before going to sleep, (b) immediately on being aroused from sleep, and (c) some time later after the electrodes had been removed and they felt fully aroused. In general, when subjects were aroused from napping, there was an initial impairment of functioning. Further, some trends in the data suggest that naps were effective in improving final performance. Significantly greater performance decrement was associated with sudden arousal from delta sleep than from REM sleep. Short periods of sleep which did not include significant amounts of delta sleep caused little or no decrement in performance. Further work is in progress studying the physiological characteristics of naps and their effects on the subjective recovery from fatigue among individuals who habitually take naps versus those who do not

Our overall research goal is to establish how periods of sleep serve to ameliorate the feeling of fatigue and progressive performance decrement associated with sleep loss. While the deleterious effects of prolonged sleep deprivation have been documented in carefully controlled studies--in terms of performance decrements on objective tasks, increased irritability, difficulties in concentration, and the appearance of more extreme forms of psychopathology (see Alluisi, Chiles, & Hall, 1964; Dement, 1959; Morris, Williams, & Lubin, 1960; and Naitoh, 1969)--the effects of relatively short periods of sleep deprivation have been difficult to document experimentally. Typically, appropriately motivated subjects are able to compensate for the effects of moderate sleep loss sufficiently well to make it extremely difficult to demonstrate such effects empirically (Wilkinson, Edwards, & Haines, 1966). Nonetheless, as most of us can attest from personal experience, the loss of even a few hours of sleep is keenly felt and tends to have effects on our feeling of well-being, the ability for prolonged concentration, and perhaps even our judgment. There are, of course, considerable individual differences in the ease with which such moderate sleep losses can be handled. Because of the ubiquitous nature of such moderate sleep loss it seems particularly important to explore it, and our research has focused on how individuals recover from these effects.

The research model differs from that usually employed in studies of sleep deprivation. We asked subjects to truncate their preceding night's sleep, limiting themselves to less than four hours. Subjects were to be seen in the laboratory on the subsequent day after having had only a very moderate decrease in length of sleep. The design was to utilize their performance under these circumstances as the baseline and determine whether a period of daytime sleep might have salutary effects on performance and the feeling of being well rested.

There are a series of questions which ultimately need to be resolved in order to determine the extent to which individuals can make up the effect of sleep loss and how they may do so most efficiently: for example, whether rest as opposed to sleep had equivalent restorative qualities, whether special states of consciousness such as meditative states, "the alpha state,"* or related phenomena may have beneficial effects, whether there are differences between different kinds of sleep periods--a very likely possibility since sleep is known to be far from homogeneous in its physiological effects. Furthermore, there seems little doubt from anecdotal evidence that individuals differ widely in the extent to which they are able to utilize daytime naps productively--an issue of considerable practical importance which we intend to explore further during the forthcoming year.

The model involves studying not the effects of sleep deprivation but rather the effects of sleep--and potentially other states--on the recovery from varying degrees of sleep loss. We felt that such a paradigm might well help us demonstrate effects which otherwise would elude observation. An important conceptually unrelated question which might

---

*This question which is currently being investigated by Dr. Laverne Johnson and his collaborators might prove particularly interesting.

easily have confounded these studies concerns the different effects resulting from awakening in different stages of sleep. Again anecdotally, it is well known that on some days waking up in the morning is a far more joyful experience than on others; even being aroused from sleep is far more troublesome at some times than at others--regardless of the reason for being awakened. It seems entirely plausible that arousal time from Stage 4 (delta) sleep would be experienced quite differently from arousal during other stages of sleep. Since morning awakening is likely to be from REM sleep, one might well anticipate that an individual arousing during REM would somehow feel more rested and be able to function better, independent of the length of sleep attained. Furthermore, when an individual is aroused from sleep and asked to perform a complex task, he tends to show considerable performance decrement which usually disappears within a few minutes. Previous work by Scott (1969) suggests that subjects aroused from Stage 4 sleep show considerably greater confusion and impaired performance on complex tasks than subjects roused from REM. These observations, if reliable, would have considerable importance for our overall approach, and consequently our initial study explored the differential decrement in performance immediately on arousal from REM vs. delta sleep on the one hand and the possible increment of performance as a consequence of sleep after the individual is fully aroused and the transient decrement has passed.

Method

Nine subjects selected for their availability participated in our pilot studies. Each took part in several sessions and the details of these sessions are presented in Table 1. A total of 40 nights of truncated sleep,

TABLE 1

Distribution of Performance Tasks for Each Subject

Subject	No. of Sessions	Adaptation	Clock Reversal	Random Nos.	Sequential Subtraction	Descending Subtraction
1	6	2	2	1[a]	1[a]	2
2	6	1	4	2[a]	1[a]	1
3	2	1	1	1[b]	1	
4	6	1	2	2[c]	1[a]	3
5	3	1				2
6	6	1				5
7	3	1				2
8	5	1				4
9	3	1				2
Total	40	10	9	6[a]	4[a]	21

a. In same sessions as clock reversal.

b. In adaptation session only.

c. One in adaptation session, one in clock reversal session.

with sleep replacement on the subsequent day, provided the bulk of the data on which this report is based. Although subjects were free to choose whether to shorten their sleep by rising early or retiring late, all chose to retire late. Thus, our population all had reduced the total amount of sleep on the preceding night and had obtained whatever sleep they had fairly recently.

Measures

A. Physiological measures. Parietal and occipital monopolar EEG recordings referred to the mastoid, and two channels of EOG were continuously recorded throughout each sleep session.

B. Behavioral and psychological measures. At the beginning of the experiment, each subject was asked to fill out a detailed sleep questionnaire, a sample of which is included in the Appendix (Form L). On subsequent experimental days, a short questionnaire, covering only the previous 24 hours was also administered (see Appendix, Form S). These questionnaires allowed us to monitor such potentially important factors as drug ingestion, napping behavior and unusual disturbances in daily habits.

To evaluate the subject's state of arousal, he was asked at each awakening to rate his experience on a five-point scale, in which 1 represented an alert, wide-awake state, and 5 represented very deep sleep (as at night). It should be noted that this rating did not refer to the subject's current state of arousal, but to his estimate of state just prior to awakening.

During the sleep session, the subjects were abruptly awakened

(Goodenough, Lewis, Shapiro, Jaret, & Sleser, 1965) by a continuous, moderately loud bell (10 dB above ambient). The time elapsed from the onset of this bell to the first sign of EEG arousal was recorded. The bell continued to ring until the subject picked up a telephone receiver located on a bedside table, providing a measure of the speed with which the abruptly awakened subject could perform a familiar motor task (Scott, 1969).

Three time estimation tasks were included in the behavioral measures. Subjects were asked to estimate (1) the amount of time elapsed since the experimenter last spoke, (2) how long they had slept, and (3) how long it took them to answer the phone. Differences between these times and the actual elapsed time were recorded.

Procedure

Because of the exploratory nature of the work reported here, the procedures changed several times during the course of the experiment. The time window during which awakenings could take place, as well as the task, was altered as we learned more about the nature of sleep replacement. On the first day of the experiment, the subject filled out the long questionnaire, was then taken to the experimental chamber, and given practice on the task or tasks to be used. The procedures and the rating scales were explained. A pre-sleep task trial was then administered, electrodes attached, and the subject allowed to go to sleep. Data from the first sleep session on each subject have been omitted from most of the data analysis. Any data analysis which includes this adaptation day has been so labeled.

On Day 2 and each subsequent day, the subject filled out the short sleep questionnaire, was conducted to the experimental chamber, and electrodes were attached. For most of the experimental sessions, the subjects were then put to bed, given a pre-sleep task trial, and allowed to go to sleep. For 14 sessions, all of which included the descending subtraction task (see below), two pre-sleep trials were given, one sitting up before the electrodes had been attached and one after the subject had been put to bed.

A related question, which we felt could be investigated within the context of this experiment without interfering with its main purpose, was the relationship between the subjective ratings of sleep depth and time since sleep onset, regardless of stage. For 24 of the sessions, therefore, the subject was awakened 5 to 20 minutes after the first sleep spindle, asked for a subjective state estimate, and allowed to go back to sleep. No orderly relationship was apparent in the data, and the procedure was dropped. No evidence that this change in procedure affected the results of other manipulations was found, and the data have been combined.

During the first sessions of the experiment, a window was set within which delta (Stage 4) or REM awakenings could take place. The subject was required to have been sleeping at least 45 minutes. Within this limitation, an attempt was made to awaken either from Stage REM or delta sleep. The time window soon proved to be too restrictive. Subjects often showed consolidated Stage 4 sleep, but by the end of 45 minutes were no longer in Stage 4. Consequently, the window was discarded, and the experimenter woke the subject as soon as the desired stage seemed to be well consolidated. While the goal had been to have an equal number of REM and delta awakenings, and with this in mind, morning and afternoon experiments were scheduled (Karacan, Finley, Williams,& Hursch, 1970), the manipulation was not totally successful, and delta awakenings were more frequent than REM awakenings.

In a typical experiment, two awakenings were possible, not including the onset awakening. For each of these awakenings, the subjects were asked, as soon as they picked up the phone, for subjective state estimates and time estimates. They were then given a task, on completion of which they were asked how long they thought they had taken to do the task. After this procedure was carried out for the final time of each sleep session, the experimenter entered the room, removed the electrodes, and asked the subject to dress. A final task trial was then administered, thereby completing the session.

Tasks

One of the initial objectives was to find an appropriate task which would be sensitive to the effects of fatigue. Of interest was a task that could be administered fairly rapidly, that would not require the subjects to write, and that, preferably, could be carried out with eyes closed. Further, performance should rapidly asymptote, and therefore it should not be subject to meaningful increments with practice. Finally, it was desirable that the task yield a number of data points facilitating statistical analysis.

A. Clock reversal. The initial procedure employed was similar to that utilized by Cartwright (1966) and described by Scott (1969) in his efforts to distinguish between REM and delta awakenings. The subject is given a time, such as 10:07 and asked to state what time it would be if the hands of the clock were reversed, i.e., 1:50. The length of time required to correctly solve the problem is the measure. If the subject does not give a correct answer, the problem is repeated until a correct answer is given. While this task seemed promising, it became apparent that the clock problems varied widely in difficulty and that rather extensive parametric work would be necessary to develop a sufficiently well matched set of problems. The amount of within-subject variability was so great that the task was dropped after nine experiments.

B. Random number generation. The random number task was essentially the same as that reviewed by Wagenaar (1972). The concept of randomness is explained to the subject, and he is asked to generate random sequences of the numbers from 1 to 10 at a rate of about one per second. To do well, the subject must avoid sequences such as 2-4-6-8 or 1-2-3-4-, etc. In past research within the laboratory the ability to generate random numbers was found to be a useful index of attention deployed. As the subjects would become drowsy, they soon began to show clear evidence of sequencing, with increased drowsiness, repetitions began to occur, and so on. Subjects are instructed to pace themselves at the rate of one per second, and the procedures we have employed permit them to generate numbers at their own rate so that work curves could be investigated. Both the randomness of the numbers and the quantity of numbers produced per unit of time were evaluated because subjects tended to slow their rate of number generations, which improves randomness. This task also did not seem to be sensitive enough to the variables in which we were interested and therefore had to be discarded after six sessions.

C. Sequential subtraction of 7's. This procedure, widely used as a mild stressor in physiological studies, involves giving subjects a large number and asking them to serially subtract by 7's. However, since we found strong practice effects, the procedure did not turn out to be useful as a repeated measure. Subjects soon learned the predictable sequence of digits, and the procedure had to be modified again after four sessions.

D. Descending subtractions. The task that proved to be most promising was selected because it required skills similar to those necessary for the successful performance of the clock reversal task. Thus, in the clock reversal task the individual is required to picture the clock in his mind or at least hold one set of positions or angles in mind while he solves the question; i.e he must firmly keep in mind where the old minute hand was in order to correctly convert it to the required hour-hand, etc. It seemed to us that the requirement to carry out a mental manipulation while simultaneously keeping in mind something else might be the kind of task which is sensitive to the effects of sleep loss and the effects of the transient drowsiness immediately following awakening. In this procedure the subject is presented with a large number such as 976. He must then subtract 9 from that number, then subtract 8 from the remainder, then 7 and so on until he subtracts 2 after which he begins again with 9 and repeats the sequence until told to stop (after approximately two minutes). In our present example, he would subtract 9 from 976, say out loud 967, then subtract 8 from that number and say 959, and so on. Inherent in this procedure is the necessity for the subject to keep in mind not only the base number but also how far down he has progressed in the descending order. Losing track of either leads to an error. Because this task appeared, after several sessions, to be considerably more promising than the others, it was used throughout the rest of the study.

Several measures are available from the descending subtractions task. First, it is possible to look at how many numbers are produced per unit of time and this can be plotted in the form of a work curve, making it possible to determine where in the approximately two-minute task the subject works most rapidly and where he works most slowly. Secondly, a performance decrement score can be computed, based on the mean time required to produce each number. This score expresses the change in performance rate as a percent of pre-sleep performance rate. Finally, several possible error scores can be derived: the number of errors over the approximately two-minute period, the number of items produced before an error is made, and the type of errors are all of potential interest. Though the type of error may prove to be particularly important, we have encountered considerable difficulty in classifying the errors and are now working on ways to make such analyses more reliable.

Results

I. Sensitivity of the Performance Measure

1. The Effect of Practice.

In evaluating the utility of the descending subtractions task as a criterion measure, it should be noted that the data from the first day of the performance were eliminated; all subjects therefore were familiar with the task. Since practice effects should be apparent when fairly similar waking performances are compared, the post-nap performance for each day was compared with the pre-nap performance on the subsequent day. No significant differences were observed (t = .26, df 10). To further evaluate the practice effect, 15 subjects were given two pre-nap trials, and no reliable differences could be observed between them (t = .81, df 14). Finally, the post-nap performances over sessions were examined. These performances should be closely comparable; however, between them each subject would have had at least four experiences with the task. No trend suggesting post-nap performance improvement as a function of the number of sessions was observed. We therefore conclude that, given a minimal amount of experience with the task, no further appreciable practice effects are likely to be found.

2. The Effect of Interrupting Sleep.

A. Sensitivity of the performance task to the effects of sudden arousal from sleep and the nap itself. If the task is truly sensitive, it should reflect the decrement in performance associated with sudden arousal from sleep. Table 2 shows the four measures of performance which were used for this analysis and their sensitivity to abrupt awakening. While

TABLE 2

Performance Scores on Descending Subtraction Task[a]

Measure	Pre-Nap	First Awakening	Second Awakening	Post-Nap
Number of sessions	21	21	17[b]	21
Mean time per number	3.80	4.94	4.88	3.76
Performance decrement[c]	---	.32	.29	.02
Number of errors[d]	3.10	5.29	2.75	2.86
Numbers prior to first error	16.30	15.00	18.00	25.50

a. Means are based on all sessions. Since there were an unequal number of sessions per subject, some subjects contribute more to the means than others.

b. Four of the sessions were terminated after the first awakening.

c. Performance decrement score = Mean time to produce sets of eight numbers at awakening, less mean time pre-nap, divided by mean time pre-nap. No performance decrement score is therefore available for the pre-nap task.

d. Based on the first 40 numbers produced.

these measures cluster somewhat, they clearly tap different aspects of performance. The mean time per number is a simple rate measure independent of errors. Performance, as described by this measure, dropped significantly at both the first and second awakening, but was essentially unchanged from baseline during the post-nap test. The number of errors is a simple measure based on the first 40 numbers produced. The number of errors increased following the first awakening, but recovered by the time of the second awakening and was essentially unchanged from the initial baseline during the post-nap test.

A convenient way of reflecting the change in performance is the performance decrement measure. This is based on the average speed with which sets of eight numbers (serially subtracting 9 through 2) are produced. It is computed by taking the mean time to produce sets of eight numbers at awakening, minus the mean time to produce sets of eight numbers during the pre-nap baseline, and dividing the remainder by the mean time to produce sets of eight numbers during the pre-nap baseline. The result is a percentage decrement score--the greater the score, the poorer the performance relative to baseline.

The final measure was the number of serial subtractions correctly completed before making the first error. This measure appears to tap the subject's ability to maintain concentration while carrying out this very demanding task. Interestingly, on this measure we did not find the difference between performance immediately on awakening and the pre-nap baseline which was observed with other measures. Even more promising was the significant difference between the post-nap test and the pre-nap test which was not apparent when performance was analyzed in other ways.

Because the different measures appear to reflect different mental functions even though they are derived from the same task, no effort was made to combine them into an overall performance measure; on the contrary, it would seem more useful at this time to treat them as if they were largely independent measures.

B. The effects of abrupt awakening on task performance. In order to separate the effects of the disorientation which occurs when the subject is abruptly awakened from a sound sleep from the effects of the nap itself, task performance immediately after the final awakening was compared with task performance after the subject had been awake for several minutes and all electrodes had been removed. Improvements between the second and third performance were noted on mean time per number, the number of correct subtractions prior to the first error, and on performance decrement. After the electrodes had been removed, 15 of the 21 subjects produced more items before the first error ($p = .04$) and 18 of the 21 improved their mean time per number ($p = .001$) even though the two test administrations occurred only approximately 10 minutes apart. A further pilot study was carried out consisting of two sessions each for four subjects. Subjects were given a 10-minute reading task after the first awakening and then retested with the descending subtraction task. Under these circumstances little or no evidence of improvement was noted despite the fact that subjects appeared alert and no longer confused. This situation was quite different, however, from the preceding one in that the subjects after reading expected to return to sleep as opposed to those where electrodes had been removed and they naturally expected to stay awake. It is like , that set differences might account for the failure to improve performance after 10 minutes of reading. It is also possible that alerting does not take place fully until the individual makes a definite decision to become fully awake. Whether this can be accomplished while resting is of some interest. It is entirely possible that postural changes and movement are particularly helpful in improving performance, a question which we hope to explore in the future.

C. The effect of sleep on performance after becoming fully aroused. During very early pilot studies we observed a significant increment in performance after the subject was fully aroused when this was compared with his earlier performance prior to going to sleep. We were particularly encouraged by this observation. Unfortunately, significant results with small samples are not necessarily reliable since they may be heavily influenced by idiosyncratic characteristics of one or two subjects. With additional sessions and a somewhat enlarged sample we failed to find a post-nap performance increment and the number of subtractions produced per unit time were no different from those prior to the nap. Nonetheless, a significant difference was still present in the total number of correct subtractions produced prior to the first error. The difficulty in demonstrating the effects of sleep replacement is, of course, consistent with previous observations that it is very difficult to show the effects of moderate sleep deprivation. We hope that the effects on the number of items correctly subtracted before the first error, apparently related to som aspect of attention, will persist in future work since the availability of a performance measure of this kind would make the research considerably easier. In any case, however, the task performance appears to show significant and lawful relations to other dimensions of sleep which in themselves more than justify the further use of this criterion measure.

II. Relationship of Performance with Stage of Sleep

1. The Relationship between Performance and the Stage from Which the Subject was Awakened.

The mean performance decrement was greatest when subjects were awakened from delta sleep ($\bar{X}$ = .45, N = 12), less during REM awakenings ($\bar{X}$ = .28, N = 5), and least when subjects were awakened from Stage 2 ($\bar{X}$ = .13, N = 3). While the number of subjects awakened from REM and Stage 2 is too small for confident interpretation of these data, both t-tests and Mann-Whitney U tests suggest that there is a meaningful difference between delta and Stage 2 awakenings (t = 2.79, $p < .02$; U = 5, $p < .10$). The results differed when mean time per number was used as the performance score. Again, the greatest effect was for delta sleep ($\bar{X}$ = 5.55 sec.), but Stage 2 awakenings were similar ($\bar{X}$ = 5.30 sec.). REM awakenings, however, resulted in significantly faster performance ($\bar{X}$ = 3.74 sec.) than delta (t = 2.46, $p < .05$; U = 9, $p < .05$). These data indicate that performance is slowest when subjects are aroused from delta sleep and somewhat slowed when aroused from REM, while relatively fast when subjects are aroused from Stage 2. While the data for delta sleep are based on a reasonable pilot sample, the samples for REM and especially Stage 2 are so small that only the most tenuous inference is possible.

2. Further Analyses of the Time Spent in Specific Sleep Stages and Performance on Awakening.

Subjects napping after partial sleep deprivation rapidly enter non-REM sleep, often enter delta, and remain in this state for some 45 minutes or more before entering REM. Since we did not find it feasible to control the number of minutes subjects slept, we observed systematic differences between the number of minutes subjects slept and the stage of sleep from which they were awakened. The average number of minutes subjects slept prior to REM awakenings was 71.7; for Stage 2 awakenings, it was 52.3; and for delta awakenings, it was 44.2. Since, as has already been pointed out, subjects awakened from delta show the greatest performance decrement, and these subjects slept the shortest total time, it seemed possible that the highly significant correlation between the amount of delta sleep obtained and the performance decrement might prove to be an artifact of the experimental design; in other words, subjects awakened from REM or Stage 2 would have slept a longer period of time and are therefore likely to have had more delta sleep than subjects awakened from delta. Consequently the apparently deleterious effects on performance of the amount of delta sleep could possibly be simply a function of the stage from which the subject is aroused.

For this reason, another analysis was carried out, using only those awakenings where subjects were aroused from delta sleep, thereby avoiding this possible confounding factor. Somewhat surprisingly, we observed a significant correlation of +.54 ($p < .01$) with the length of the delta epoch immediately prior to arousal, and an insignificant correlation of +.35 with total delta, still in the same direction as that noted previously, and even more striking, a significant negative correlation of -.48 ($p < .05$) with the amount of time spent in Stage 2. If these surprising findings prove to hold with larger samples, it would suggest that the amount of delta sleep obtained during napping, followed by arousal before the nap is completed, has a negative influence on performance upon awakening. Conversely, the amount of Stage 2 obtained during a nap from which the subject is prematurely awakened correlates positively with performance. This exciting lead suggests that one of the possible differences between individuals who find short naps extremely helpful and individuals who do not consists in the amount of delta versus Stage 2 that they habitually obtain under these circumstances. Those individuals who utilize their nap time by entering delta sleep and remain there are likely not to experience a restorative effect of a nap, whereas those who have somehow learned to nap in Stage 2 might well be those individuals who find it helpful.

3. <u>Relationship with the Type of Sleep Obtained</u>.

Table 3 shows the effect of the amount spent in different stages of sleep and the time asleep on performance when subjects are awakened from sleep. The effects of the amount of sleep obtained in different stages are consistent for both the performance decrement score and the mean time per number but seem to bear little relationship to the number of errors made. The total amount of time asleep, the amount of time spent

TABLE 3

Relationships Between Performance Measures and Sleep Variables

Sleep Variable	Performance Decrement r	Performance Decrement p<	Time per Number r	Time per Number p<	Errors r	Errors p<
Total time since Experimenter last spoke	-.56	.01	-.56	.01	-.001	NS
Time asleep	-.30	NS	-.29	NS	+.14	NS
Time in Stage 2	-.54	.01	-.48	.025	+.13	NS
Time in Stage REM	-.23	NS	-.53	.01	-.11	NS
Time in Delta	+.31	NS	+.50	.01	+.18	NS

in Stage 2, and the amount of time spent in REM correlate negatively with performance decrement; that is, the longer these times, the better the subject's performance. The amount of delta sleep, however, showed a positive correlation with performance decrement: the more delta sleep, the worse the performance.

4. The Effect of the Length of Nap Session on Performance.

One of the primary foci of this research has been to explore the positive function sleep serves in preventing performance decrement. One might anticipate with a longer nap a better task performance would be observed; however, in the present study the analysis of this effect is confounded with the performance decrement observed with sudden arousal from sleep. Nonetheless, the relationship between performance scores and the actual amount of time slept prior to the first awakening was examined. Low and non-significant correlations between performance scores and amount of sleep to first awakening were found: for performance decrement, -.31; for mean time per number, -.29; for errors, +14. However, the total length of the sleep session--that is, the time elapsed from lights out to the first awakening--showed a much stronger effect: for performance decrement, -.56 ($p < .01$); whereas for errors the correlation was zero. Thus, the longer the period of the nap session--independent of the actual amount of time slept within the session--the faster the performance.

III. Relationship Between Performance and Measures of State

1. Subject State Reports.

Subjects' reported state on awakening was not related either to the mean time per number or to the number of errors made. However, a significant correlation ($r = .37$, $p < .05$) was found between subjective state and performance decrement.

2. Time to EEG Arousal.

Again, no significant correlation was found between time to EEG arousal and mean time per number ($r = .16$) or the number of errors made ($r = .29$). Performance decrement was more sensitive: a positive correlation of .45, $p < .025$ was found. Time to EEG arousal therefore showed a pattern of prediction very similar to that found when the subjective estimate was used as a measure of state.

3. Reaction Time.

Comparing the time required for subjects to answer the telephone on arousal and their performance on the task immediately thereafter yielded a positive correlation of .39 and .38 respectively with the amount of time per number and the amount of performance decrement. These correlations are significant at the .05 level. However, neither overall number of errors nor the number of correct subtractions prior to the first error were related to reaction time.

4. Estimate of Time since Experimenter Last Spoke.

Mean time per number was highly correlated with this time estimate ($r = .64$, $p < .01$), but only a low correlation with performance decrement was observed ($r = .36$, $p < .10$).

5. Prediction of Performance on Awakening.

The variables which significantly predicted performance decrement are shown in Table 4. The stage of sleep at awakening, the amount of time spent in Stages 2, delta and REM, the total length of the session, the subjective report of the individual on awakening, time to EEG arousal, reaction time, and estimate of time since the experimenter last spoke all were correlated with performance measures. The extent to which predictions of performance decrement could be improved by combining these variables was therefore investigated.

Eleven of the 28 resulting multiple correlations increased the explained variance by 10% or more. Examination of the correlation coefficients suggested that subjective state report, EEG arousal time, accuracy of time estimation and time spent in delta sleep and in Stage 2 were the most powerful predictors of performance decrement. Subsequent multiple correlations based on four variables supported this conclusion. EEG

TABLE 4

Correlations Between Performance Decrement and Other Measures

Variable	r	p<
Session Length	-.56	.005
Time in Stage 2	-.54	.01
Time in Delta	+.31	NS
Time in REM	-.23	NS
Subjective State	+.37	.05
EEG Arousal Time	+.45	.025
Reaction Time	+.38	.05
Time Estimation	+.36	.05
Multiple Correlations		
Time in Delta, Subjective State, EEG Arousal Time	.77	.005
Time in Delta, Subjective State, Time Estimation	.71	.005
Time in Stage 2, Subjective State, Time Estimation	.73	.005

arousal time, subjective state and time in delta predicted 59.5% of the variance in performance decrement ($r = .77$). Subjective state, time estimation and time in delta predicted 49.8% ($r = .71$), and subjective state, time estimation and time in Stage 2 predicted 53.4% ($r = .73$).

Discussion

Our initial experiments indicate that the serial subtraction task will provide a useful criterion measure of performance. It appears to be the kind of measure which taps an individual's capacity to carry out one task while simultaneously keeping in mind another parameter which is continually changing. In contrast to simpler performance measures, this procedure reliably identifies the performance decrement associated with sudden arousal from sleep and has been tentatively shown to relate to a simple measure of subjective state, the subject's behavioral and EEG reaction time on awakening from sleep, as well as the EEG sleep stage from which the individual is aroused. While findings are less encouraging in our efforts to demonstrate the restorative effects of naps on performance, they nonetheless appear worth pursuing. Certainly the model which studies the function of recovery from fatigue rather than the gradual decrement performance over time appears a powerful paradigm to study problems of operational significance.

The very exciting finding that delta sleep appears counterproductive during relatively brief naps demands detailed investigation. This observation has major theoretical implications for our understanding of sleep. If it proves to be demonstrable under other experimental circumstances, it may serve to clarify why some individuals are capable of benefiting from short naps and others are not. Some apparently unrelated observations would seem to fit such a view. Thus, older people are known to have far less delta sleep than young adults. Further, many individuals who had not napped during most of their adult life find short periods of sleep useful and restorative as they grow older. Younger individuals who tend to nap spontaneously are typically easily aroused and alert when awakened from their naps as opposed to those individuals who do not habitually nap; non-nappers are more difficult to arouse and show signs of confusion on awakening.

During the forthcoming year we intend to pursue these findings and expect to clarify the relationship between delta sleep during napping and post-napping performance. One set of studies, particularly relevant to this issue, will compare individuals who habitually take "cat naps" of 10 to 20 minutes with those who do not find such short periods of napping helpful. We anticipate significant differences in the amount of delta sleep during naps, with those individuals who prefer napping showing far less tendency toward delta sleep during their naps. In these studies of spontaneous napping behavior we intend to use individuals who are not sleep deprived and will therefore not utilize performance measures during the initial studies, focusing instead on the physiological parameters of sleep on the one hand and subjective measures aimed at quantifying the restorative experience of the nap on the other.

Our work to date suggests that the ability to make up sleep loss through the use of naps varies with individuals. Thus far, we have utilized samples of subjects chosen for their availability rather than for their specific sleep histories. One of the most powerful research strategies which will be employed in the forthcoming year is to select individuals with specific kinds of sleep histories. We have already collected and analyzed sleep questionnaire data on two large samples of subjects. The subjective reports obtained appear to fall into definite clusters of responses. We intend to extend our questionnaire studies of napping behavior to additional samples, first to validate our findings and then to utilize the preliminary observations as the basis for devising a more powerful questionnaire. Subjects will then be selected who show a distinct preference for napping and who habitually utilize this procedure even when faced with very moderate loss of sleep. A special effort will be made to distinguish these individuals from another group who nap for enjoyment or because of boredom or because of psychological difficulties rather than as a means of making up for lost sleep.

The same questionnaire data will be used to provide a contrast group of individuals who avoid napping even when they have undergone considerable sleep loss. Thus we have found individuals who prefer to remain awake, even though they might be quite tired and have an hour or two available, because in the past they have found than an attempt to sleep a relatively short period leaves them more tired than before. These individuals report that it is simply not worth their while to sleep if they do not have at least four or five hours available. We expect that the patterns of daytime sleep will be different between this group and those persons who nap briefly to make up for lost sleep. Furthermore, we expect to find quite different effects of naps on the performance of the two groups. Naturally, since individuals are selected on the basis of subjective reports, clear differences in experiential reports following short periods of sleep should be obvious.

Once it has become possible to determine the kind of mechanisms which allow an individual to utilize short periods of sleep as an effective means of alleviating fatigue, the effects of these skills on maintaining performance under the conditions of prolonged partial sleep deprivation can be evaluated. Whether these skills are related to the ability of some individuals to function without any objective or subjective evidence of deprivation will need to be established. Regardless of this relationship, however, there is considerable anecdotal evidence that many of those individuals who have been able to maintain a high level of performance over long periods of time have done so with the aid of repeated short periods of sleep. It is the ultimate aim of this research to identify the mechanisms which make this possible and develop means by which those individuals unable to benefit from short periods of sleep may learn to do so as an effective means of alleviating both the performance decrement and the subjective feelings associated with fatigue.

References

Alluisi, E. A., Chiles, W. D., & Hall, T. J. Combined effects of sleep loss and demanding work-rest schedules on crew performance. Technical Report No. AMRL-TDR-64-83. Filed with Defense Documentation Center, Access #AD602-214, October 1964.

Cartwright, Rosalind D. Dream and drug-induced fantasy behavior. Archives of General Psychiatry, 1966, 15, 7-15.

Dement, W. C. Psychophysiology of sleep and dreams. American Handbook of Psychiatry, 1959, 3, 290-332.

Goodenough, D. R., Lewis, Helen B., Shapiro, A., Jaret, L., & Sleser, I. Dream reporting following abrupt and gradual awakenings from different types of sleep. Journal of Personality and Social Psychology, 1965, 2, 170-179.

Karacan, I., Finley, W. C., Williams, R. L., & Hursch, C. Changes in stage 1-REM and stage 4 sleep during naps. Biological Psychiatry, 1970, 2, 261-265.

Morris, G., Williams, H., & Lubin, A. Misperception and disorientation during sleep deprivation. Archives of General Psychiatry, 1960, 2, 247-254.

Naitoh, P. Sleep loss and its effects on performance. Technical Report No. 68-3. Filed with Defense Documentation Center, Access #AD699-505, August 1969.

Scott, J. Performance after abrupt arousal from sleep: Comparison of a simple motor, a visual-perceptual, and a cognitive task. Proceedings of the American Psychological Association, 1969, 77, 225-226.

Wagenaar, W. A. Generation of random sequences by human subjects: A critical survey of literature. Psychological Bulletin, 1972, 77, 65-72.

Wilkinson, R. T., Edwards, R. S., & Haines, E. Performance following a night of reduced sleep. Psychonomic Science, 1966, 5, 471-472.

Recovery from Fatigue

Appendix

Unit for Experimental Psychiatry
Institute of the Pennsylvania Hospital

UEP:10-ECS:1

Patterns of Sleep Questionnaire

FORM L

Name:______________________________________ Date:___/___/_____
last first middle

Date of Birth:___/___/_____ Sex:______ Time of day:___:___ __________
A.M. or P.M.?

Instructions:

People vary greatly in their patterns of sleep and in their preferred times for sleeping. We are interested in obtaining data on various patterns of night-time sleep and also on the frequency of ability to sleep during the daytime. We would very much appreciate your cooperation in giving us information on how you sleep, when you sleep, and how deeply you sleep, by filling in this questionnaire.

Please answer each question by checking the appropriate description of the frequency of occurrence or by filling in the blanks on the questions which have them. There is room for general comments at the end of the questionnaire. Please answer every question.

1. Do you fall asleep readily?

   always _____ usually _____ sometimes _____ rarely _____ never _____

2. Approximately how long does it usually take you to fall asleep?

   _______ _________
   hours minutes

4. During the past year how many hours of sleep have you regularly gotten per night? ______________________________

5. Was there ever a period after the age of 10 when you regularly slept a different number of hours than you answered in question 4? __________

5a. If yes, how many hours? ____________ During what ages? __________

6. Are you a deep sleeper?

always _____ usually _____ sometimes _____ rarely _____ never _____

7. Do you wake up some time during the night?

always _____ usually _____ sometimes _____ rarely _____ never _____

8. Do you get up some time during the night?

always _____ usually _____ sometimes _____ rarely _____ never _____

8a. If ever, how often during the night? ______________________________

9. Have you ever awakened during the night to find that you had bitten your tongue? ______________________________

10. Do you take cat naps during the day?

always _____ usually _____ sometimes _____ rarely _____ never _____

11. Could you fall asleep and nap during the day if you had the time? _____

12. Would you like to be able to nap during the daytime? ____________

13. Do you get as many hours of sleep as you would like? ____________

13a. How many hours sleep per night would you like to get? ____________

14. Do you sleep as deeply as you would like? ____________________

15. If you could choose any schedule of sleep, at what hour would you choose to go to sleep? ______ ______________
hour A.M. or P.M.?

15a. At what hour would you choose to awaken? ______ ______________
hour A.M. or P.M.?

16. Were the hours of sleep you described in questions 15 and 15a ever your pattern of sleep? ______________________________

16a. If ever, during what ages? ______________________________

17. At the present time how often are the hours of sleep you answered in questions 15 and 15a your present pattern of sleep? _______

always _____ usually _____ sometimes _____ rarely _____ never _____

18. Do you usually have the same number of hours of sleep over the summer as during the academic year? ______________________________

18a. If different, please list:

Academic year: ____________ Summer: ____________
no. of hours no. of hours

19. Do you go to sleep and awaken at approximately the same times during the academic year and the summer? ______________________________

19a. If different, please list:

	<u>go to sleep</u>		<u>awaken</u>	
Academic yr.:	______ hour	______ A.M. or P.M.?	______ hour	______ A.M. or P.M.?
Summer:	______ hour	______ A.M. or P.M.?	______ hour	______ A.M. or P.M.?

20. Over the past academic year, have you usually slept the same number of hours per night on the weekend as during the week? ______________________________

20a. If different, please list:

Weekdays: ____________ Weekends: ____________
no. of hours no. of hours

21. Do you go to sleep and awaken at approximately the same times during the week as on the weekends? ____________

21a. If different, please list:

	go to sleep		awaken	
Weekdays:	____ hour	____ A.M. or P.M.?	____ hour	____ A.M. or P.M.?
Weekends:	____ hour	____ A.M. or P.M.?	____ hour	____ A.M. or P.M.?

22. Do you have trouble sleeping?

always _____ usually _____ sometimes _____ rarely _____ never _____

22a. If ever, to what would you attribute this? ____________

____

23. Do you take sleeping medications?

always _____ usually _____ sometimes _____ rarely _____ never _____

24. Have you taken tranquilizers?

regularly ____ frequently ____ sometimes ____ rarely ____ never ____

25. Do you take sedatives during the daytime?

regularly ____ frequently ____ sometimes ____ rarely ____ never ____

26. How many cups of coffee or tea do you usually have per day? ________

26a. At approximately what times during the day? ____________

____

27. Do you smoke? ____________

27a. If yes, how many per day of cigarettes _____ cigars _____ pipes? _____

28. How sleepy are you now?

very sleepy _____ drowsy _____ normally tired for this time of day _____

in a normal wake state _____ wide awake, too awake to sleep _____

29. Did you sleep well last night? ______________________________

30. What time did you wake up this morning? _____ hour _____ A.M. or P.M.?

31. What time did you get up this morning? _____ hour _____ A.M. or P.M.?

32. What time did you go to bed last night? _____ hour _____ A.M. or P.M.?

33. Approximately what time did you go to sleep? _____ hour _____ A.M. or P.M.?

34. Did you wake up during the night? ______________________________

35. Did you get up during the night? ______________________________

36. How many hours did you sleep last night? ______________________________

37. Did you take any naps today? __________ if so, for how long? _____

____

38. Could you go to sleep now if you had the time? ______________________________

39. Have you taken any medications in the past 12 hours (e.g., No-Doz, Darvon, aspirin, cold pills, penicillin, Codeine, hay fever pills, etc.)?

Please list: ______________________________

40. How many cups of coffee or tea have you had today? ______________________________

41. How many cups of coffee or tea have you had during the past three hours?

____

Additional comments regarding your patterns of sleep not covered above:

Unit for Experimental Psychiatry
Institute of the Pennsylvania Hospital

UEP:10-ECS II+

Patterns of Sleep Questionnaire

Form S

Name:________________________________Date: __/__/______
last first middle

Date of Birth:__________Sex:______Time of day:__:__ ________
a.m./p.m.

Instructions:

People vary greatly in their patterns of sleep and in their preferred times for sleeping. We are interested in obtaining data on various patterns of nighttime sleep and also on the frequency of the ability to sleep during the daytime. You have previously completed a questionnaire regarding your general sleep patterns and we would very much appreciate your cooperation in giving us further information regarding how you slept last night by filling in this questionnaire.

Please answer each question by checking the appropriate description of the frequency of occurrence or by filling in the blanks on the questions which have them. There is room for general comments at the end of the questionnaire. Please answer every question.

1. How sleepy are you now?

very sleepy_____drowsy_____normally tired for this time of day____

in a normal wake state_____wide awake, too awake to sleep______

3. What time did you wake up this morning? ______ ____________
hour A.M. or P.M.?

4. What time did you get up this morning? ______ ____________
hour A.M. or P.M.?

5. What time did you go to bed last night? ______ ____________
hour A.M. or P.M.?

6. Approximately what time did you go to sleep? ______ ____________
hour A.M. or P.M.?

7. Did you wake up during the night? ____________________

8. Did you get up during the night? ____________________

9. How many hours did you sleep last night? ____________________

10. Did you take any naps today? ______ if so, for how long? ____________

11. Have you taken any medications in the past 12 hours (e.g., No-Doz, Darvon, aspirin, cold pills, penicillin, Codeine, hayfever pills, etc.)?
Please list: ____________________

12. How many cups of coffee or tea have you had today? ____________

13. How many cups of coffee or tea have you had during the past three hours? ____________________

Additional comments regarding your sleep:

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD A117379	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) RECOVERY FROM FATIGUE		5. TYPE OF REPORT & PERIOD COVERED ANNUAL SUMMARY REPORT 1 August 1971 to 31 July 1972
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) MARY R. COOK, HARVEY COHEN, AND MARTIN T. ORNE		8. CONTRACT OR GRANT NUMBER(s) DADA 17-71-C-1120
9. PERFORMING ORGANIZATION NAME AND ADDRESS CONTRIBUTORS TO THE PENNSYLVANIA HOSPITAL 8th and Spruce Streets Philadelphia, Pennsylvania 19107		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102A.3M161102BS01.00.032
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND, Fort Detrick, Maryland		12. REPORT DATE 31 July 1972
		13. NUMBER OF PAGES 43
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

NAPPING	DEPTH	DELTA SLEEP
FATIGUE	SERIAL SUBTRACTION	PSYCHOPHYSIOLOGY
REACTION TIME	PERFORMANCE	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

To study the effectiveness of daytime sleep (napping) in alleviating the subjective and objective consequences of fatigue, partially sleep-deprived subjects volunteered to take naps in a controlled laboratory setting. EEG and EOG records were obtained as well as a behavioral performance measure, reaction time measures, and subjective depth of sleep reports. Subjects carried out a serial subtractions task (a) before going to sleep, (b) immediately on being aroused from sleep, and (c) some time later after the electrodes had been removed and

20.

they felt fully aroused. In general, when subjects were aroused from napping, there was an initial impairment of functioning. Further, some trends in the data suggest that naps were effective in improving final performance. Significantly greater performance decrement was associated with sudden arousal from delta sleep than from REM sleep. Short periods of sleep which did not include significant amounts of delta sleep caused little or no decrement in performance. Further work is in progress studying the physiological characteristics of naps and their effects on the subjective recovery from fatigue among individuals who habitually take naps versus those who do not.