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Sleep Deprivation and Performance:
Aging and Repetition

Final Report

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SUMMARY

The effects on performance across forty eight hours (including two nights of sleep loss) were studied. The experimental variables were subject age and repetition of deprivation periods. Six 18-22 year old subjects were subjected to five repeated 48 h sessions with an intervening three weeks between periods. Subjective measures and vigilance tasks showed substantial deprivation effects; cognitively demanding tasks were less affected. Where repetition resulted in change the effects were decremental rather than offsetting. The performance of 10 subjects who were 40-50 years of age was compared with younger subjects (above) using a single deprivation. The older subjects, who generally exhibited superior performance, were also more affected by acute sleep deprivation.

This is the final report of the project funded from 1 August 1978 for one year and extended without additional funds through 31 August 1979.

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The purposes of these experiments were to investigate 1) the potential effect of a repeated series of prolonged performance which included two nights without sleep on selected performance measures, and 2) the potential effect of age as an interaction variable on prolonged performance.

A test battery was developed. This was comprised of sleep sensitive measures, cognitive tasks, and physical fitness measures. These are described in Appendix A.

These tests were programmed on two displays linked to a TERA computer. Exceptions were the auditory vigilance task and the physical fitness measures.

The tests were scheduled in a five hour block (Figure 1).

The schedule of testing and the sleep periods are portrayed in Figure 2. The subjects reported to the laboratory and slept for one night (11 PM - 7 AM) which was EEG recorded. The next day they received a "practice day" of two blocks at 9 AM and 4 PM. They slept again in the laboratory and began 48 hours of performance. Test blocks were administered at 9 AM, 4 PM and 12 PM. They then went to sleep at 9 AM and slept until they spontaneously awakened. Subjects returned for "recovery" testing after one week and completed two test blocks at 9 AM and 4 PM. Physical fitness tests were given after the first night of laboratory sleep (8 AM - 9 AM) and at the end of the 48 hr period of wakefulness and performance (8 AM - 9 AM).

Subjects participated in pairs.

All subjects were submitted to a general physical examination prior to participation. Subjects were selected on a "first volunteer" basis in response to an advertisement in the student paper (younger subjects) and a mailing to faculty members between the ages of 40-50. All served as paid volunteers.

Age and Continuous Performance

In the first summer period (August 1, 1978), four older subjects participated in a pilot run to test the feasibility and problems associated with older subjects and to test the computer based testing program.

The testing of the 6 younger control group subjects was then begun and completed through the fall (see Repetition effects below).

Ten older subjects completed this testing during the summer of 1979.

Repetition Effects

The six subjects (18-22) serving as the age control group repeated the sequence of testing described above for four additional sessions spaced in three week intervals. However, Days 1 and 2 of Figure 1 were deleted. In short, they slept one night in the laboratory and began their continuous testing period at that time.

Aging Effects: Results

The results of the analysis of the aging effects on performance have been reported (See Reference 1). A summary statement

from the reference may be cited:

It is clear from this exploratory study that the powerful effects on acute sleep deprivation typically observed in young adults on monitoring and persistence tasks and subjective measures are nowhere as pervasive for comparatively more demanding information processing tests.

The data empirically indicates that deprivation effects are greater in older subjects both with tests which emphasize speed of performance e.g., Visual Search, Reasoning or Object Usage) and those which do not (Auditory Vigilance). However the simple interpretation of an "age" effect per se is not simple due to differences in initial performance levels in the two groups with the older subjects generally giving higher performance scores. This could reflect higher initial motivation in the older subjects which could not be sustained across the deprivation period. However, this explanation is clouded by the higher subjective measures (mood and sleepiness scales) in the younger subjects. Alternatively, higher performance levels may be more susceptible to sleep deprivation and continuous performance. Unfortunately, we can find no data in the literature on an age controlled group to resolve this possibility. Our subjective observations of the subjects inclines us toward a belief in an aging effect.

Repetition Effects: Results

The results of these analyses are under review by the journal Ergonomics (See Reference 4). A summary of these findings are as follows:

A number of cognitive and information processing tests were used in the testing battery. When compared with the less demanding and more time extended tasks such as vigilance and addition, they were, in general, less effective in detecting deprivation and continuous performance effects. These findings are in accord with the now well-established differential task related sensitivity to sleep loss and continuous performance (Naitoh, 1968). Short term and more challenging tasks which generally

characterize the cognitive battery were less sensitive to the motivational assessments. However, Object Usage, Word Memory, and the Reasoning test did not yield positive results using limited scoring criteria.

In operational terms, the results indicate that repeated experiences with sleep loss and continuous performance are not likely to result in the development of compensatory or coping tendencies which will affect performance decrements. Rather, such experiences may exacerbate these effects, probably as a result of decrements in motivation. Moreover, we may expect these effects to be task-related in a manner previously noted in single deprivation studies.

Physical Fitness and Sleep Responses: Results

Two additional reports have been developed from these data (References 2 & 3).

Reference 2 reports on the effects on a physical fitness battery given prior to and following 48 hours of continuous performance using both 6 younger and 10 older subjects.

While the older subjects had lower initial physical fitness scores, the scores of neither group showed significant decrements across the 48 hours of performance.

Reference 3 reports on the entrance into sleep after two nights without sleep. The summary may be quoted:

EEG sleep stage measures were obtained on younger subjects (18-22 years) and older subjects (40-50 years) at 9 a.m. after 2 nights of sleep loss. The first 200 min were compared. Both groups displayed sharply reduced latencies and increased Stage 4 sleep. The proportionate distribution of stage amounts and numbers was not different. However, the younger group entered slow wave sleep more quickly.

Figure 2

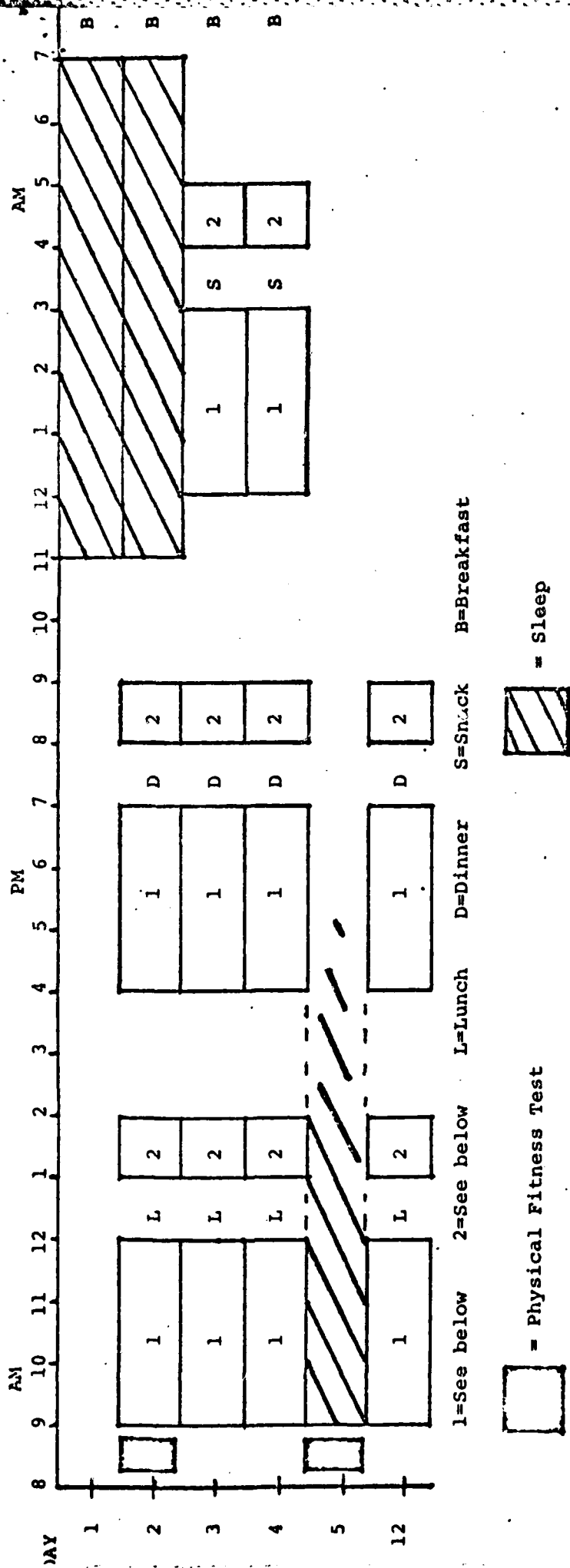
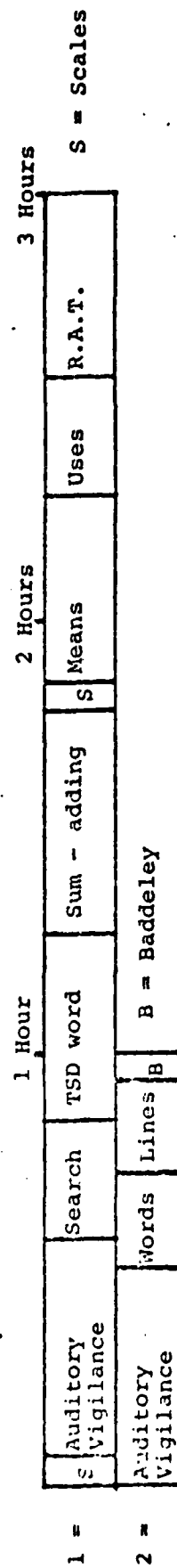


Figure 1



APPENDIX

Twelve explicit experimental tasks and two self-initiated tasks were scheduled during work periods.

STANFORD SLEEPINESS SCALE. The computer displayed a 7-point scale devised by Hodes, et al. (1973) in which each integer value was labelled in detail, e.g. "(1) Almost in reverie; sleep onset soon; lost struggle to remain awake....(7) Feeling active and vital; alert; wide awake." This task invariable began each work session and was given half-way through each session.

MOOD SCALE. A mood scale always followed the presentation of the Sleepiness Scale. The subject was asked to enter an integer between 1 ("very depressed") and 10 ("elated").

ADDING. The subject was presented with a column of five 3-digit number to sum (Wilkinson, 1970). The computer generated each set on a random basis, subject to the restrictions that each of the five numbers had to be unique and that no more than two digits could be identical within a number. When the subject entered a response from the keyboard, the computer immediately presented another problem. The 30-minute task was self-paced. Response latency and accuracy were measured.

VISUAL SEARCH. This task was an adaptation of the procedure reported by Neisser (1957). The subject was presented with an array of letters (20 rows, 7 columns) and asked to indicate as rapidly as possible when he had detected the presence of a

predefined target letter. The target letter was either "X" or "Q" presented within a background of rounded letters (e.g., GOCD) or angular letters (e.g., VNKY). Within each 80 trial block, the subject was required to search equally often for an "X" within an angular or a rounded background or for a "Q" within the same background. The target was programmed to appear equally often within each row, and like the choice of target and background, was randomly determined within each session. Subjects were instructed to conduct their searches from top to bottom and left to right.

LINE JUDGMENT. Liberally adapted from the classic paradigm developed by Crutchfield (1951), the line judgment task required the subject to compare a set of three horizontal lines and report which was neither the longest nor the shortest. A session always began with 15 Easy trials where the differences in length among the lines was so great that pilot subjects made correct perceptual reports more than 90% of the time. No feedback concerning accuracy was given to the subjects during these trials. Subsequently, 45 Difficult trials were given in which the differences in line length were small. On 15 randomly determined trials no feedback was given. Feedback of one of two types was given after the remaining Difficult trials. On half of these the subject was informed, "When a group of 400 men your age saw these lines, they reported that Line x was neither longest nor the shortest," and on the remaining trials, "The last time you saw

these three lines you reported that Line x was neither the longest nor the shortest." While these statements were spurious (i.e., no large scale sampling had been done and these reports were noncontingent upon a subject's response), plausibility was maintained by accurately pointing to the appropriate response on one-third of the occasions, and either the incorrect largest or the smallest line on two-thirds of the occasions.

The task was made demanding intentionally in order to maximize the opportunity for inducing conforming responses (i.e., responding on the basis of nonvertical information). The lines were vertically displaced differentially with respect to their origins, and were displayed for 1000 msec. On the Difficult trials a random number between 30 and 45 was generated; one line was constructed of that number of underscores and the other two lines were formed by adding or subtracting two underscores from the base number. In contrast, on the Easy trials a random number between 10 and 15 was generated to determine the number of underscores for one line; the other lines were twice or thrice as long.

The dependent variables included: number of accurate reports, number of incorrect responses (which were subdivided into conforming and non-conforming responses); judgmental confidence, measured for each response on a 7-point Likert scale; and response latency.

SHORT-TERM MEMORY FOR UNRELATED WORDS. In this task 30 words were individually presented for 2000 msec each with a 1500 blank

interval between words. After the last word was presented the subject was auditorily cued to begin recalling the materials in any order (free recall). Subjects were encouraged to enter their responses as rapidly as possible without regard to typographical accuracy. When the subject indicated he had recalled all that he could, he was given an opportunity to edit his response protocol for typing errors, duplications, word form, etc.

The set of to-be-presented materials was selected for each session from a pool of 390 items consisting of 5-letter, one-syllable, high frequency words (e.g., WORDS). One trial was administered per work session.

WORD DETECTION. This task was a problem in signal detection where the target was a 5-letter low-to-moderate frequency word and the "noise" background consisted of 5-letter nonwords of the same form, i.e., consonant-vowel-consonant-vowel-consonant. Half of the 100 trials given within an administration of the task were noise trials in which 25 nonwords were presented sequentially in the center of the screen at a rate of 10 items per sec. On the remaining signal trials, a target word was unsystematically selected from a pool of 102 items and presented. The target word appeared in a randomly determined position within the list between serial positions 12 and 18. The signal trials were randomly interspersed with the noise trials, except that every eighth trial block contained an equal number of signal and noise trials. The dependent variables were the Hit Rate and False Alarm Rate.

REASONING. The procedure originally described by Baddeley (1968) was slightly modified. The task required the subject to compare a simple sentence (e.g., "A precedes B") and a pictorial relation (e.g., BA) to determine if the former was an accurate description of the latter. In constructing the sentences, the 8 possible combinations of "A" as the subject vs. the object of the sentence, use of "precedes" vs. "follows", and affirmative vs. negative were factually combined. When crossed with the two possible pictorial relations (AB and BA) 16 sentence/picture combinations are formed, half of which are true. On even numbered administrations of the task the right index finger was used to depress a key to indicate a "True" response and the left index finger to initiate a "False" response. On the alternate administrations, this relationship was reversed. Subjects were encouraged to respond as quickly and accurately as possible. This self-paced task lasted 3 minutes in each administration. Response latency and accuracy were measured.

NUMERICAL ESTIMATION. This task was described by Irwin, Smith, and Mayfield, (1956) and modified to meet the constraints imposed by the computer system. Subjects were to imagine that the computer had two shuffled decks of 500 cards. On any administration of the task a set of 20 cards would be selected and the top pair of cards would be exposed. The subject's task was to estimate whether the mean value of the first deck was larger or smaller than the mean for the second deck, and to indicate his confidence in this judgment. The exposed cards could then be covered by the next pair of cards from the sample, and the subject was

required to make the same estimation using all of the information he had about the two samples. This procedure continued without feedback until all pairs from the samples had been exposed. The cards were returned to the master decks, shuffled, and another two sets of 20 cards withdrawn for the second block of trials. Six blocks of trials were given in each administration of the task.

Although it was never revealed to the subject, each sample was drawn from a deck which had been generated from a normal distribution with a mean value was zero and a standard deviation of 2.5. Accuracy and confidence ratings were recorded for each judgment.

USES TEST. Based upon the task reported by Wilson, Guilford, and Christenson (1953) the procedure required the subject to write all of the possible (common and uncommon) ways he could think of to describe the uses of an object. In the present instance, the subject was given a word and an illustrative common usage and then given 2 minutes to generate responses. Since the task was timed, and in order to eliminate typing skills as a factor, subjects wrote their responses in script. Six trials were given in each administration of the task, each with a new set of stimulus objects. The number of distinct, plausible responses given to each object was the major dependent variable.

REMOTE ASSOCIATES TEST. In Mednick's (1962) Remote Associates Test, the subject is presented with a word triad (e.g., "cookies, sixteen, heart") and asked to generate the word which

is associateively related to each (i.e., "sweet"). Twenty-five triads were each displayed for 60 sec., after which another set was shown even if the subject had not reorted an answer.

AUDITORY VIGILANCE. The task was devised by Wilkinson (1970) and has been repeatedly used in sleep deprivation experiments. It requiries subjects to monitor 0.5 sec. tones occurring every 2 sec. with a background noise of 85 db. In a half hour test, 20 test tones, each 375 msec in duration, occur at un-systematic intervals. The subjects' hits and false alarms are recorded.

As noted earlier, there were two self-initiated tasks given to the subjects in addition to the explicit experimental tasks described above. These shared the following features: they were of the nature of arbitrarily defined "laboratory rules", instructions about them were given during the orientation of the subjects in considerable detail and reminders to execute them were prominently posted, their measurement accomplished surreptitiously by either the computer system or the laboratory technicians, and there were no attendant consequences for performing or failing to perform the tasks. More specifically, subjects were initially instructed to enter their subject code number (either the digit "1" or "2") when they began a work session, and when they returned from each break. The experimental tasks began normally whether or not the subject logged on to the system in this simple fashion, and the computer recorded the subject's action (or failure to act).

When a rest break was scheduled, the terminal displayed a message indicating this fact for 30 sec. If the subject logged off appropriately within this interval, the system cleared the screen and recorded the subject's action. Otherwise, a failure to respond was noted, the screen erased, and the system prepared for the post-break tasks.

Physical Fitness Tasks

HIP JOINT FLEXIBILITY. A measure of the elasticity of the lower back and hamstring muscle group. Taken in a sitting position and measured by a flexometer box with a zero score at toe-touch level and plus or minus scores above or below the toe-touch level. Best of three trials was the criterion measure.

GRIP STRENGTH. Measured by a Grip Dynamometer (C. H. Stoelting Co. Chicago 24, Ill.) to the nearest kilogram. The subject stood, held the dynamometer with a straight arm out to his side and took three trials with each hand. The best score was used.

RESTING HEART RATE. This is measured by a Lafayette Digital Solid State Heart Monitor in beats per minute in a relaxed, sitting position.

WORK HEART RATE. The heart rate after 6 m. on an ergonamic bicycle at 600 rpm/m (below).

MEAN ARTERIAL BLOOD PRESSURE (systolic & diastolic). Mea-

sured by an Aneroid Sphygmomanometer and stethoscope in millimeters of mercury.

PEAK EXPIRATORY FLOW. Maximum flow rate of expiration maintained at least .01 second. Measured by using the average of three trials on a Wright Peak Flow Meter in liters per minute. (Leiner, 1963).

PEAK EXPIRATORY CHANGE. The difference between the calculated standard for expiration based on age and height and the measured expiration. $\text{Standard} = [3.95 - (0.151 * \text{age in years})] * [\text{height in cm}]$ for men. (Leiner, 1963).

PHYSICAL WORK CAPACITY. A bicycle ergometer at a load of 600 kpm/min for a second six minutes, 1200 kpm/min for a third six minutes, etc. until a heart rate of 150 beats per minute is reached. The serial minute at which the heart rate reached 150 bpm was used.

PREDICTED MAXIMUM OXYGEN CONSUMPTION ($\text{VO}_2 \text{ max}$ - Volume of Oxygen maximum). $\text{VO}_2 \text{ max}$ is the best single indicator of cardiovascular efficiency. The value given is the prediction based on the heart rate response to the exercise on the bicycle. It was calculated from tables in Astrand, Per-Ol of Work Tests with the Bicycle Ergometer AB Cykeltabriken Monark, Varber, Sweden, and adjusted for age.

BODY COMPOSITION. This measures the percent of adipose (fat tissues) and percent lean tissue by use of the Lange Skinfold Caliper on biceps, triceps, subscapular, and iliac chest. This

measures was discarded due to lack of dietary control during the experiment.

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Appendix B

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Appendix C

PERSONNEL RECEIVING CONTRACT SUPPORT

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Dreblow, Lewis M. Computer Analyst

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