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SLEEP DEPRIVATION AND PERFORMANCE: THE OPTIMUM USE OF LIMITED SLEEP PERIODS

Final Report

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The performance of three groups of young adult subjects has been measured across a 72 hour period. A computer programmed battery of tests was used which included test established as sensitive to sleep loss (auditory vigilance, addition and subjective scales), and a cognitive battery (memory tasks, anagrams, word detection, visual search, line judgements with various feedbacks, object usage, reasoning, digit symbols). The experimental variable was the placement of four hours of

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) sleep opportunities. The control group had no sleep, one experimental group slept from 10-12 PM prior to "night" two and three (preparatory sleep) and one slept from 8 to 10 AM after "nights" two and three (recovery sleep).

This report presents preliminary analysis of the data as well as data analysis completed on earlier continuous performance measures.

Foreward

For the protection of human subjects the investigators have adhered to policies of applicable Federal Law 45CFR46.

SLEEP DEPRIVATION AND PERFORMANCE:

THE OPTIMUM USE OF LIMITED SLEEP PERIODS

Summary

This research is concerned with continuous performance over extended time periods. The particular efforts of this report measured the effects of two placements of 4 hours of sleep compared with no sleep across seventy two hours. The performance battery included sleep sensitive tasks as well as an extensive battery of cognitive tasks. Two hour of "preparatory" sleep from 10PM-12PM were permitted in one group before the second and third "night" (12PM-8AM). Two hours of "recovery" sleep from 8AM to 10AM was permitted for a second group after "nights" two and three. The control group had no sleep. Six young adults served in each group. It is clear from preliminary analyses that significant effects are obtained.

In addition this report includes summaries of earlier studies of extended performance from earlier efforts.

Statement of the Problem

In certain military operations continuous performance may be required across extended periods of time. In certain scenarios this is particularly likely for two groups of personnel: high speciality skill areas and command levels. The limited number of such personnel as well as the high demand levels increase the likelihood of continuous performance requirements and the utilization of high level cognitive skills.

Background

This laboratory has an extensive background research on sleep, sleep loss and time schedules of sleep. For the past three years, during the summers, it has focussed on the problems of extended performance. It first studied the effects of repeated 48 hour extended performance on young subjects to determine if persons could be "immunized" against the effects of sleep loss during extended performance. A copy of a paper under submission attached (Appendix A).

A second concern has been to determine if sleep loss and extended performance is more difficult in the case of command level personnel who, as a group, would be older. Three reports of these efforts are attached (See References).

Throughout this research an effort has been made to extend the performance measures to include cognitive precessing.

The current report is on more extended performance (72 hours) and the optimum placement of limited periods of sleep. Specifically, we have been concerned with the effects of the introduction of four hours of sleep in two selected times: "preparatory sleep" (10PM-12PM) immediately prior to the second and third "night" periods and "recovery sleep" (8AM-10AM) immediately following the second and third "night" of sleep loss. Performance is primarily scheduled on a computer display and data recording system and includes and extensive battery of cognitive tasks.

Method

The time schedules of the experimental groups and the testing schedules are shown in Table I.

Six subjects have completed the following experimental conditions: 1) no naps 2) night (preparatory) naps and morning (recovery) naps.

Results

Preliminary analyses of the data show striking effects of the schedules. The results from the two "standard" measures of sleep deprivation effects - Auditory Vigilance and Addition - are presented.

An initial analysis revealed that, in spite of unselected assignment of subjects to the three groups, the three groups differed in initial levels of performance. Thus an analysis of covariance design was required to adjust for initial level differences. Secondly, each time block of testing must be treated independently. There were potential circadian performance effects, i.e., differential performance potentials as a fuction of time of day. Further, time blocks were preceded by different experimental conditons. Specifically, the PM testing periods were immediately preceded by a sleep period in one group and the AM testing periods were preceded by sleep in the other group.

As a result of the considerations our analyses to date of the three groups used an analysis of covariance design in which the covariance control was the non deprived condition of day 1 and the dependent variable was the period after maximum deprivation on day 3. Each period was matched to equivalent time of day in each test.

Table II shows the data for Additions Attempted in the afternoon sessions with the least deprived condition as the dependent variable and the most deprived condition as the independent variable. The scores displayed are the "corrected" covariance scores. The significance levels are also shown.

Conclusions:

Our preliminary analyses of tests sensitive to sleep loss show an ameliorative effect of interpolated naps. However, these data indicate that the interpolated naps may reduce performance in the period immediately subsequent to the nap. Thus the procedure must be concerned with net savings and management of the affected period.

THIRD ARMY EXPERIMENT — Table I

Day	0	1			2			3			4	11
Group	All	M	E	N	M	E	N	M	E	N	All	All
0800		R	R	R	S	X	X	S	X	X	S	R
1000		A	A	A	A	A	A	A	A	A		A
1200		B	B	B	B	B	B	B	B	B		B
1400		C	C	C	C	C	C	C	C	C		C
1600		B	B	B	B	B	B	B	B	B		X
1800		A	A	A	A	A	A	A	A	A		
2000	Intro	F	F	F	F	F / P	F	F	F / P	F		
2200	P	X	X	X	X	S	X	X	S	X		
2400	S	A	A	A	A	A	A	A	A	A		
0200	S	B	B	B	B	B	B	B	B	B		
0400	S	C	C	C	C	C	C	C	C	C		
0600	P	F / P	F	F	R / P	R / F	R / F	R / P	R / P	R / P		
0800												

Group: M = Morning Sleep, E = Evening Sleep, N = No Sleep

A = Battery A
(Terminal 1)
1. Scale1
2. Auditory Vigilance
3. Word Memory
4. Wilkinson Reaction Timer
5. Anagrams
6. Baddeley
7. Visual Search
8. Line Judgment - Crutchfield
9. Scale2
10. Break

(Terminal 2)
1. Scale1
2. Auditory Vigilance
3. Word Memory
4. Baddeley
5. Anagrams
6. Line Judgment - Crutchfield
7. Visual Search
8. Wilkinson Reaction Timer
9. Scale2
10. Break

B = Battery B
1. Scale 1
2. Long Term Memory - presentation
3. Addition
4. Uses
5. Digit Symbol
6. ~~Word Detection~~
7. Long Term Memory - testing
8. Scale2
9. Break

C = Battery C
1. Scale1
2. Addition
3. Word Detection
4. Anagrams
5. Scale2
6. Break

X = Battery X (Time filler)
1. Alien
2. Digit Symbol
3. Remote Associates Task
4. Trails
5. Break

R = Reading Test

S = Sleep

P = Electrode Placement

F = Free Time
In addition to this time there is approximately 20-30 minutes free time at the end of each battery (break).

Table II

Addition Attempted

Afternoon	M	Recovery	Prep.
No Nap	29.5	.000	.000
Recov.	43.3		.81
Prep.	42.4		
Night			
No Nap	34.0	.01	.75
Recov.	43.2		.000
Prep.	32.8		

These data indicate that both nap procedures offset sleep loss during the afternoon runs (mid way between treatments) but the preparatory sleep depressed performance during the night period which was immediately preceded by a two hour nap.

Table III presents the data relative to Auditory Vigilance.

Table III

Auditory Vigilance % Hits

Afternoon	M	Recovery	Prep.
No Nap	34.5	.01	.000
Recov.	64.6		.17
Prep.	80.4		
Night			
No Nap	40.7	.46	.15
Recov.	52.1		.26
Prep.	69.5		

During the afternoon period we see again the effectiveness of the naps in reducing sleep loss effects. However, during the night period while both groups were some what superior this was not significant. Furthermore, the decrement seen in the preparatory period for Additions was not present.

Further analyses of these tests, the subjective scales and the cognitive tests are underway.

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Appendix A

EFFECTS OF SPACED AND REPEATED TOTAL SLEEP DEPRIVATION

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University of Florida

Running head: Spaced and Repeated Total Sleep Deprivation

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Abstract

Six young adult males were sleep deprived for 2 nights on 5 successive occasions at 3-week intervals. During the deprivation period they completed subjective ratings and performed on an extensive battery of tasks. Subjective measures and vigilance tasks showed substantial deprivation effects; the cognitively-demanding tasks were less affected. Where repetition of sessions resulted in changes, relative to sleep deprivation the effects were those of "sensitization" rather than "immunization".

EFFECTS OF SPACED AND REPEATED TOTAL SLEEP DEPRIVATION

1. Introduction

The systematic assessment of the effects of total sleep deprivation has a long and extensive history. The dependent variables have included an exhaustive repertoire ranging from biochemical and physiological effects to behavioral effects. The primary independent variable has been length of time without sleep. Associated variations have been added to deprivation time, e.g., laboratory vs. field settings, with or without drugs, knowledge of results and the like. There are substantial reviews of sleep deprivation effects (Horne, 1978; Kjellberg, 1977; Kleitman, 1963; Naitoh, 1968, 1977).

This is a report about the effects of repeated, spaced sessions of sleep deprivation and their effects on performance. A review of the literature reveals only one directly relevant precedent (Wilkinson, 1961). In that experiment subjects were deprived of sleep for one night each week in two week blocks (Tuesday or Thursday) and this regimen was repeated three times, resulting in six periods of sleep deprivation across six weeks. Performance, measured by a 5-choice reaction time test, became poorer across sessions. The author suggested that this decrement may be the result of reduced "novelty" of both the sleep deprivation and the test, and thereby reduced offsetting motivational components. From these limited data it could be argued that previous periods of sleep deprivation prior to a critical period of sleep deprivation should be avoided.

An alternative position, however, can be reasonably developed. Sleep deprivation can be considered to be a "stress" condition, or, without involving such an intervening construct, sleep deprivation results in less adequate or "adversely affected" performance. From either perspective the wealth of literature on "stress" and "coping responses", the concept of "desensitization", the profusion of "emergency" and "field training" applied programs and, not least of all common sense, form a background for a counter argument. From these considerations it is reasonable to hypothesize that repeated experiences with the "stress" and/or decremented aspects of sleep deprivation may permit the development of adaptive responses to offset the effects of sleep deprivation.

This experiment extended the variables of Wilkinson's (1961) experiment. The sleep deprivation period involved two successive nights. The repeated sessions were more widely spaced and the performance measures were more extensive.

2. Method

Subjects

Six young adult males, whose ages ranged from 18 to 22 years, were selected as paid volunteers in response to an advertisement in a campus newspaper. The first six subjects available across the required 16 week period were accepted. They were screened for deviant sleep habits by the University of Florida Sleep Inventory, and were found to possess none. Before participation, each subject received and passed a general medical examination.

Procedure

Pairs of subjects participated in a schedule of sessions represented in Figure 1. Subsequent to the

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Insert Figure 1 about here

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completion of this schedule, subjects reported to the laboratory at three week intervals and repeated the regimen five times. The repeated sessions included a night of laboratory sleep (11 PM - 7 AM), the physical fitness examination and the sequence outlined in Figure 1 for "days" 3, 4, and 5. No return testing on day "12" occurred in the repeat sessions. Subjects remained in the laboratory throughout the experimental periods and were under constant supervision to maintain wakefulness. Our analysis included only the first four sessions; deletion of the last session carries the advantage of eliminating an "end effect."

Tests

The test battery was comprised of tests previously established as sensitive to sleep deprivation (subjective ratings of sleepiness and mood, auditory vigilance, addition, and short term memory tests). A number of additional tests were selected and modified to measure information processing and cognitive functioning. The order of the tests and their approximate durations are shown in Figure 1. The specifics of the tests follow.

STANFORD SLEEPINESS SCALE. A 7-point scale devised by Hodes, Zarcone, Smythe, and Dement (1973) was displayed. The subject indicated his sleepiness by referring to an integer, e.g. "(1) Almost in reverie; sleep onset soon; lost struggle to remain awake....(7) Feeling active and vital; alert; wide awake." This task invariably began each work session (Scale I) and was given again half-way through each session (Scale II).

MOOD SCALE. The subject selected an integer between 1 ("very depressed") and 10 ("elated"). This test was also presented twice each session (Mood Scales I and II) immediately following the administration of the Sleepiness scales.

AUDITORY VIGILANCE. The task was devised by Wilkinson (1970) and has been repeatedly used in sleep deprivation experiments. It requires monitoring 0.5 sec. tones occuring every 2 sec. within an 85 dB background noise. In a half-hour test, 20 test tones, each 375 msec. in duration, occurred at unsystematic intervals. Hits and False Positives were recorded.

ADDITION. The subject was presented with a column of five 3-digit numbers to sum (Wilkinson, 1970). Each set was generated on a random basis subject to the restrictions that each of the five numbers was unique and that no more than two digits were identical within a number. Response latency and accuracy were measured during the 30-min. self-paced task.

WORD MEMORY. Thirty words were individually presented for 2000 msec., each separated by a 1500 msec. blank interval. After the last word was presented an auditory cue signalled the subject to begin recalling the materials in any order (free recall) as rapidly as possible without regard to typographical accuracy. He was later given an opportunity to edit his response protocol.

The materials for each session were drawn randomly from a pool of 390 5-letter, one-syllable, high frequency words (e.g., WORDS). One trial was administered per session.

WORD DETECTION. This task was a problem in signal detection. 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 in a session were noise trials in which 25 nonwords were presented sequentially 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 in a randomly determined location between serial positions 12 and 18. The signal trials were randomly interspersed with the noise trials, except that every block of 8 trials contained an equal number of signal and noise trials. The dependent variables were the Hit and False Positive rates.

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 indicated as rapidly as possible when he had detected the presence of a predefined target letter. Subjects were instructed to conduct their searches from top to bottom and left to right. The target was either "X" or "Q" presented within a background of either rounded letters (e.g., GOCD) or angular letters (e.g., VNKY). An "X" embedded in angular letters or "Q" surrounded by rounded letters defined a "Similar" condition; transposition of these targets defined a "Dissimilar" condition. Similar and Dissimilar trials were given equally often, in an unsystematic order, during the 80 trials administered per session. The target appeared equally often within each row within each session.

REASONING. The task (Baddeley, 1968) 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. Subjects were encouraged to respond as quickly and accurately as possible. 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 factorially 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. This self-paced task lasted 3 min. in each administration. Response latency and accuracy were measured.

REMOTE ASSOCIATES TEST. In this test (Mednick, 1962) the subject was presented with a word triad (e.g., "cookies, sixteen, heart") and asked to generate the word which is associatively 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 reported a solution.

OBJECT USES TEST. Based upon a task reported by Wilson, Guilford, and Christenson (1953), the procedure required the subject to write all possible 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 min. to generate responses. Subjects wrote their responses in script in order to eliminate typing skills as a factor. 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.

NUMERICAL ESTIMATION. This task, described by Irwin, Smith, and Mayfield, (1956), was modified to meet the constraints imposed by the laboratory computer. Subjects' were to imagine two shuffled decks of 500 cards. On each administration of the task a set of 20 cards was selected and the top pair of cards exposed. 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 of zero and a standard deviation of 2.5. 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 were then covered by the next pair of cards, and the subject was allowed to adjust his responses after incorporating the new information. This procedure continued without feedback until all pairs from the samples were 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 session. Accuracy and confidence were recorded for each judgment.

LINE JUDGMENT. Adapted from the classic paradigm developed by Crutchfield (1951), the task required the subject to compare a set of three horizontal lines and report which was neither the longest nor the shortest. The lines were vertically displaced differentially with respect to their origins, and were simultaneously displayed for 1000 msec.

A session began with 15 Easy trials in which pilot subjects were accurate more than 90% of the time. Subsequently, 45 Difficult trials were given in which the differences in line length were small: one line was constructed of 30 - 45 underscores and the other lines differed by ±2 underscores. On 15 randomly determined Difficult trials no feedback was given. Feedback of one of two types was given after the remaining 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 noncontingent upon a subject's response, plausibility was maintained by pointing to the correct response on one-third of the occasions. The task was made demanding intentionally to maximize the opportunity for inducing conforming responses. The dependent variables included number of accurate reports, number of incorrect responses (which were subdivided into conforming and non-conforming responses), judgmental confidence, and response latency.

UNOBTRUSIVE MEASURE. This was a self-initiated task with two components. It was an arbitrarily defined procedural rule: Subjects were initially instructed to enter their subject code number (either the digit "1" or "2") when they began a work session, before they left for a scheduled rest break, and when they returned from each break. The experimental tasks began normally whether or not the subject logged on to the laboratory computer, and the system 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 was erased, and the system was prepared for the post-break tasks.

SLEEP MEASURES. Subjects were instructed to sleep as long as possible during the sleep recovery period which followed each deprivation period (Figure 1, Day 5). Sleep recordings were obtained and scored by standard procedures described by Agnew and Webb (1972).

Apparatus

With the exception of the Auditory Vigilance task, all behavioral testing was controlled by a dedicated TERAK

8510a microcomputer system. All visual stimuli and instructions appeared as white letters on a black background. They were presented at 9600 baud on a pair of CRT screens.

Time-sharing constraints on the system were minimized by scheduling all time-critical tasks (e.g., those requiring precise control over stimulus duration and the collection of response latencies) on one terminal and remaining tests at the other. The system controlled all task sequencing, time/date-stamped all critical activities, and logged all responses.

Baseline and Deprivation Measures

The measures used to test the effects of deprivation were drawn from the testing periods of maximum deprivation. These were the last periods of testing from Session I - IV that occurred between 12 AM and 5 AM during the second night without sleep (see Figure 1). The last night session (V) was not used to eliminate a clearly present "end effect".

The baseline periods were selected to measure performance without prior sleep deprivation and to include all prior learning or attitudinal carryover effects associated with the deprivation period testing. For Session I this was the "recovery period" tests occurring 7 days after Session I from 9 AM to 2 PM (Figure 1). The baseline periods for Sessions II, III and IV were the initial testing periods of Sessions III, IV and V from 9 AM to 2 PM. The 7 day return period was used for Session I rather than the 21-day Session II period because it had served as a non-deprived baseline in an associated study of the effect of aging on sleep deprivation (Webb & Levy, 1982).

We recognize that the different testing times result in a confounding of deprivation and circadian effects. These variables deserve and will receive further independent analyses. However, for the primary purpose of this experiment, the effects of repetition on deprivation, we assumed that the circadian effect would operate to increase the deprivation effects. The use of a post-deprivation baseline incorporated all of the prior learning and experiential aspects of the preceding deprivation period.

Statistical Analyses

The primary statistical procedure utilized was a Deprivation x Repetition x Subjects ANOVA (Linquist, 1965). Deprivation effects compared baseline and deprivation, Repetition effects compared across sessions and Subjects effects compared across subject variance. The D x S (5 d.f.), R x S (15 d.f.) and D x R (3 d.f.) were used, respectively, as the error terms for these effects. Of

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Deprivation effects

As may be seen in Column 2 of Table 1, those measures which had previously been found sensitive to sleep deprivation effects showed deprivation effects in this experiment, viz., the subjective scales (Sleepiness and Mood), Auditory Vigilance (Hits) on both adminstrations, Addition attempts and Word Memory (correct recalls). The extent of the effects are illustrated in Figure 2 (Sleepiness Scale I), Figure 3 (Auditory Vigilance II), Figure 4 (Addition attempts) and Figure 5 (Word Memory).

False positives in the Auditory Vigilance test were not significantly affected. This was probably due to the low rate. This low rate did not permit a valid calculation of beta or $\underline{d}'$ (Bonnet & Webb, 1978). It is likely that the low error rate in the Addition task also accounted for the failure of the percentage correct measure to show a positive effect. The percent correct exceeded 96% for all subjects.

An effort was made to extend the examination of deprivation effects by the introduction of additional tasks which emphasized more complex information processing. This met with limited success. The Word Detection scores showed no overall deprivation effects. They are characterized by wide individual differences in performance levels and strategies. One subject averaged 41 hits (of a possible 50) and 7 false positives; another averaged 12 hits and one false positive. For one subject there was a clear decrement in hit rate across sessions which averaged 15% under deprivation conditions. One subject averaged 11 false positives per session and these were approximately doubled in the deprivation period.

The Visual Search test did not show significant deprivation effects. However, a review of this task reveals two flaws. First, the subject was not required to identify where in the matrix the target letter appeared; thus there could be no "error" score. A "response" could be a detected target, an "error", or simply a target-independent response. This problem is inherent to the design of the task. In addition, one terminal occasionally presented a spurious symbol in the margin of the display which indicated the line containing the target.

The Object Uses test, when scored for total objects named, was successful across repetitions but was not significant in the first session.

The Reasoning and the Remote Associates tests yielded complex interactions relative to repetitions and deprivation (Figures 6-7) that will be discussed further. However, it is noted that neither test yielded significant deprivation effects on the first session.

The Numerical Estimation test yielded no deprivation effects. An analysis of the measures of the confidence ratings and post-test interviews indicated that the task was perceived as extremely complex and became one of random guessing. It is possible that a further analysis of these data may provide results relative to the effects of deprivation and repetition effects.

Repetition Effects

In considering repetition effects it should be noted that the measures used in this analysis include considerable prior repetition. The Auditory Vigilance test and the Sleepiness and Mood scales had been administered 16 times previously, and all other tests had been administered seven times prior to the first deprivation period and eight times prior to the recovery (baseline) test. In short, the contribution of learning may have reached an asymptote before the periods in this analysis.

As can be seen in the third column of Table 1, several tests showed a simple deprivation effect, i.e., a decrement in both the deprivation and the non-deprivation condition: Mood Scale II, hits on Auditory Vigilance I (p = .06) and II and false positives on Auditory Vigilance I, Word Detection scores and Visual Search times (similar condition). The Mood scores were lower, the Auditory Vigilance hits fewer (see Figure 3) and false positive were greater, Word Detection hits less and time taken less, and Visual Search times reduced by 12%. Since all except the Visual Search test could be judged to be exhibiting poorer performance, and occurred in both the non-deprived and deprived conditions, we attribute these repetition effects to motivational/attentional decrements relative to both conditions. As noted above, it was not possible to score errors on the Visual Search task; the reduced reaction ties could simply be due to an increase in the number of "non target" short latency responses.

Deprivation X Repetition Interaction

A primary purpose of this experiment was to evaluate the effect of repeated sleep deprivations on the performance of sleep deprived subjects. In our design, performance during repeated deprivation sessions was compared with nondeprived periods. A cumulative decremental effect on improved performance due to adaptative or coping responses would be displayed across sessions by different patterns of performance during deprivation and nondeprivation conditions. Such an effect was evaluated using the Deprivation X Repetition interaction.

First, it should be noted that only two tests displayed a significant interaction, indicating that although performance on many tests changed across sessions (see Repetition Effects, above), the relative effects of deprivation on these tests generally were not influenced by repetition. In short, repeated deprivations neither sensitized or desensitized the subjects to the effect of deprivation on these tests.

Two cognitively demanding tasks -- the Remote Associates (number correct) and Reasoning (number correct) tests -- yielded the only significant interactions of repeated sessions and deprivation. Differential response between the baseline and deprived conditions increased across sessions for both tests. The tendencies exhibited by these tests, however, were in opposition. The Reasoning test revealed an increasing number of attempts (with no loss of accuracy) across sessions during the baseline periods and a relatively steady level of performance during the deprived conditions. In contrast, on the Remote Associates tests there was a relatively steady level of performance across the baseline periods and an increase in correct solutions over the deprivation conditions. One can reasonably attribute the Reasoning test results to development of increasing numbers of automatic, learned (relatively non-cognitive) responses to these items. This may have been offset in the deprivation condition by the lowered rate of responding due to lowered motivation. However, the Remote Associates test with increasing performance during sleep deprivation does not lend itself to such an explanation. Hamilton et al. (1972) found a paradoxical increase in efficiency of responding under deprivation conditions with a running digits test. They attributed their findings to an auditory buffering process. Such an effect could not have been operative in this test. Several subjects did comment on the particularly challenging virtues of this task. The data, at least, suggest that repeated deprivation results in an increased capacity to retrieve remote associations.

Because the interactions were of major interest in this experiment, additional Deprivation X Repetitions analyses of the first and fourth sessions were undertaken.

A decreased effect of deprivation could be seen as a dimunition of the significance of the deprivation variance between the first and the fourth sessions; an increased effect by an increase in significance. The significance levels (exceeding .1 on either session) for the deprivation and subject variances are given in Table 2. While it is recognized that significance levels cannot

Insert Table 2 about here

be precisely compared, this table generally reaffirms the findings obtained from the prior analyses. The subjective measures of mood and sleepiness maintained high sensitivity across sessions. The Auditory Vigilance Hit rates were somewhat less sensitive for the initial (I) measure and the first session appeared relatively more sensitive while the converse held true for the second testing within a session. The Reasoning, Remote Associates, and Object Uses tests showed greater sensitivity in the later session than the first session.

Beyond the well-established sensitivity of the subjective scales and the auditory vigilance, these analyses also emphasize the fact that significant deprivation effects on the remaining tests, when applied to this small sample, were attributable to their repeated use across four sessions.

Individual Differences

For almost all of the measures showing significant effects, there were substantial between-subjects differences reflecting wide and reliable individual differences in behavior on each test. The only exceptions were on the second Sleepiness Scale, the Visual Search task with dissimilar targets and backgrounds, the percent correct on the Reasoning task, and the Unobtrusive measures where the lack of individual differences may be the result of a ceiling effect. For example, the percent correct measures on the Reasoning task for the baseline average were 98, 97, 94, 92, 87, and 85 for the six subjects. It is interesting to note that three of these measures (percent correct on the Reasoning task, dissimilar condition in Visual Search, and the Unobtrusive measures) were among the few which are not sensitive to deprivation effects.

A number of tasks showed significant S X D interactions. An examination of the individual scores of these tests revealed that, in each instance, these reflected greater sensitivity of some subjects to deprivation. For example, the mean number of problems attempted by one subject on the Reasoning task during baseline was 33, and under deprivation, 21. By contrast, another subject had a baseline average of 36 and a deprivation mean of 32. Further examination of these tasks may yield tests which differentially determine the degree of individual resistance to the effects of sleep deprivation. The highly significant S X R interaction for number of Additions reflected one subject's increasing response rate and a declining rate for several others over the repeated sessions.

4. Discussion

Two possible consequences of repeated periods of sleep deprivation on repeated measurement performance were hypothesized. As suggested by Wilkinson (1961), there may be an increased response deficit displayed due to lowered motivation ("boredom," "decreased challenge," etc.) -- a variable which exacerbates sleep deprivation effects. Alternatively, there may be a reduction in the effects of sleep deprivation as tasks become overlearned and "automated" or "stress" effects are reduced and "coping" mechanisms developed. Either alternative would result in differential and opposite effects when compared with baseline performance. If Wilkinson is correct, the differences should increase with repeated deprivation. If the alternative is correct, deprivation should diminish the differences.

The data clearly support the position outlined by Wilkinson. Most of the tests showed a decline in performance across sessions in both the non-deprived and deprived conditions. This can be most parsimoniously interpreted in terms of effects of reduced motivation. There was evidence that this reduced level of motivation is differentially enhanced by the deprivation effects. A direct comparison of non-deprived vs the deprived conditions of Sessions I and Sessions II (Table 2) showed sharp increases in the sensitivity to deprivation effects in the second Auditory Vigilance test, Word Memory (response time) and Object Usage. Two significant Deprivation x Sessions interactions were noted. The Reasoning test displayed an increased performance during baseline sessions but no change during deprivation. THis result can be interpreted within the motivational context. The Remote Associates Test showed a paradoxical increased efficiency during deprivation.

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 excerbate 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.

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Table 1

Significant Sources of Variation Across Experimental Tasks

	Source of Variation					
	Ss	Dep	Rep	S X D	S X R	D X R
d.f.	5	1	3	5	15	3
TASK and MEASURE						
Sleepiness Scale						
I	.002	.000*				
II		.000				
Mood Scale						
I	.002	.000		.004	.02	
II	.001	.000	.04	.000		
Auditory Vigilance						
Hit Rate						
I	.000	.002				
II	.000	.000	.003		.04	
False Positive Rate						
I	.000		.02		.02	
II	.000					
Addition						
Number Attempts	.000	.000			.01	
% Correct	.000			.02	.05	

Table 1 (continued)

	Source of Variation					
	Ss	Dep	Rep	S X D	S X R	D X R
d.f.	5	1	3	5	15	3
TASK and MEASURE						
Word Memory						
Number Correct	.000	.000				
Word Detection						
Hit Rate	.000		.01			
False Positives	.000		.05	.01		
Response Time	.03		.02			
Beta	.001		.05	.01		
d′	.01					
Visual Search						
Similar	.000		.05			
Dissimilar						
Reasoning						
Number Attempts	.001	.000	.01	.001		.003
Remote Associates	.005	.006	.001			.05
Object Uses	.001	.02				

*p<.001

Table 2

Deprivation Effects in Sessions I and IV

	Session I Dep	Session IV Dep
Sleepiness-I	.00*	.00
Sleepiness-II	.01	.01
Mood-I	.01	.01
Mood-II	.01	.06
Aud. Vig.-I (Hits)	.05	.13
Aud. Vig.-II (Hits)	.20	.10
Addition (N)	--	--
Word Memory (N)	--	.08
Reasoning (N)	--	.03
Remote Associates	--	.05
Object Usage	--	.10

* $p < .01$

Figure Captions

1. Schedule of one repetition of the experimental procedures.

2. Mean reported sleepiness in the first administration of each scale during the first four repetitions of the regimen. The solid line displays baseline performance and the dashed line shows performance after 40-45 hr. of total sleep deprivation.

3. Mean number of hits in the first administration of the Auditory Vigilance task during the first four repetitions of the regimem. The solid line displays baseline performance and the dashed line shows performance after 40-45 hr. of total sleep deprivation.

4. Mean number of attempts on the Addition task during the first four repetitions of the regimen. The solid line displays baseline performance and the dashed line shows performance after 40-45 hr. of total sleep deprivation.

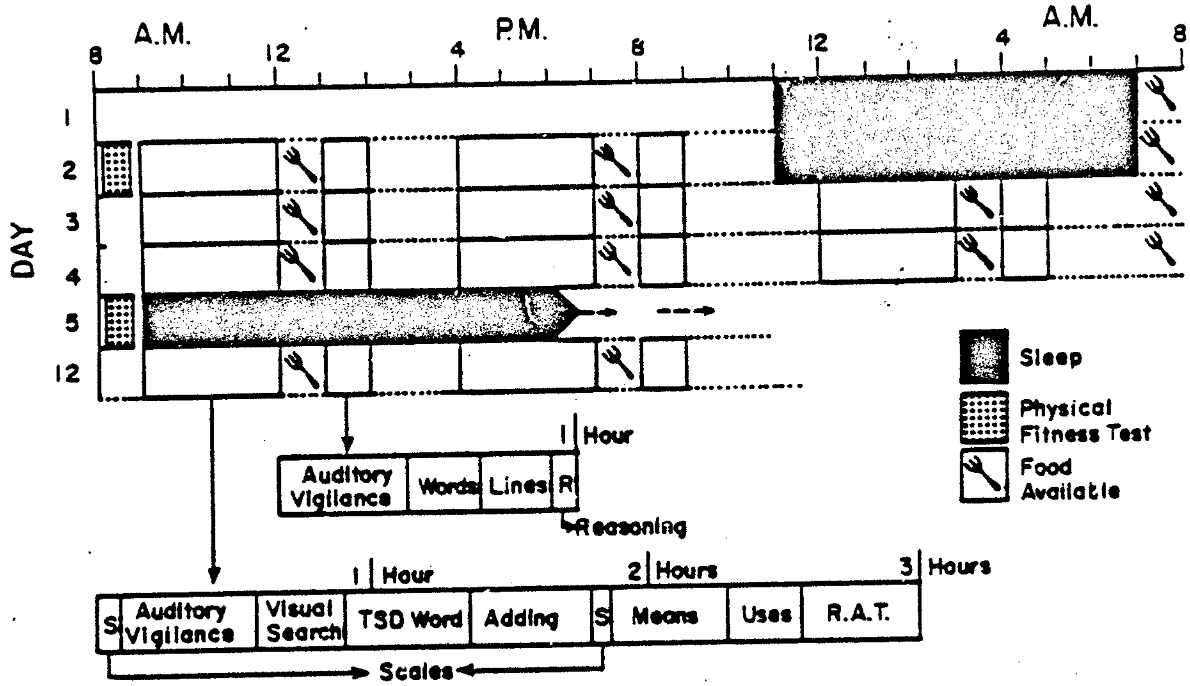
Figure Captions (continued)

5. Mean number of correct words recalled on the Word Memory task during the first four repetitions of the regimen. The solid line displays baseline performance and the dashed line shows performance after 40-45 hr. of total sleep deprivation.

6. Mean number of attempted solutions to the Reasoning problems presented during the first four repetitions of the regimen. The solid line displays baseline performance and the dashed line shows performance after 40-45 hr. of total sleep deprivation.

7. Mean number of correct responses to the Remote Associates test during the first four repetitions of the regimen. The solid line displays baseline performance and the dashed line shows performance after 40-45 hr. of total sleep deprivation.

Figure 1.


A.M.
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A.M.
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Sleep
Physical Fitness Test
Food Available
Auditory Vigilance
Words
Lines
R
Reasoning
1 Hour
S
Auditory Vigilance
Visual Search
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Adding
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Means
Uses
R.A.T.
1 Hour
2 Hours
3 Hours
Scales

Figure 2.

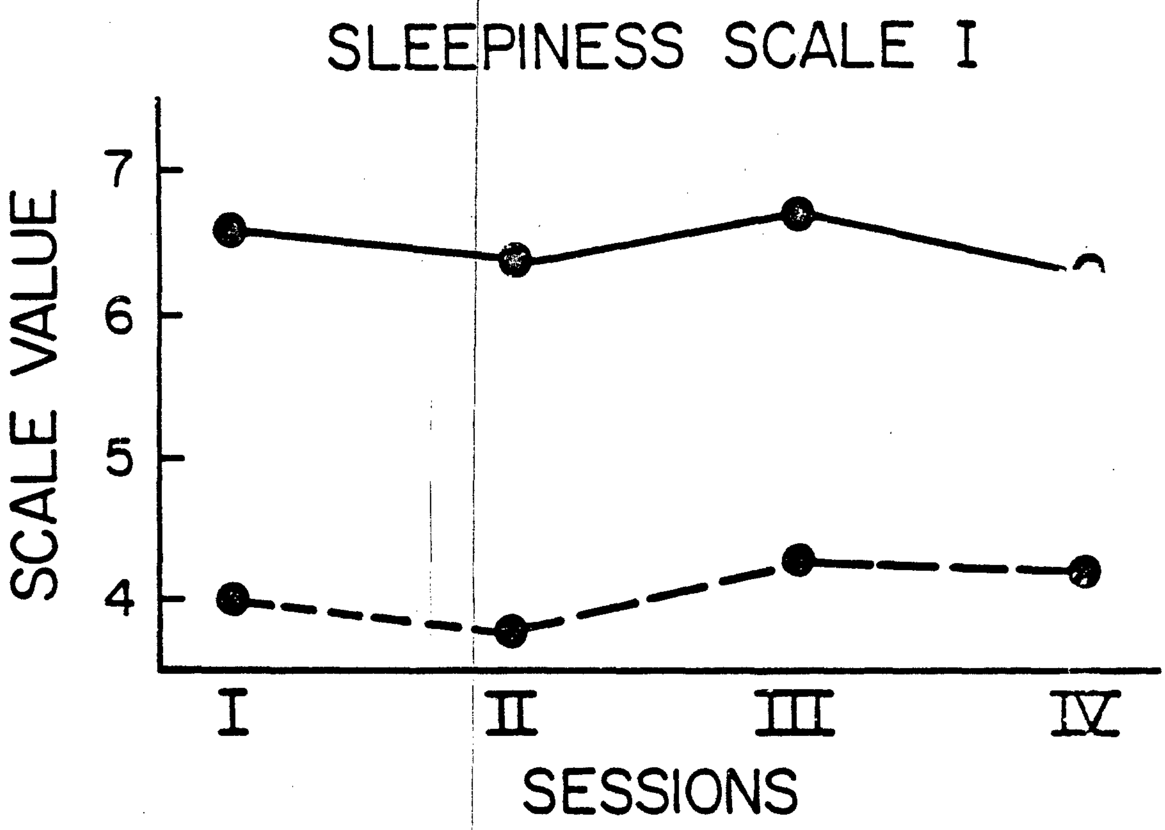


Figure 3.

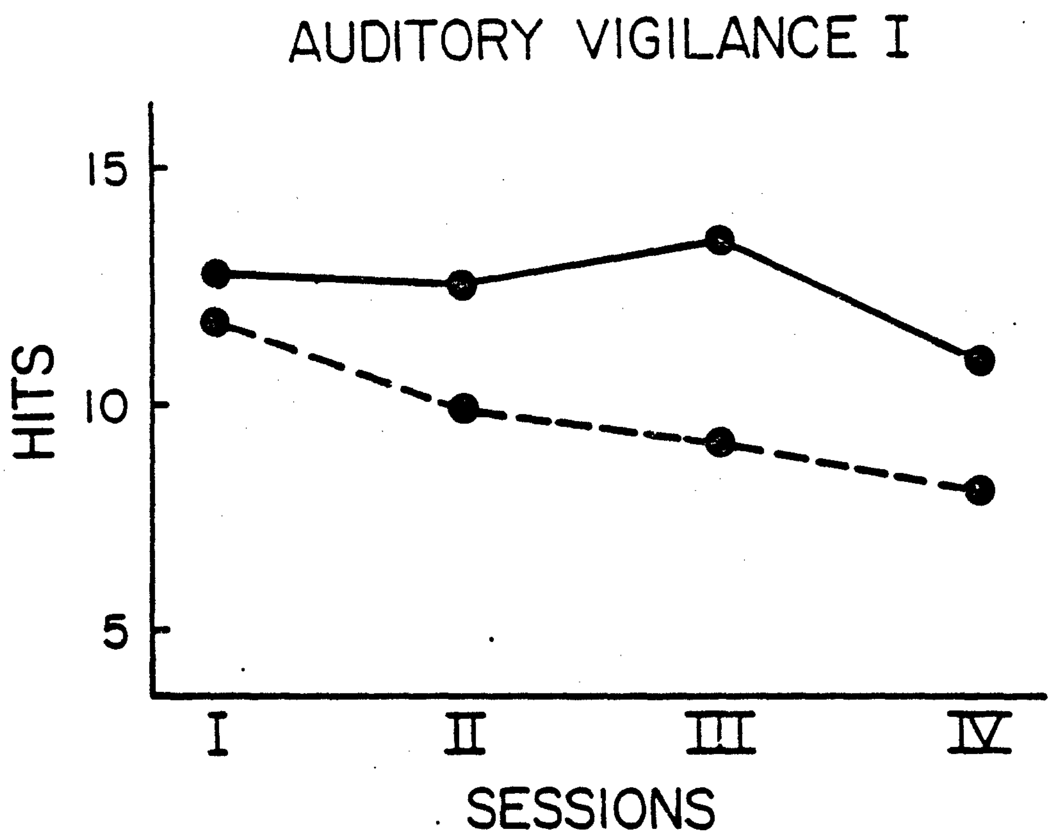


Figure 4.

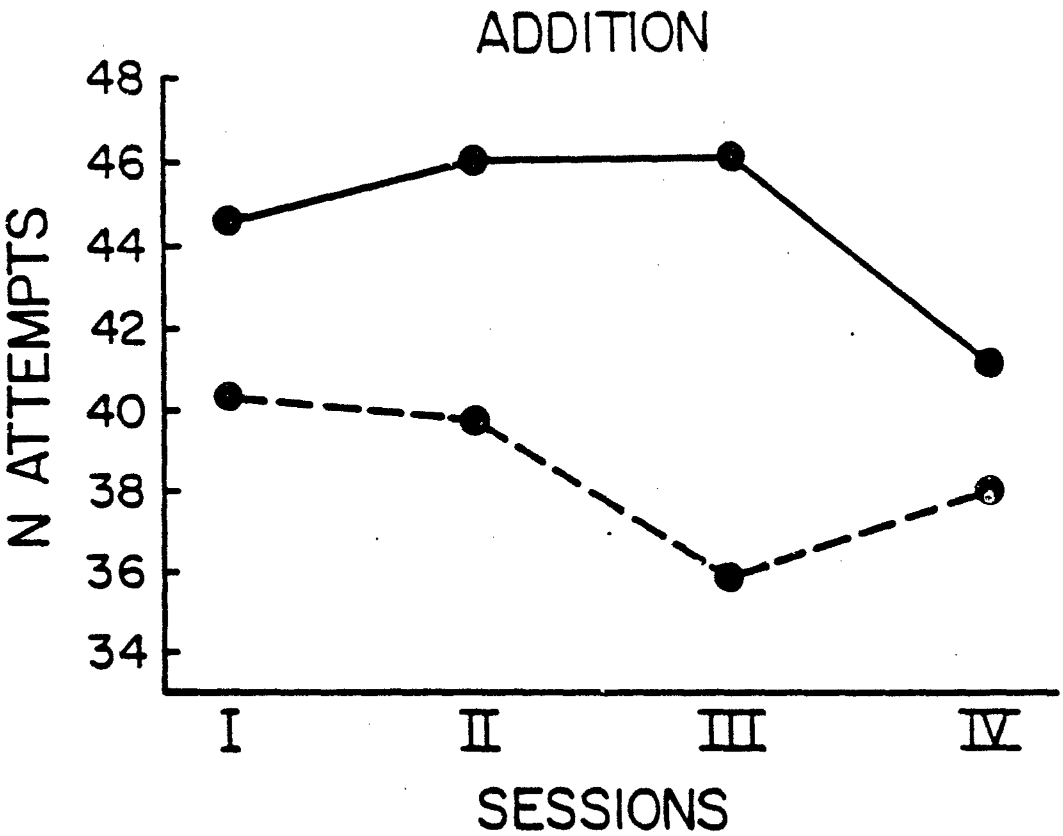
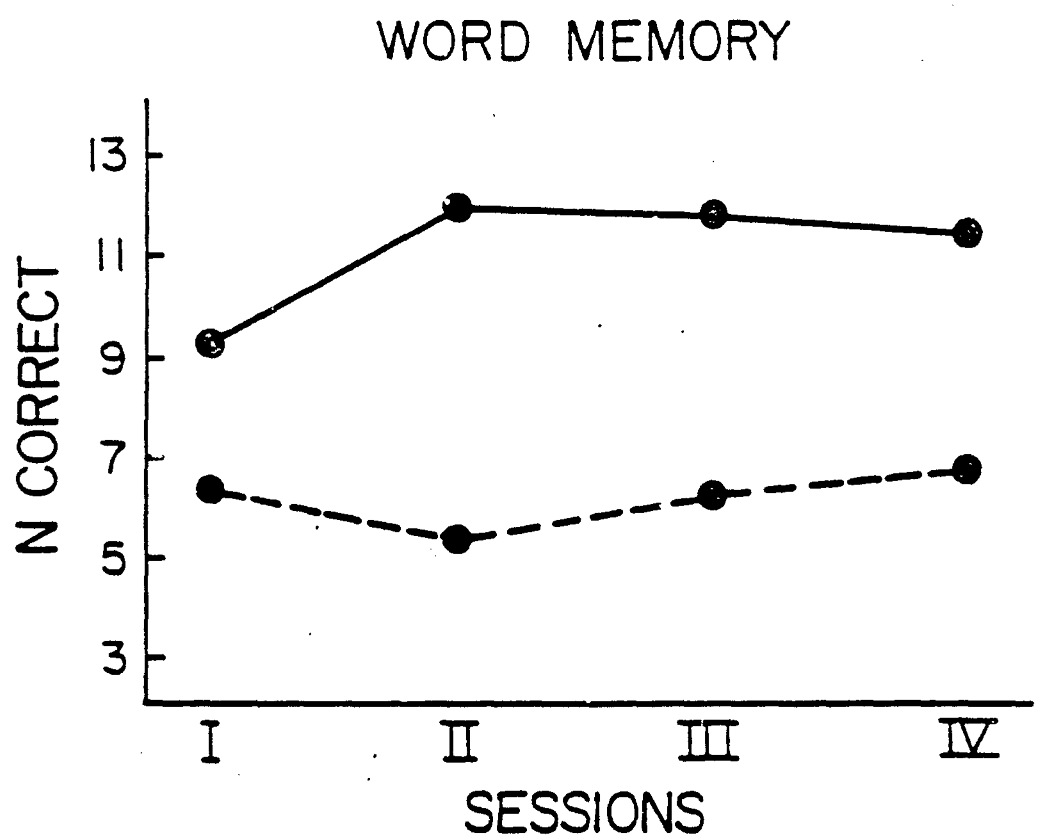


Figure 5.



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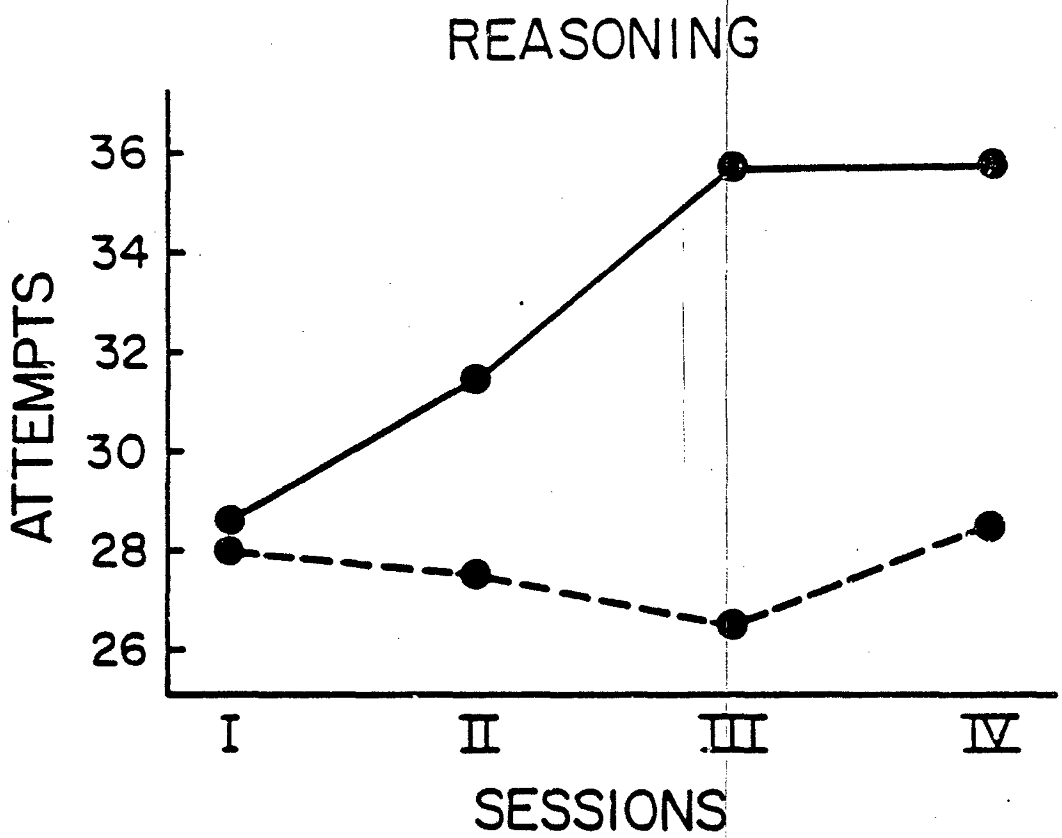
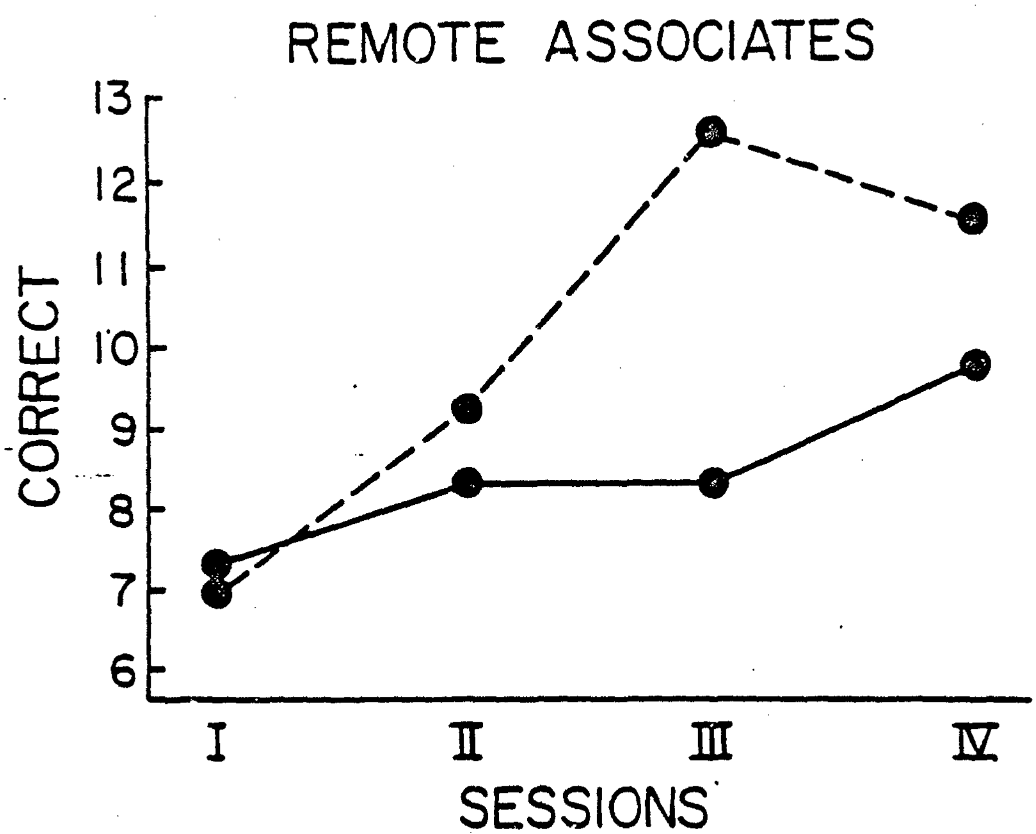


Figure 7.


REMOTE ASSOCIATES
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7
6
CORRECT
I
II
III
IV
SESSIONS