Responses to Material Presented During Various Levels of Sleep

by

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GLOSSARY

E	Experimenter
S	Subject
EEG	Electroencephalograph, or electroencephalogram

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The RAND Corporation

Recently, there has been an increased interest in the possibility of learning during sleep. A critical review of the few scientific studies in this field to date lead to the conclusion that the evidence supporting claims of learning during actual sleep is inconclusive. The chief criticism against the existing studies is their failure to continuously determine the sleep state of Ss during the stimulus input period (16).

After considerable exploratory work (15), the present experiment was designed to study the effect of presenting material at different levels between wakefulness and deep sleep on the ability of Ss (a) to respond to it immediately, and (b) to recall it later upon awakening. It was hypothesized that learning during sleep was improbable.

Method

Subjects

Twenty-one male experimental Ss were used. In order to facilitate the detection of gradual changes which occur in the EEG between wakefulness and light sleep, it was necessary to use only Ss having a persistent occipital alpha rhythm when awake and relaxed

with their eyes closed. Ten Ss were junior college students, nine were scientists, and two were policemen. Results from students and policemen were combined since they were similar on critical variables. Mean and standard deviations of descriptive variables for the experimental subgroups were determined. For the scientist group, these values were: age, 30.6 years ± 5.0; IQ, 122.6 ± 6.0; items correct on pretest, 11.7 ± 3.4. For the college men and policemen combined, these values were: age, 23.2 years ± 6.3; IQ, 108.6 ± 4.7; items correct on pretest, 6.8 ± 3.0.

Forty junior college males and 24 male scientists acted as a control group without regard for their alpha rhythm. These Ss were used to obtain an estimate of the probability of correct answers being chosen on a multiple-choice test, since it seemed unlikely that educated Ss would select their answers to unknown questions solely by chance. This control group was first given a pretest to determine the number of test questions known without training and before seeing the multiple-choice alternatives. With no intervening training, scores on this pretest significantly predicted scores on the recognition test after items known on the pretest were removed. This prediction was not materially improved by using age and IQ (Otis) in a multiple-regression equation. Mean values of all control subgroups' scores were not significantly different from the corresponding experimental subgroups' scores. Variance for both control subgroups were equated with the experimental subgroups on the critical pretest score. Only variance for the scientist subgroups were equated for IQ and age.[2]

Apparatus

The Ss slept in clean comfortable beds in three separate sound-proof, air conditioned, electrically-shielded booths. EEG electrodes were applied to the right occipital area, the vertex, and the left mastoid process. The electrode wires were arranged to allow relatively free movement and comfort during sleep. Two monopolar EEG recordings (right occipital and vertex) were made from each S using a six-channel Offner electroencephalograph and Dynograph inkwriter. A marker pen mounted on the inkwriter automatically marked the exact time an auditory stimulus was presented to a S. The learning material was recorded on magnetic tape and played through loud-speakers placed inside the booths. A two-way intercommunication system allowed Es to communicate with Ss.

Procedure

Pretesting period. Several hours before retiring, Ss were pretested to discover what information they knew in order to have a base from which to evaluate how much had been learned following "sleep-training" on the same material. They were encouraged to guess answers to as many questions as they could, since a chance guess might be the correct one. No time limit was imposed.

Ninety-six general information questions were culled from various books on the basis of the following criteria: (a) the information was not generally known; (b) the answers required were not outside the verbal experience of the Ss; (c) questions could be answered in short phrases or single words. These same

96 questions and their answers were recorded on tape at 5-min. intervals for presentation during the sleep period. The answer was presented as a restatement of the question with the critical information near the end. For example, Question: "In what kind of store did Ulysses S. Grant work before the war?" Answer: "Before the war, Ulysses S. Grant worked in a hardware store."

Preliminary period. Following the pretest, Ss prepared for bed and the EEG electrodes were applied. Three Ss were run simultaneously. Since it was not possible to adjust the auditory intensity of the stimulus material in each booth individually, it was necessary to find a level satisfactory to all three. "Satisfactory" was defined as the point at which the training material could be heard clearly by the waking S, yet not be loud enough to materially disturb him once he was asleep. As the Ss lay in their booths, practice verbal material was played at approximately the same loudness as the experimental stimulus material was to be played. This loudness level was adjusted after a number of tests so that the S with the highest threshold was able to hear the words clearly.

Before turning out the lights and allowing the Ss to go to sleep, the following instruction were given: (a) if they awakened during the night at any time, they were to call out their name and booth number as soon as possible and to say that they were awake; (b) if they heard the answer to any of the question-answer combinations during the night, they were to wait until the answer

was completed, and then call out their name and booth number. In order to impress these instructions on the S, each was asked to repeat them back to the E.

Training period. Within 5-min. after S retired, the tape recorder was turned on and the question-answer combinations were played into the booths at approximately 5-min. intervals. A pen automatically marked the EEG record whenever a question or answer was played. The Es marked on the record whether or not S stated he heard the answer. Records of any other pertinent information were kept, e.g., if S awoke, his remarks, and so forth.

Posttest period. Shortly after the last question and answer was played, Ss were awakened (if they were not already so), permitted to dress, and wash their face and hands. The same questions which they received on the pretest and during the training were again presented for them to answer; as before, Ss were encouraged to guess. This unaided recall was followed by a multiple-choice test in which five alternative answers (including the correct one) were provided with the questions.

Control group testing. All members of the control groups were given the 96 questions and asked to answer them by guessing whenever they were not certain. Following a brief rest and no training, they were given the questions along with the multiple-choice answers and retested.

Intelligence testing. Following the completion of the experiment, both experimental and control groups were given the 30-min. Otis Self-Administering Test of Mental Ability, Form D.

Results

The basic data available for analysis were: (a) the levels of sleep during the training period as indicated by EEG records, (b) the frequencies with which Ss immediately reported they had heard an answer, and (c) the frequencies with which Ss correctly recalled an answer, both unaided and by recognizing the correct multiple-choice alternative.

Sleep Levels

Those portions of the EEG record occurring simultaneously with the presentation of the answers were categorized into 22 distinguishable patterns. These 22 EEG patterns were divided into eight groups, or sleep levels, which were ordered on their proportion of visually observable cyclical activity within the alpha frequency range (8-13 cps) and on their amplitude, frequency, and the effects of stimulation when alpha frequencies were no longer present. This order corresponds to S's state of consciousness between wakefulness and deep sleep and is described in Table 1.

Insert Table 1 about here

The categories were based on Ss having continuous or nearly continuous waking alpha and read primarily from the monopolar

occipital record. The letter symbols and the [redacted] descriptions of the sleep levels in Table 2 approximate those of other experimenters in the field. Most investigators believe that an individual is asleep when Level C is reached, although some believe the onset of sleep occurs toward the end of Level B (3,5,9,11,12).

The EEG records were analyzed independently by two Es, after first agreeing on a few major classification principles. Their independent readings of the eight levels correlated .877 (corrected contingency coefficient) with $\sigma_C = \pm .024$ when the true correlation is zero. Following this first reading, the two Es worked together to agree on the categories for all 2,016 items, elaborating on the principles for such categorization and compromising in a few cases where it was necessary. The breakdown of EEG levels during the drowsy stages before sleep is finer in this paper than has been reported previously. In the final analysis of the 2,016 sections of record, 7% were unclassifiable due to artifacts which obscured the EEG pattern.

Levels O through A will be designated as "alpha levels" and B through E as "non-alpha levels." Cyclical activity within the alpha frequency range (8-13 cps) is found in the first four levels and is absent in the second four, with the exception of highly questionable alpha frequencies appearing during stimulation at the borderline between waking and sleeping. Sleep levels always refer

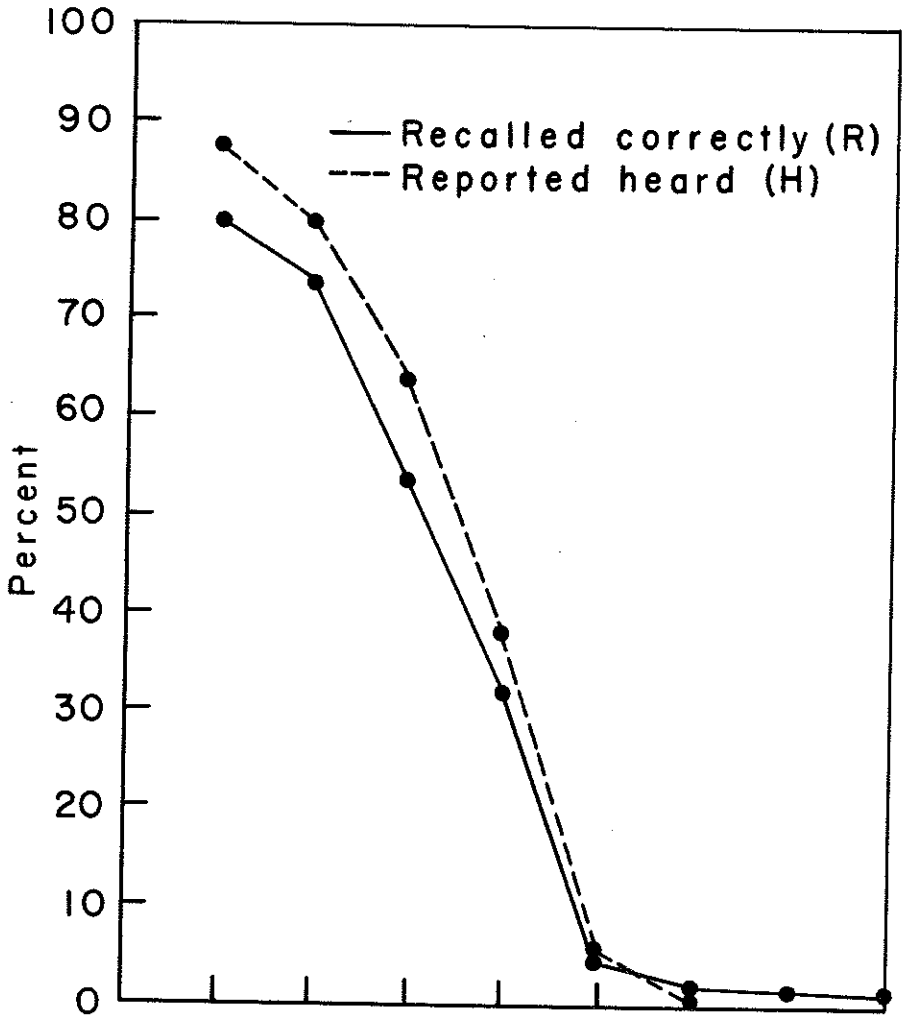
to the levels at the time of stimulus presentation and never at the time of the immediate response or of later recall. All scoring of the EEG records was completed prior to the scoring of the information tests. When there was doubt as to the presence of alpha due to its low amplitude, very small quantity, or masking by other activity, it was the policy to place these patterns into the deepest alternative level.

Immediate Response and Unaided Recall

The "immediate response" or "reported heard" analysis was based on 1827 items; items were removed when the EEG was obscured by artifacts and when it was impossible to determine which of the three Ss running simultaneously had responded. The "unaided recall" analysis was based on 1690 items; items were removed when the EEG was obscured by artifacts and when the items were known on the pretraining test.

The percentage of items reported heard at time of presentation and the percentage correctly recalled unaided, upon awakening, are shown in Fig. 1. These percentages in Fig. 1, based on the combined data for all Ss and items occurring at each level, decrease as the amount of alpha decreases and delta appears, that is, as the sleep level deepens.

Of the items recalled correctly on the entire test, the following percentages were reported heard: Level 0, 90%; Level A+, 85%; Level A, 79%; Level A- 69%; Level B, 49%. Below Level B no items were reported heard and only 8 out of 508 items were answered correctly. Four Ss indicated that after an extended period of wakefulness,



Sleep level	O	A+	A	A-	B	C	D	E
No. of subjects	19	21	20	21	21	21	19	12
Total items (H)	163	168	225	275	440	355	138	63
Total items (R)	159	156	210	257	400	333	117	58

FIGURE 1

they heard answers but deliberately failed to report since they wanted to go to sleep. Thus, the number of items reported heard and correctly recalled were probably somewhat higher than indicated.

The percentage correct at each level when based on the combined data did not differ significantly from the percentage correct computed as the mean of all Ss' individual percentage correct ($t = 1.82$, 7 d.f.). All individual Ss showed the same tendency to reduce the percentage heard and recalled as alpha disappeared.

However, some items were immediately responded to and recalled later in Levels B through E. The breakdown of these items by level, type of response, and number of Ss contributing are shown in Table 2.

Insert Table 2 about here

Twelve of the 19 correctly recalled items presented in Level B appear to be the effect of bona-fide learning. These were cases when the Level B EEG patterns were of specific types occurring during stimulation and were related to arousal from sleep. These patterns were characterized by low level, fast random activity quite similar to the "activation pattern" found in animals (10,14) as well as by an increase in random activity containing both high and low frequency components. In the latter pattern, mixed alpha frequencies occurred simultaneously with significant quantities of delta activity. Both patterns appeared to be different aspects of a stimulus effect at the borderline between sleep and wakefulness. Since both alpha and delta appeared, the pattern was assigned to Level B, the transition state, rather than Level A- in accordance with the policy stated earlier.

When these patterns are observed, arousal is imminent if stimulation continues. All of the items reported heard and recalled correctly (HR), half of the items reported heard only (H-), and four of the items recalled correctly (R-) in Level B could be accounted for by these patterns associated with arousal.

Eight items in Table 2 were heard only without any arousal patterns being observed. It cannot be determined from this study whether the answers which were reported heard were also understood; at least, they were not recalled.

Were the remaining items recalled correctly in Levels B through E (after removing items occurring during the arousal patterns) really learned during sleep training? Since the range of reasonable answers to many of the questions in this experiment were restricted, the likelihood of a correct guess on the posttest increased if a S habitually changed his answer from first to second trial. Although it can never be proven that these 15 out of 508 items were answered correctly by guessing, the hypothesis was tested as follows: An index of changeability was determined for each S by examining only those items which he answered incorrectly on both pre and posttests; this was done in order to avoid changes brought about by obvious learning. When the number of items recalled correctly without being reported heard and not associated with arousal EEG patterns was correlated with the percentage of incorrect answers changed between pre and posttests by the 21 Ss , the relationship was positive ($r = .68$). This

correlation, significant below the .01 probability level, supports the hypothesis that those persons changing their answers the most increased the number of correct guesses that they made. In other word, the 15 correct items could be the result of guessing.

Examination of individual S's data revealed that they all followed the same trend as shown by the curves in Figure 1. The few cases of apparent recall that are shown in Table 1, accounting for roughly 1.5% of all the items below Level B, are attributable to only a few Ss. No S contributed more than two items and their occurrance in any sleep level was haphazard.

Recognition Test

Figure 2 shows the percentage of items recalled correctly

Insert Figure 2 about here

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for all Ss when multiple-choice answers were provided, along with the standard error of these percentages. As in Figure 1, with a decrease in alpha frequencies at the time of presentation, there was a corresponding decrease in the number of items recalled later. Unlike the others, however, the recall curve from this recognition test leveled off around 23% instead of dropping to zero.

Since it was possible for Ss to answer correctly solely by chance on the multiple-choice test, it was necessary to compare the percentages obtained by the experimental groups with an empirical estimate of what the theoretical percentage would be. Although 20%

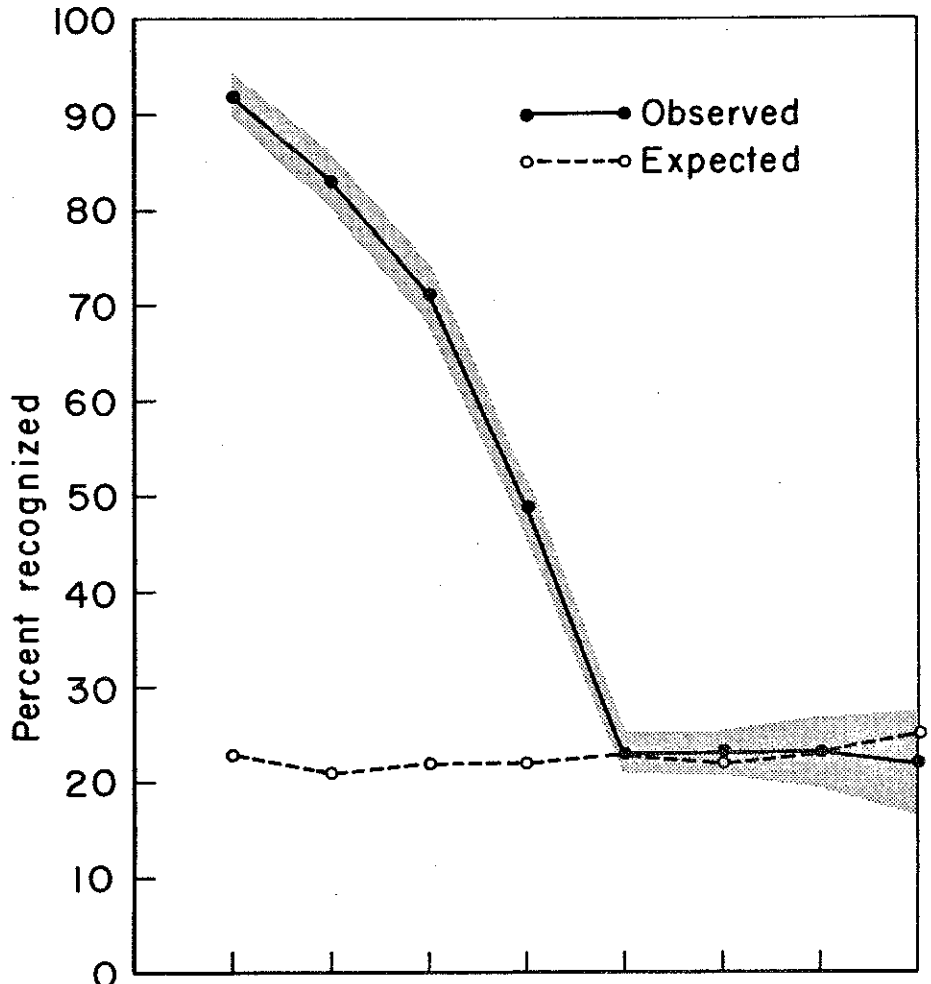
was chance expectancy for this test, the difficulty of making a perfect multiple-choice test with answers equal in selectivity caused the Es to use scores of a control group as the basis for estimating the expected value.

It was found that the scientist control subgroup answered 26% correctly without training and the college control subgroup answered 22% correctly. The expected percentages shown in Figure 2 were based on empirical values from the control groups weighted according to the items contributed by the scientist and college-police experimental groups in each sleep level.

Thus, from Figure 2, it can be seen that the expected values remain essentially the same for all sleep levels, while the values observed from the experimental group changed. In Levels 0 through A-, the experimental Ss showed a considerably higher percentage correct, while in Levels B through E, the percentage correct for the experimental group was essentially equal to (within $\pm$ .5%) and in most cases less than the mean expected value.

Since the values in Figure 2 were based on combined data for all Ss, hiding possible individual learning, the data was analyzed by S. In order to have a sufficiently large expected value for computing X^2 for each S, Level 0 through A- (alpha levels) were combined as were Levels B through E (non - alpha levels). These were compared with the mean percentage correct for the appropriate control sub-group. The X^2s from these analyses are shown in Table 3. No

FIGURE 2



The percentage of answers recognized on the multiple choice test after being presented at varying levels along the continuum between a waking and deep sleep state. The shaded portion represents plus and minus one standard error of the percentage. The expected value was that obtained from an untrained control group of comparable ability answering the same items.

Insert Table 3 about here

experimental S recalled correctly significantly more multiple-choice items than would be expected from the estimated percentages obtained from the untrained control group.

In order to determine whether any learning had occurred in the lightest sleep level but had been masked by combining that data with the deeper sleep levels, individual X^2s were computed whenever possible for the results in Level B. Twelve of the Ss had scores equal to or less than the expected value. Three Ss scored insignificantly higher than the expected value (X^2s = .34, .21, and .01; 1 d.f.). For five cases, expected values were so small that X^2 could not be computed. Two of these, with a 22% expected value, had 5 out of 14 and 4 out of 16 answered correctly while three Ss, with a 26% expected value, had 4 out of 7, 2 out of 4, and 3 out of 10 answered correctly. Only one S showed a significant X^2 of 5.9, with 1 d.f. for Level B. For this S, 11 out of 24 items were answered correctly. Of these 24, eight occurred when EEG patterns associated with arousal occurred; when these items were removed, 5 out of 16 were correct where 4 correct were expected.

Discussion

The results support the hypothesis that learning during sleep is unlikely. Although a few items were answered correctly unaided, with the easier recognition test (13) no more items were answered

in Levels B through E by the experimental group than would be expected from the performance of the untrained control group. Since it is generally conceded that sleep occurs somewhere during Level B, then it appears that learning was slight, if any, at this point or below. There appears some basis for assuming that many of these atypical cases were artifacts and not true sleep-learning.

What had been done in the present sleep-learning study that had not been done adequately in any previous studies (16) was the careful monitoring of Ss during the presentation period so that their levels of sleep during training were always known. The use of the EEG for this purpose proved most adequate.

The experiment was designed to get a continuous function rather than a dichotemous relation between responsiveness and consciousness along the wake-sleep continuum. Preliminary exploration (15) suggested the present design to be an appropriate one, although it involved certain calculated limitations related to the selection of Ss, the conditions under which experimental and control groups were tested, and the number of stimulus repetitions.

Research on alpha dominant Ss cannot justifiably be generalized to the general population, although there is no conclusive evidence that alpha dominant and rare alpha individuals differ on factors contributing to learning--certainly not on intelligence (11). Ss were chosen with above average IQ's to maximize the probability of learning. In the preliminary work, Ss with considerably less dominant

alpha rhythms were sometimes used. Although the borderline between drowsiness and sleep was more difficult to detect from the EEG with these Ss, material presented when delta activity was present was never recalled later.

Experimental and control groups were tested under slightly different conditions. The control group in the present study was given one unaided pretest followed by the multiple-choice posttest with no intervening training. The experimental group received an unaided pretest followed by training and then a second unaided posttest before taking the multiple-choice posttest. To what extent the additional unaided posttest effects the comparison between groups is unknown. However, it has generally been shown that additional practice such as this second test provided enhances learning (6). This again would increase the probability that the experimental group would show even more learning on the multiple-choice test than the control. This was not found to be the case in the Levels B through E associated with sleep.

Experimental Ss were given each item only once during training.[3] This was necessary to correlate an answer with a sleep level, for sleep levels varied throughout the night and had items been repeated, there would have been no assurance that they would have occurred in the same levels each time. Neither Stampfl (17), Hoyt (7), nor Coyne (2) found that varying the number of repetitions had any effect in their sleep-learning studies. None of these investigators

found evidence of sleep-learning. The meaningfulness and simplicity of the test items tend to favor retention (6); tests showed that approximately 86% of previously unknown items could be retained by awake and alert Ss with a single repetition.

The above three limitations were accepted by the Es since in most cases they should tend to enhance any sleep-learning potential that might exist and thus disfavor the hypothesis which was tested. In spite of this, the evidence for learning was inconsequential as long as a rigid control on the measure of the depth of sleep was maintained.

Although it appears that learning during real sleep is not feasible, the practical utilization of the drowsy state for training is still open to speculation. The results in this study show that approximately 30% of the simple and highly organized material presented in the period just prior to sleep was recalled. Just how efficient learning in this state is has not been sufficiently evaluated experimentally. Anderson (1) found that the amount of recall decreases when training follows sleep closely. One must weigh the advantages of limited learning against the possible harmful effects from loss of sleep as well as against the time demanded to learn in the sub-normal receptive state. It may be that in the drowsy state preceding sleep, the individual is more susceptible to suggestion; perhaps one's attitudes or habits can be modified during this pre-sleep period when criticalness is minimized (8).

Perhaps the future development of new and unknown techniques will permit someone to learn complex material while he sleeps, but for the present, sleep-learning is not the simple matter that some Es and commercial firms, which sell equipment for this purpose, would lead us to believe.

Summary

Twenty-one Ss were selected on the basis of IQ (average or above) and an EEG showing a continuous alpha rhythm when they were awake and resting with their eyes closed. They were given a pre-information test of the sleep-training material and then permitted to sleep for eight hours. No attempt was made to control the depth of sleep although EEGs were taken continuously from the occipital region. Ninety-six questions and answers were played to the Ss once each at five minute intervals throughout the sleep period. Ss were instructed to indicate immediately if they heard an answer. On awakening the next morning, Ss were given the questions and asked to write the answers. Following this they were given five alternative answers and asked to check the correct one. EEG patterns occurring during stimulation were assigned to one of eight. Both the percentage of immediate responses and the percentage of items recalled correctly decreased as the percentage of alpha frequencies decreased. Shortly after occipital alpha frequencies disappeared from the EEG, immediate responses and item recall also stopped. This was more evident when tested by recognition than by

unaided recall. Approximately 5% of the items presented during non-alpha levels were responded to immediately, recalled later; or both. A majority of these items occurred when particular EEG patterns associated with arousal occurred; alternative explanations other than sleep-learning are offered for the few remaining items. Learning during real sleep is concluded to be impractical and probably impossible. The possibility of utilizing the drowsy state where material is retained is discussed.

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Footnotes

1. The authors wish to acknowledge the valuable assistance of Louie W. Mason, Jr. and James L. Barnes in the analysis of the data in this study. Appreciation is expressed to the faculty and students of Santa Monica City College, to the Santa Monica Police Department, and the the volunteer Ss within The RAND Corporation for their cooperation throughout the project.

2. Supporting and additional statistics along with data by S have been deposited with the American Documentation Institute. Order Document No._____, remitting $_____ for 35/mm. Microfilm or $_____ for 6 x 8 in. photocopies.

3. Prior to the publication of this paper a second study (4) was completed in which material was presented to S between 16 and 82 times. No learning occurred so long as the material was presented in non-alpha levels.

Table 1

EEG and Psychological Conditions along the Sleep-Wakefulness Continuum

Level	Items	% Ss	Electroencephalogram	Psychological Condition
0	8	90	Continuous or nearly continuous alpha of maximum amplitude and frequency of not more than 1 cps slower than the S's normal alpha frequency. Frequency and amplitude are slightly less after sleeping than before.	Awake. Relaxed with eyes closed. Responsive to external stimulation.
A+	9	100	More than 50% of the scoring period contains alpha. Also low level, random activity characteristic of an alpha block may be present with alpha disappearing at the onset of stimulation and returning shortly after its cessation.	
A	12	95	Less than 50% alpha but scoring period contains at least three cycles of activity having the same frequency as the 0 level. The alpha amplitude may be of the same or considerably lower amplitude than before.	Drowsy. Attention wanders; reverie. Increased reaction time. Partial awareness.
A-	14	100	Contains cyclical activity having a frequency more than 1 cps slower than the Level 0 record. May include waves of mixed duration with periods between .12 and .08 sec. with no one period being dominant. Also includes records showing no alpha rhythm during stimulation, but with alpha occurring within 30-sec. prior to stimulation or following but not both.	

(Table 1 continued on next page)

(Table 1, continued)

B	22	100	Absence of alpha during the stimulus period and the adjacent 30-sec. of record. Stimulus effects may occur consisting of low level fast activity or an increase in activity containing both high and low frequency components, with some waves having periods within the alpha range. Low level delta activity is present in the absence of stimulus effects.	Transition. Dream-like state. Infrequent responses to external stimulation. Onset of sleep. Easily awakened.
C	18	100	Absence of alpha with an increase of delta and the appearance of sleep spindles (14 cps). This state is characterized by stimulus effects such as the K complex and increases in amplitude of delta waves with the onset of the stimulus. Type of effects vary with individuals.	Light sleep. No behavioral responses to external stimulation (unless stimulus awakens). Dreams sometimes remembered.
D	7	90	A further increase in delta amplitude with a reduc- in frequency and diminution of stimulus effects and sleep spindles. Amplitude of delta almost at maximum.	Deep sleep. No memory for dreams. Difficult to awaken.
E	3	57	Absence of sleep spindles and stimulus effects. Very large delta activity with smooth waves of .5- to 1.5-sec. duration.	Very deep sleep.

Table 2

Number of Items Reported Heard (H-), Answered Correctly (R-), or Both (HR) in the Non-Alpha Levels

Level	Items Possible	HR	H-	R-	No. of Ss Contributing
B	400	8	18*	11**	15
C	333	0	0	5	4
D	117	0	0	2	2
E	58	0	0	1	1
All	908	8	18	19	

* Five of these were answered correctly on the pretest.

** Two of these may or may not have been heard; answers were too indistinct to determine which of three Ss reported.

Table 3

X^2s of Individual Ss showing the Significance* of Differences between Observed and Expected Values of Learnings in Alpha and Non-Alpha Levels

S's No.	Levels 0 thru A-	Levels B thru E	S's No.	Levels 0 thru A-	Levels B thru E
1	10.38	.14	12	110.89	.55
2	33.12	.40	13	37.27	.67
3	46.39	3.97**	14	37.51	.08
4	151.30	.39	15	80.58	2.65
5	7.31	.54	16	38.68	.20
6	32.43	2.00	17	32.00	3.57
7	55.69	.15	18	109.24	.84
8	5.41	.05	19	113.78	1.08
9	47.35	.01	20	78.57	.31
10	43.10	1.65	21	6.24	.19
11	.47	.03			

* X^2 values higher than 3.84 (1 d.f.) indicate that the S answered significantly more items correct on the multiple-choice test than would be expected from the mean of his control subgroup. (P = .05)

** This S answered 5 out of 49 correctly. This was significantly less than the 10.8 expected correct when based on scores of his appropriate control subgroup.

Fig. 1 The percentage of items reported heard during the stimulation at varying levels along the wake-sleep continuum and the percentage subsequently recalled correctly unaided. The number of Ss contributing to each level and the number of items from which each percentage was computed are shown.

Fig. 2 The percentage of answers recognized on the multiple choice test after being presented at varying levels along the continuum between a waking and deep sleep state. The shaded portion represents plus and minus one standard error of the percentage. The expected value was that obtained from an untrained control group of comparable ability answering the same items.

ADDITIONAL DATA AND ANALYSES PERTAINING TO "RESPONSES TO MATERIAL PRESENTED DURING VARIOUS LEVELS OF SLEEP" BY C. W. SIMON AND W. H. EMMONS, 1955

MULTIPLE CORRELATIONS, INTERCORRELATIONS, AND BETA WEIGHTS FOR Ss' AGES, IQs, AND UNAIDED PRETEST SCORES PREDICTING PERFORMANCE ON THE MULTIPLE-CHOICE TEST. (ALL CORRECT PRE-TEST SCORES WERE REMOVED FROM THE MULTIPLE-CHOICE TEST SCORES. THE DATA WERE BASED ON CONTROL GROUP SCORES.)

COLLEGE (n=40)	SCIENTIST (n=24)

Multiple Correlations

$R_{0.123} = .41$	$R_{0.123} = .59$
$\sigma_R = .03$	$\sigma_R = .12$

Intercorrelations

	IQ	Pre	MC		IQ	Pre	MC
Age	.22	.11	.12	Age	.20	.14	-.09
IQ		.43**	.08	IQ		.40	.39
Pre			.38*	Pre			.52**

Beta Weights

Age	IQ	Pre	Age	IQ	Pre
.10	-.13	.43	-.20	.25	.44

TESTS OF THE SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEANS AND VARIANCES FOR EXPERIMENTAL AND CONTROL Ss ON THREE MATCHING VARIABLES.

	IQ	AGE	PRETEST
College-Policemen			
t	1.78	1.43	1.78
d.f.	50	50	50
F#	2.68*	6.33**	2.18
d.f.	11/39	11/39	11/39
Scientists			
t	1.44	.37	1.75
d.f.	31	31	31
F#	1.21	1.10	2.56
d.f.	8/23	8/23	8/23

* $P < .05$
** $P < .01$
\# Double P value when referring to F tables as this is a two-tailed test.

LENGTH OF THE TRAINING MATERIAL ANSWERS
(This is approximately equivalent to the amount of EEG record that was scored)

Mean = 4.68 seconds; Sigma = .955 seconds. Range: 2.4 to 7.2 seconds
Total answer period during 8 hour experiment = 7 $^{1}/_{2}$ minutes (1.6%)
F test between means of time for answers during each hour of experiment = 1.12, 7/11 d.f.

PERCENTAGE OF IMMEDIATE RESPONSES

	Sleep Level							
	0	A+	A	A–	B	C	D	E
Mean (by Ss)	86	81	62	34	6	1	0	0
σ_m	5.4	6.2	6.7	5.8	2.2	1.0		
Median	100	100	68	36	0	0	0	0
No. of Items	163	168	225	275	440	355	138	63
No. of Ss	19	21	20	21	21	21	19	12

CHI SQUARE TEST OF THE SIGNIFICANCE OF THE DIFFERENCES BETWEEN PERCENTAGE OF ITEMS TO WHICH IMMEDIATE RESPONSES WERE MADE BY COLLEGE–POLICE AND SCIENTIST GROUPS BASED ON COMBINED SCORES

	Sleep Levels							
	0	A+	A	A–	B	C	D	E
College–Police	88	77	72	32	4	0	0	0
Scientists	85	87	62	44	10	1	0	0
χ^2	.031	3.53	2.18	3.10	2.26	.111	–	–

PERCENTAGE RECALLED CORRECTLY UNAIDED

	Sleep Level							
	0	A+	A	A–	B	C	D	E
Mean (by Ss)	71	69	47	30	7	2	2	2
σ_m	7.6	5.9	5.7	5.1	2.9	.9	1.8	1.7
Median	86	75	49	29	0	0	0	0
No. of Items	159	156	210	257	400	333	117	48
No. of Ss	19	21	20	21	21	21	19	12

FREQUENCY OF ITEMS REPORTED HEARD AND RECALLED CORRECTLY BY HOUR OF PRESENTATION

Hour of Presentation	1	2	3	4	5	6	7	8
Reported Heard	181	113	47	45	34	59	76	55
Recalled Correctly	150	76	32	24	48	45	58	63

UNAIDED POST TEST

Simon and Emmons

SLEEP LEVEL

Subjects	O R	O T	A+ R	A+ T	A R	A T	A- R	A- T	B R	B T	C R	C T	D R	D T	E R	E T
1.	3	4	5	9	1	3	0	3	0	27	0	18	0	10	0	5
2.	2	5	3	3	0	2	2	4	1	38	0	12	0	8	0	1
3.	13	15	3	5	3	5	1	7	0	26	1	21	0	2	0	0
4.	6	6	15	15	12	17	20	23	4	7	0	7	1	3	1	5
5.	2	2	2	2	0	0	2	12	1	14	0	34	0	7	0	7
6.	0	0	5	5	5	13	4	9	0	20	0	22	0	6	0	6
7.	1	1	4	5	10	17	7	13	0	23	0	17	0	2	0	0
8.	1	5	4	6	1	10	2	3	0	45	0	22	0	0	0	0
9.	9	10	3	4	2	6	6	13	1	23	0	24	0	4	0	4
10.	7	10	6	11	5	15	0	4	0	10	0	8	0	3	0	5
11.	0	1	0	2	0	4	3	33	2	28	0	6	0	9	0	0
12.	28	35	12	15	2	5	3	8	0	4	0	4	0	0	0	0
13.	0	1	5	7	6	8	3	13	1	16	0	14	0	15	0	7
14.	0	0	3	4	10	17	5	17	0	14	0	23	0	12	0	5
15.	7	7	10	12	11	12	2	12	1	10	2	12	0	12	0	2
16.	2	4	5	8	6	8	12	25	4	23	0	3	0	1	0	0
17.	5	6	3	5	8	14	5	17	3	24	1	10	0	1	0	0
18.	14	16	4	5	10	15	3	15	1	4	0	17	1	8	0	1
19.	18	21	11	15	4	12	0	7	0	10	1	15	0	4	0	0
20.	3	3	13	16	15	22	2	7	0	16	0	15	0	6	0	0
21.	6	7	0	2	2	5	1	12	0	18	0	29	0	4	0	10

RECOGNIZED BY SUBJECT FROM MULTIPLE-CHOICE TEST

SLEEP LEVEL

Subjects	R	O	T	R	A	T	R	A	T	R	A-	T	R	B	T	R	C	T	R	D	T	R	E	T
1.	4		4	5		9	1		3	0		3	3		27	2		18	3		10	4		5
2.	3		5	3		3	2		2	4		4	10		38	1		12	4		8	0		1
3.	14		15	4		5	4		5	1		7	2		26	3		21	0		2	0		0
*4.	6		6	15		15	15		17	22		23	4		7	1		7	2		3	0		5
5.	2		2	2		2	0		0	4		12	5		14	7		34	2		7	2		7
*6.	0		0	5		5	10		13	5		9	3		20	3		22	1		6	0		6
*7.	1		1	5		5	15		17	8		13	6		23	6		17	0		2	0		0
8.	1		5	4		6	3		10	2		3	9		45	6		22	0		0	0		0
9.	10		10	3		4	4		6	7		13	6		23	5		24	0		4	1		4
10.	10		10	8		11	8		15	0		4	2		10	0		8	1		3	0		5
11.	0		1	0		2	1		4	6		33	7		28	2		6	0		9	0		0
*12.	34		35	13		15	3		5	3		8	1		4	2		4	0		0	0		0
13.	1		1	7		7	6		8	6		13	2		16	1		14	3		15	3		7
14.	0		0	3		4	12		17	9		17	4		14	5		23	2		12	0		5
*15.	7		7	12		12	12		12	6		12	2		10	6		12	5		12	0		2
*16.	3		4	8		8	4		8	15		25	6		23	0		3	0		1	0		0
*17.	5		6	3		5	12		14	7		17	11		24	3		10	0		1	0		0
*18.	16		16	5		5	12		15	13		15	2		4	5		17	3		8	0		1
*19.	19		21	11		15	7		12	2		7	3		10	7		15	0		4	0		0
20.	3		3	13		16	16		22	4		7	4		16	3		15	1		6	0		0
21.	7		7	0		2	2		5	2		12	1		18	8		29	0		4	3		10

* Expected value estimated from control Sub-Group. = 26 %.
Unstarred Ss have expected value of 22 %.

REPORTED HEARD

Sleep Levels

Subjects	O		A+		A		A-		B		C		D		E	
	H	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T
1.	3	4	3	9	0	4	0	3	0	34	0	18	0	11	0	5
2.	5	7	4	4	2	2	0	4	4	43	0	13	0	9	0	1
3.	15	15	8	8	3	6	4	11	1	26	0	21	0	3	0	0
4.	4	5	13	16	7	17	15	24	3	8	0	8	0	4	0	5
5.	2	2	3	3	0	0	5	14	0	16	0	35	0	9	0	7
6.	0	0	4	4	8	14	5	10	0	21	0	23	0	7	0	7
7.	1	1	5	5	15	20	9	14	0	25	0	21	0	2	0	0
8.	5	5	6	6	8	8	2	3	1	46	0	23	0	0	0	0
9.	11	11	4	4	4	6	5	4	3	24	0	25	0	4	0	4
10.	10	10	10	12	14	15	0	4	1	13	0	9	0	3	0	6
11.	0	1	1	2	0	5	3	35	0	29	0	7	0	10	0	0
12.	27	33	14	18	4	5	3	9	0	5	0	5	0	0	0	0
13.	2	2	6	6	9	10	10	13	2	19	0	15	0	15	0	8
14.	0	0	3	4	14	17	10	18	0	14	0	23	0	13	0	5
15.	7	8	14	14	9	12	1	11	0	9	0	12	0	18	0	3
16.	3	3	8	9	7	8	20	29	8	31	0	4	0	2	0	0
17.	7	7	5	5	11	16	9	19	3	25	0	12	0	1	0	0
18.	12	16	6	6	10	19	0	16	0	4	0	19	0	11	0	2
19.	21	23	12	16	7	14	0	8	0	11	0	16	0	5	0	0
20.	3	3	5	15	10	22	3	7	0	18	0	15	0	7	0	0
21.	5	7	0	2	1	5	2	12	0	19	0	32	0	4	0	10

CHI SQUARE TESTS OF PERCENTAGE RECOGNIZED ON

MULTIPLE-CHOICE TEST

SLEEP LEVEL

	O	A	A	A-	B	C	D	E
Scientists:								
% OBSERVED:	95	91	80	63	30	31	30	0
% EXPECTED	24	22	22	25	26	27	30	23
χ^{2*} :	260.5	229.0	21.5	96.5	1.04	.61	.21	2.96
COLLEGE-POLICE:								
% OBSERVED:	87	73	61	35	20	19	20	30
% EXPECTED:	22	20	22	21	23	21	22	25
χ^{2*} :	152.2	122.5	83.3	14.6	1.22	.43	.09	.27

$\chi^2 < 1.38$ is significant above .40 P level.

$\chi^2 > 3.84$ is significant below the .05 P level.

$\chi^2 > 14.06$ is significant below the .00018 P level.

SIGNIFICANCE OF THE DIFFERENCES BETWEEN POPULATIONS
ON PERCENTAGE RECALLED CORRECTLY UNAIDED

	PERCENTAGE AT EACH SLEEP LEVEL							
	0	A+	A	A-	B	C	D	E
SCIENTISTS	84	81	60	43	10	4	5	7
COLLEGE-POLICE	67	62	38	21	2	0	0	0
χ^{2*}	5.74	6.03	8.08	13.70	9.91	4.66	+	+

* $\chi^2 = 3.84$ at .05 level of significance

+ Expected cell frequency less than five.

CHI SQUARE TESTS OF PERCENTAGE RECOGNIZED ON
MULTIPLE-CHOICE TEST AFTER ITEMS CORRECT ON
UNAIDED TEST ARE REMOVED

	SLEEP LEVEL							
	0	A+	A	A-	B	C	D	E
% OBSERVED	59	32	40	25	20	22	22	23
% EXPECTED	24	25	21	22	23	22	23	25
χ^2	19.9*	.90	19.5*	.80	2.45	.03	.08	.04

*Significant below .0001 level of confidence.