SLEEP LEARNING UNDER CONDITIONS OF TRANSFER AND MOTIVATION

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ABSTRACT

The purpose of the experiment was to determine what effect presentation of verbal material during sleep would have on subjects subsequent learning of the same material when awakened. The influence of motivation on sleep was also studied.

Prior to sleep all subjects were given an incentive to pay particular attention to a syllable that would appear in a list of syllables presented to them during sleep. During sleep one group of subjects received a list of syllables and the other received no input. All subjects were immediately awakened and given a free recall test on the syllables.

The results suggest immediate sleep learning gains, and illustrate the importance of the motivational variable in sleep learning experiments.

CHAPTER I

HISTORICAL BACKGROUND

The possibility that man might be able to learn during sleep has interested both scientists and layman, and has provided the stimulus for many attempts to utilize this unique ability. Research on this problem is, however, fraught with difficulties and adequate control of important variables was missing in many of the early studies. The recent development of methods for assessing and monitoring depth of sleep has given fresh impetus to research in this area.

Pre 1955 Studies

In the literature prior to 1955 several researchers reported that learning does occur during sleep (Thurstone 1916; Le Shan 1942, 1943; Elliot 1947; Hedges 1950; Fox and Robbins 1952; Leuba and Bateman 1952; Coyne 1953). Other studies, however, did not corroborate these findings (Hoyt 1953; Stampfle 1953).

In these studies various procedures were used to determine the important criteria as to whether or not the subjects were asleep: (a) the time of night (Fox and Robbins 1952); (b) observation of whether subjects moved (Stampfle 1953, Le Shan 1942, Hoyt 1953); (c) subjects were asked to report whether they had been awakened during the night (Leuba 1942, Stampfle 1953); (d) subjects were asked to press a button whenever they awoke (Coyne 1953, Hoyt 1953); (e) the electroencephalograph was turned on once briefly at the onset of the stimulus input period to determine the subjects depth of sleep (Elliot 1953).

None of these methods was adequate, however, since each failed to determine whether the subject was asleep throughout the stimulus input period. Elliot's method, although not eliminating this criticism, was impressive in that he recognized the value of the electroencephalograph in monitoring the subject's level of sleep.

Upon further examination of these ten studies it is evident that several investigators employed too small a subject sample (Le Shan 1943, Hedges 1950, Leuba and Bateman 1952, Stampfle 1953, Coyne 1953). In each of these studies six or fewer subjects were used. Some investigators failed to use a control group and failed to use subjects as their own controls in these cases (Thurstone 1916, Hedges 1952, Leuba and Bateman 1952). Further, in only five of the ten studies was the data treated statistically (Elliot 1947, Fox and Robbins 1952, Hoyt 1953, Stampfle 1953, Coyne 1953).

On the basis of studies prior to 1955 there appears to be no conclusive evidence that learning during sleep can occur.

Post 1955 Studies

Since 1955, attempts have been made to conduct studies which would avoid some of the methodological problems noted in the earlier studies. In particular, the more recent studies have taken into account the subject's depth of sleep during the presentation of material to be learned. These studies can be grouped into three major categories:

I. Recall and Recognition of Factual Material Presented During Sleep

Emmons and Simon (1956a) continuously monitored the electroencephalograph of subjects during the presentation period so that their levels of sleep during training were always known. The electroencephelograph patterns occurring during the tape-recorded playing of 96 questions and answers to subjects (once each at five minute intervals) throughout the sleep period, were assigned to one of eight sleep levels. It was found that both the percentage of items recalled by the twenty-one subjects, and the percentage of immediate responses, defined as responses "reported heard", bore a direct relationship to the percentage of alpha frequencies (8 - 13 c.p.s.) occurring during stimulus input. The performance of the experimental group, however, did not differ significantly from the untrained control group. Upon completion of this investigation the experimenters designed another study to supplement the first.

In their second experiment, Emmons and Simon (1956b) investigated the possibility of their negative results being due to a failure to give repetative training, i.e. a failure to present the training material more than one time. In this second study the procedure involved a repetition of one syllable nouns as many times as possible during an 8 hour sleeping period to 9 experimental subjects. Again continuous electroencephalograph recordings took place and the presentation of the training material was immediately discontinued upon evidence of alphafrequencies. At the termination of the 8 hours the experimental group, when asked to select words on the training list from a list of 50 words, did not do so significantly better than the control group. These negative findings indicate that the failure to demonstrate sleep learning in the first experiment was not due to insufficient repetition of material.

On the basis of these studies employing recall and recognition methods, Emmons and Simon concluded that sleep learning did not occur.

II. Discrimination During Sleep

In an experiment with one subject, Oswald (1958) observed discrimination between tones of 530, 690 and 790 c.p.s. during sleep. During training sessions several hundred of these tones were presented at varying intervals, the 690 c.p.s. tone being followed by an electric shock and an intense light flash on one-half of the occasions. Upon presenting these tones later during sleep, the middle of 3, the 690 c.p.s. tone evoked a statistically significant greater number of K complexes than the others. K complexes are electroencephalograph waves that occur most frequently during stage C sleep. They consist of 2 or 3 principal components, the first one of which is inconstant: (a) a small sharp wave lasting $\frac{1}{4}$ sec; (b) one or more large slow waves; (c) faster waves of 12 c.p.s. (Oswald 1960).

In a later study complex auditory stimuli of speech were used. Oswald, Taylor and Treisman (1960) looked for evidence of discrimination between names. Prior to sleep the subjects had received instructions to clench their fists in response to their name. Electroencephalograph recordings were taken from the scalp and the electromyogram was recorded from the hand. Oswald concluded that the subject's own name was significantly more likely to provoke an electroencephalograph K complex than other names, even if the subject failed to respond overtly. It was also found that names repeated to a sleeping subject when played in a forward direction were more likely to evoke K complexes than if they were repeated backwards. In both cases the subject's own name represented more meaningful stimuli than either the other name or the subject's name repeated backwards. A significant feature of this study was that only sleep where the electroencephalograph signs were of medium depth sleep to deep sleep were considered in assessing the results.

The question arises whether the discrimination actually took place in sleep. It could be argued that, "....the sheer noise of each stimulus caused an arousal response in which cerebral vigilance was momentarily raised to wakefulness levels, and that during this period information stored in some short-term memory location was examined discriminatively so that, where appropriate, overt responses could subsequently be made. The third phase of the electroencephalograph K complex would seem a likely time for such raised vigilance. However, Oswald's data revealed that, in fact, complex discriminations preceded arousal, at least insofar as it was manifested by the K complex." (Oswald 1960, pg. 48)

A study by Zung and Wilson (1961) required subjects to discriminate between familiar and unfamiliar sounds in stages of sleep ranging from transitional to deep. No significant differences in the subject's response to the content of the stimuli in these stages was found. However, 10 subjects received additional instruction that if they were to awake completely to either one of two specifically designated sounds they would be rewarded with extra payment for their services. These subjects were able to discriminate in all levels of sleep, waking up more frequently to the motivating auditory stimuli. Thus these results indicate that although a person may not discriminate between familiar and unfamiliar sounds under normal sleep conditions in any stage, he can and does discriminate between sounds in all stages of sleep when motivated to do so.

III. Discriminative Conditioning During Sleep

There is evidence (Beh and Barratt 1965) that, as observed by changes in the electroencephalograph, it is not only possible for the human organism to discriminate between stimuli during sleep on the basis of their meaningfulness, but that stimulus significance "built-in" during sleep appears to carry over to the waking state. The first experiment involved "building-in" stimulus meaningfulness during wakefulness by means of conditioning and testing discrimination of the conditioned stimulus during sleep. During a pre-sleep conditioning session experimental subjects received a 500 c.p.s. tone paired with pulsed shock to the forefinger at a "painful" level. A 300 c.p.s. tone was also presented, but it was not followed by shock. The control subjects underwent the same procedure, except that neither of the tones was ever paired with the shock. Results indicated that the experimental group responded to the 500 c.p.s. tone at a significantly higher level than to the 300 c.p.s. tone. They also responded to the 500 c.p.s. tone at a significantly higher rate than did the control group. Upon testing the 2 groups of subjects on the 2 tonal stimuli during stage C of sleep there was a significant difference between the 2 groups on trials to extinction and percentage of conditioned responses.

The second experiment (Beh and Barratt 1965) involved "building-in" stimulus significance during medium depth sleep and testing for discrimination of the conditioned stimulus both during and after sleep. During a medium depth of sleep it was found that a pulsed shock produced a clear K complex without waking the subject. During sleep the 300 c.p.s. tone was paired with shock and it provoked significantly more K complexes than did the 500 c.p.s. tone which was not paired with shock.

Thus, on the basis of this study it would appear that even during lowered levels of vigilance some sort of scanning mechanism operates, separating important from unimportant information. In a session conducted after sleep, subjects were tested for blocking of the alpha rhythm when presented with the 300 c.p.s. tone and the 500 c.p.s. tone. T-tests revealed that in the experimental group spontaneous recovery occurred with conditioned 300 c.p.s. stimuli and not with the 500 c.p.s. tone. Although this study suggests that learning does take place during sleep, results are inconclusive due to there being no control for K complexes occurring simultaneously to the 300 and 500 c.p.s. tone, and there being no control for pure stimulus effects or sensitization.

Introduction To The Problem

So far, studies of sleep learning have failed to establish whether or not such learning is indeed possible. A review of these studies suggests several features which should be more rigorously controlled in such experiments.

Type of material. The auditory sense is the most practical to use for sleep learning (Simon and Emmons, 1955). Aural presentation of types of material to subjects has included music, tones, morse code, foreign language phrases, numbers, questions and answers, paired associates and nonsense syllables. Presentation of verbal items in learning studies is the most common, however (Stevens, 1951).

It is only by introducing nonsense syllables that some control of meaningfulness of verbal stimulus material can be provided. Several of the early investigators realized the advantage of employing nonsense syllables as verbal stimuli in sleep learning studies (Le Shan 1942, Stampfle 1953, Coyne 1953). Only one of the recent investigators presented verbal stimuli and they appeared in the form of questions and answers (Simon and Emmons 1956). The probability of reducing reminiscense from extra experimental sources is greater with nonsense syllables than with many of the other stimuli employed. In addition, presentation of nonsense syllables has the advantage of providing a short stimulus input period where repetition can be maximized. This is particularly important in sleep learning studies as it is sometimes difficult to keep the subject in a constant depth of sleep long enough to present the material. With respect to this latter point, drugs should not be used to induce sleep, (as was the case in the study by Beh and Barratt (1965)), since they could have a detrimental effect on the learning process.

Motivation. There is general agreement that subjects who are motivated to learn, will learn faster than subjects who fail to have this optimal condition. In the only experiment on motivation during sleep that appears in the literature, Zung and Wilson (1961) determined the effectiveness of motivation on complex discrimination learning in all stages of sleep. Although this study suggests the value of motivation as an aid in discriminatory tasks during sleep, it has never been established whether it is a necessary condition. Oswald, Taylor and Treisman (1960) report discriminations occurring without motivation.

It does not appear, however, that any of these tasks were as complex as the tasks involved in Zung and Wilson's study; in fact, motivation may be necessary to bring about more complex discriminations. Similarily, giving a subject an incentive to learn material may facilitate and perhaps be necessary for the waking recall of material presented during sleep. Payment of extra money to subjects as was used in Zung and Wilson's study (1961) appears to provide a subject with a good incentive condition.

Methodology. The extent of retention is affected by the method of measurement (Stevens 1951). The savings method used by Thurstone (1916), was not ideal for his sleep learning study with one group of subjects, however, because there was no way of knowing whether savings was due to consolidation of learning or sleep learning. Also, the subject's learning before and after sleep could not be compared because on both occasions the subject was experiencing different degress of fatigue. A more adequate procedure when employing the savings method would be to use two groups of subjects. Even then, however, if a factor such as the effect of motivation on sleep learning was being investigated, and instructions were such that giving them during the original learning period would render the effect of the variable investigated unmeasurable, another method of measuring retention would be favoured.

The recognition method as used by Simon and Emmons (1955) is not a sensitive test of learning as there is a 50/50 chance that the subject would select each of the words on this test as one which had been introduced during sleep. Also, use of the recognition test together with the recall test would involve interference effects from irrelevant nonsense syllables in the recognition test.

The recall method is especially suitable for the retention of verbal material, and lends itself to a sleep learning experiment. This was used by Simon and Emmons (1955) and involves recording the percentage of material presented during sleep that can be recalled by each subject. Although serial anticipation is more sensitive than free-recall, it is not suitable to the present study, since it would require subjects to learn the list in order and slight learning effects as are frequently obtained in sleep learning studies may not be manifested.

EEG methods. The EEG record is both a valid and reliable criterion of wakefulness and sleep in the normal adult (Simon and Emmons 1954). In addition it offers other advantages:

1) Recording the EEG does not alter the sleep state.
2) It minimizes individual differences in that objective records of sleep can immediately be interpreted at the time they are being made.
3) Its records appear to vary concomitantly with levels of consciousness and are relatively unaffected by other extraneous conditions.

Five distinct levels have been identified by a number of investigators. For the purpose of the present study sleep is defined according to Loomis' classification (Oswald, 1962, pp. 36-41) and in terms of the following characteristic:

Stage A - drowsiness. Some alpha is still present.

Stage B - light sleep. Alpha is lost. Low voltage waves of 4 - 6 c.p.s. usually appear and become greater in amplitude as sleep deepens.

Stage C - medium depth sleep. Waves vary from 1 to 6 c.p.s. Spindles of 12-15 c.p.s. occur, but sometimes are as low as 8 - 9 c.p.s.

Stage D - deep sleep. Spindle activity of stage C is present, but is superimposed on a background of slow waves of 1 - 2 c.p.s. and higher voltage than the activity of stage C.

Stage E - spindle activity is less obvious and the record is dominated by high-voltage slow waves at about .5 - 1 c.p.s.

Presentation of material to a subject only during stage C of sleep or deeper would ensure that the subject was asleep during the stimulus input period. This procedure was employed by recent investigators (Oswald 1958; Beh and Barratt 1965).

<u>K complexes</u>. It has been shown that an EEG K complex is most often evoked by stimuli which have personal significance for the sleeping individual than by those lacking such significance (Oswald 1958; Beh and Barratt 1965). It is likely that such personal significance could be obtained by providing a subject with a special incentive con-

dition attached to one of the nonsense syllables which he is to learn while asleep. Syllables with no special incentive or motivating conditions attached to them are considered to be lacking in significance and to be neutral in meaningfulness.

The present study is designed with the intention of incorporating the above features in an effort to eliminate some of the methodological inadequacies encountered in other sleep learning studies. This investigation is an attempt to examine three hypotheses.

1) If nonsense syllables are presented during sleep they will be recalled better than syllables which have not been presented during sleep.

2) If, prior to sleep, a subject is given an incentive to learn certain syllables to be presented during sleep, these syllables will be recalled better than other syllables which are presented during sleep, but which have had no incentive condition attached to them.

3) The number of EEG K complexes evoked during sleep will be greater for syllables that the subject has been given an incentive to learn, and greater also for syllables which were learned quickly.

CHAPTER II

METHOD

The experiment was divided into 3 phases:

Phase I (pre-sleep)

Prior to sleep all Ss were instructed that they would be given extra money if they paid special attention to a particular nonsense syllable, which would appear immediately following a cue word in a list of syllables that would be read to them during sleep.

Phase II (sleep)

During Stage C of sleep or deeper (Loomis' classification) a list of nonsense syllables (list I) was read to the experimental group (E) 10 times. The control group (C) received no input.

Phase III (post-sleep)

Ss were awakened immediately following Phase 2. During Phase 3, Ss learned a list of 8 nonsense syllables (List I') to a criterion of 2 successful reproductions. Free recall of syllables was allowed between each presentation of the list. For Group E the design should facilitate transfer.

Subjects

The Ss were 20 female nurses, 10 of whom were assigned randomly to Group E and 10 to Group C. They were 19 to 21 years of age and of the same educational level (senior matriculation and 1 to 3 years of nurses' training). They were working night shifts (midnight - 8 a.m.) and were accustomed to sleeping during the time of day the experiment was conducted. All Ss who volunteered for the experiment were allowed to participate except those who did not have a persistent waking occipital alpha rhythm. Each of the Ss were paid $4 for the services following the experiment.

Apparatus

The Ss slept in a sound-proofed, air-conditioned room, next to the E's room, which contained an electroencephalograph and tape recorder. EEG electrodes were attached with collodion to each S, bilaterally, on the frontal and occipital areas of the skull. The electrodes were arranged to allow relatively free movement during sleep. Four monopolar EEG recordings were made from each S using the 6 channel type III, Offner Portable EEG. The occipital waves were monitored during Phase 2 to determine the Ss level of sleep, and the frontal waves were monitored to detect K complexes. The syllables to be learned were presented by tape recorder and played through a speaker inside the Ss room. A 2-way intercommunication system allowed the E to communicate with the S.

Materials

The nonsense syllables presented to the Ss were standardized on student nurses drawn from the same population as the Ss participating in the sleep study. All were classed as being of 70% associative value (see Appendix A).

List I, presented to Group E during Phase 2, consisted of 9 syllables:

MIG PEZ DUF "GUD" HIB ZIM MEV YIT POB

For 5 Ss in the E Group "GUD" appeared between syllables in the 3rd and 4th position, and for the other 5 Ss it appeared between syllables in the 5th and 6th positions of the list. The incentive syllables following the cue "GUD", and a neutral syllable (which the S had not been given an incentive to learn), both occupied positions 4 and 6 of the list, so that the effects of order versus incentive could be counterbalanced.

List I', presented to Group E and Group C during Phase 3, was identical with List I, except that the cue syllable "GUD" was omitted.

All syllables in both lists (Lists I and I') were pretaped by an individual naive as to the experimental design. The output was controlled by having the reciter of the syllables a fixed distance from the microphone, and the tape recorder volume set at a constant level. To control for the variation of meaningfulness, the position of each syllable in the list was randomly determined for each S in the E and C group. For group E, the design would facilitate transfer if learning occurred.

Procedure

Phase I. Each S was permitted to go to sleep at approximately 9 a.m., after they were instructed and the EEG electrodes had been applied.

The following instructions were read to the Ss: "A list of nonsense syllables will be repeated to you during sleep. In this list the syllable 'GUD' will occur a number of times. If you pay particular attention to the syllable immediately following 'GUD', you will receive extra money for your services. You will be able to sleep until the first part of the experiment is over. Alright? Remember, you are to pay particular attention to the syllable immediately following 'GUD'."

Phase II. Following the instruction the Ss depth of sleep was consistantly monitored, and when a medium depth of sleep was reached (i.e., Stage C - Loomis' classification) List I, was presented to the E group. The C group received no input. The syllables in List I were repeated in a fixed order to each experimental S 10 times, and at time intervals between syllables varying from 1.5 to 4.5 seconds. The randomized time intervals were introduced to minimize EEG habituation effects which Oswald had observed when stimuli were repeated at fixed time intervals during sleep (Oswald 1962). As each syllable was read the EEG record was marked with a vertical line through that point, and the first letter of each syllable was written above the line for later identification.

If the S passed into stage B (Loomis' classification) during the presentation of syllables, the tape was stopped and started again only when the S re-entered Stage C sleep. If, however, the S wakened fully or displayed a stage A record (Loomis' classification) the list was started from the beginning when the S resumed stage C of sleep. It was felt that the interference effects from the waking state might disrupt learning.

Phase III. Immediately following the presentation of the list in Phase II, each S was wakened by the E calling her name. The S was then instructed as follows: "Get into a comfortable position with your back to me and you will hear a list of nonsense syllables played from the tape recorder a number of times. After each repetition of the list, I shall say 'start', and I would like you to tell me the ones you remember. These syllables need not be recalled in any particular sequence. Just repeat all the syllables you remember." The syllables in the list presented to the Ss (List I') were repeated at 2 sec. intervals and the S was given a maximum of 2 minutes to recall the syllables she remembered after each repetition of the list. When performance reached a criterion of 2 perfect reproductions, phase III was terminated.

CHAPTER III

RESULTS

Effects of Sleep Presentation On Learning

Serial position curves were obtained by determining the average number of errors for syllables presented at each position in List I' during trials to criterion in each group (Fig. I). Errors are defined as incorrect reproductions or omissions of a syllable. The learning criterion was two perfect repetitions of List I'. As Fig. I indicates, the sleep learning group made fewer errors than did the control group.

Fig. I inserted here

Table 1 shows that analysis of the number of errors to criterion on list I' reveals no significant difference between group E receiving sleep presentation, and group C receiving no input during sleep. Significant within subject variability among serial positions appears to be a result of a serial position effect.

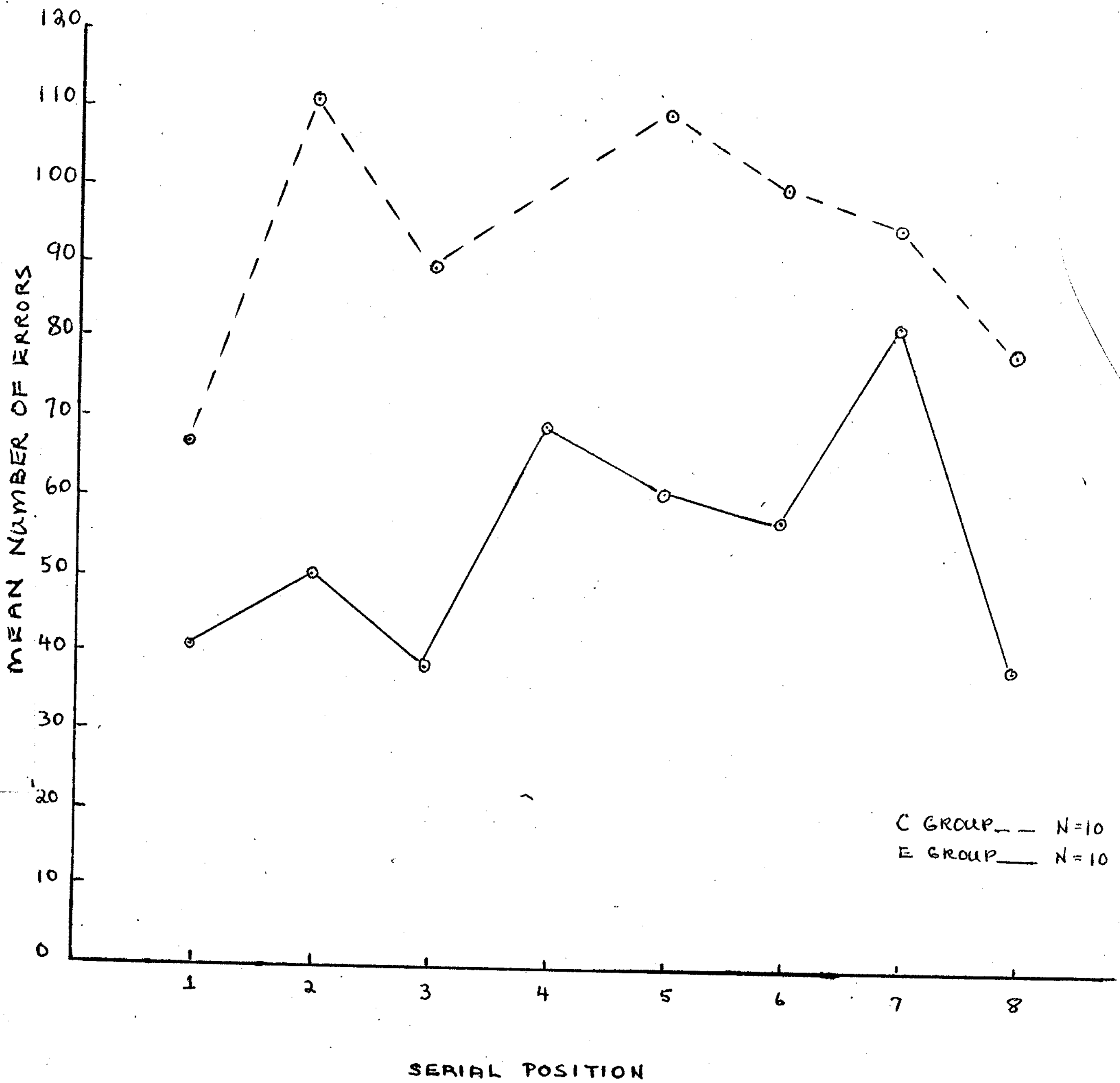

Fig. I. SERIAL LEARNING CURVES BASED ON X NO. OF ERRORS TO CRITERION ON LIST I' FOR E AND C GROUPS

TABLE 1

ANALYSIS OF THE NUMBER OF ERRORS MADE AT EACH SERIAL POSITION ON LIST I' FOR THE E AND C GROUPS

Source	df	ms	F
Between E and C Ss	19		
Sleep presentation	1	693.05	3.6531
Error between	18	189.71	
Within Ss	140		
Serial position	7	40.2	2.583*
Serial positions X sleep presentation	7	13.042	.788
Error within cells	126	16.533	

* $p < .05$

Results of additional between-group analysis appear below in Table 2. Performance of the E and C groups compared on measures made during total trials to criterion on list I' revealed a significant difference in number of incorrect associations between ordered stimulus pairs. Trials to criterion are defined as the number of trials to and including two correct reproductions of list I'. Incorrect associations are defined as two syllables which occur in sequence in list I', but which are reproduced in the wrong order or omitted entirely from list I' on recall. In reviewing the data, it was found that the E group showed an obvious gain on the first few trials of recall. Statistical analysis of number of errors and number of incorrect associations on only the first five recall trials revealed that this gain was significantly greater for the E group.

TABLE 2

COMPARISON OF THE SLEEP PRESENTATION GROUP AND THE CONTROL GROUP ON LEARNING LIST I'

	MEANS		VARIANCE			
Measure	Exptl. Group	Control Group	E Group	C Group	t	p
Trials to criterion	15.3	20.6	34.23	82.26	1.5	$>.05$
Number of incorrect associations to criterion	77.3	99.5	143.34	372.94	3.1	$<.05$
Number of errors on the first five trials	12.5	20.8	53.24	40.05	2.7	$<.05$
Number of incorrect associations on the first five trials	27.6	32.3	59.80	7.57	3.2	$<.05$

Graphical representation of the number of errors obtained on the first five trials appears in Fig. II.

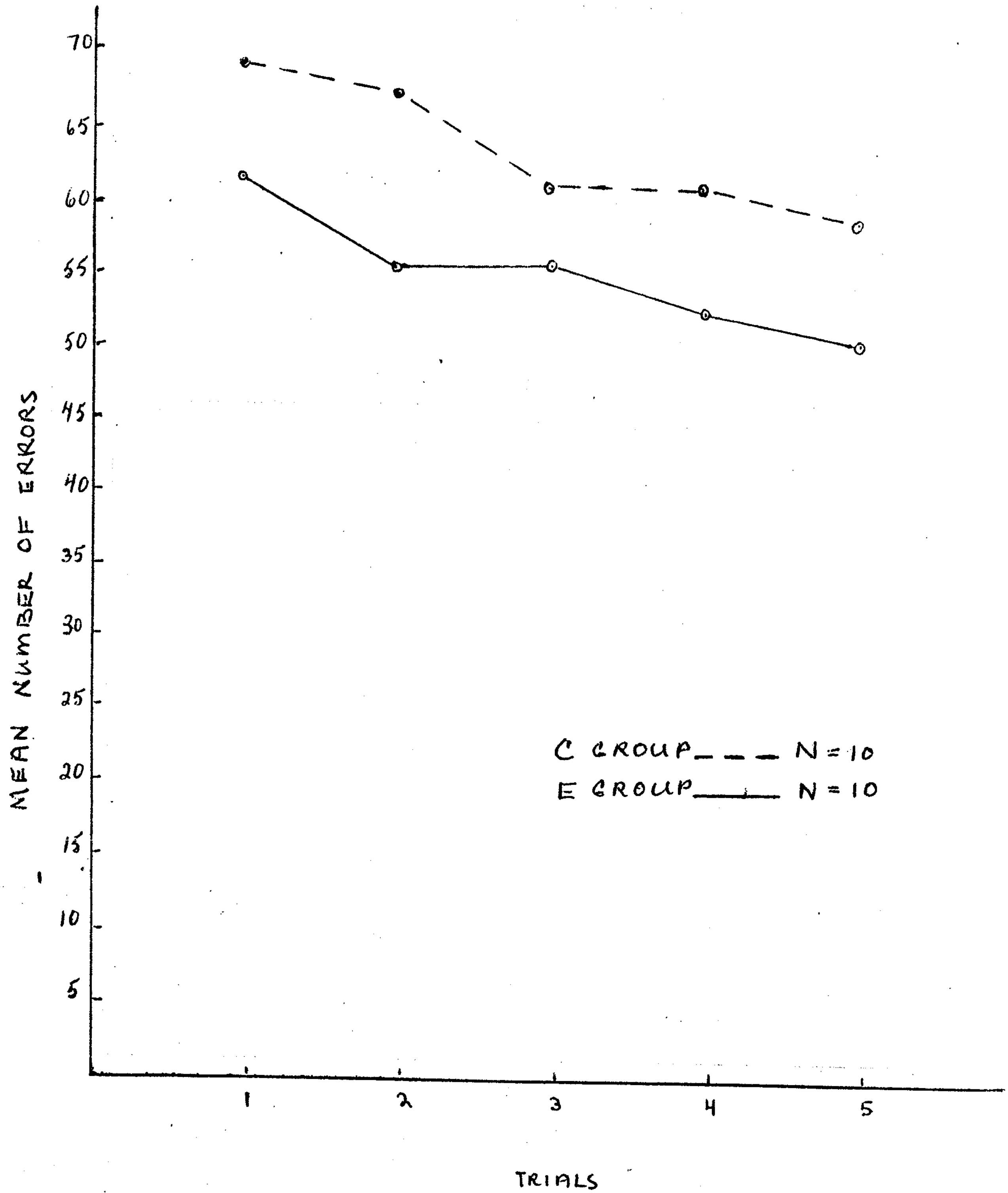

Fig. II. NUMBER OF ERRORS FOR GROUPS E AND C ON THE FIRST 5 POST-SLEEP REPETITIONS OF LIST I'

Effects of Incentive Manipulation on Sleep Learning

Two measures were employed to compare learning of the neutral (NEU) and incentive (INC) syllables on list I' within the sleep presentation group: (a) number of errors on the NEU and INC syllables to two successive correct reproductions of the entire list and (b) number of errors to two successive correct reproductions of only the NEU and INC syllable. The two measures yield discrepant results. The former indicates a significant difference in the number of errors on the NEU and INC syllables, in favour of the INC syllable; the latter, no significant difference in the number of errors on the NEU and INC syllables (Table 3). Using a more powerful test, an attempt to reduce error variance was made by considering serial position of the syllables in an analysis of variance. The analysis yielded the serial position of the syllables insignificant for each of the above measures ($F = .8$, p $.05$; $F = .49$, p $.05$ respectively).

TABLE 3

MEAN ERRORS ON THE NEUTRAL AND INCENTIVE SYLLABLES MADE BY SLEEP PRESENTATION GROUP

	MEANS		VARIANCE			
Criterion Measure	INC Syllable	Control Syllable	$\bar{D}$	$S_{\bar{D}}$*	t	p
Two successive correct reproductions of list I'	4.4	8.2	3.8	1.34	2.8	$<.05$
Two successive correct reproductions of NEU and INC syllables	3.8	5.3	1.5	2.26	.66	$>.05$

* for grouped data

Graphical representation of the number of errors obtained on the NEU and INC syllables during trials to criterion for list I' appears in Fig. III. While statistical analysis of the effects of incentive manipulation were inconclusive, examination of the figural representation of the data reveals differences in learning the NEU and INC syllables suggestive of a slight facilitating effect of incentive manipulation.

EEG K Complexes

EEG records were studied for the existence of K complexes. We could not observe any clear relationship between the occurrence of K complexes and presentation of stimuli or speed of learning. Identification of K complexes and their clear separation from other changes in the characteristics of the EEG was accomplished in only a few subjects. In the remainder, evidence for K complexes was not sufficient to include such analysis in the results.

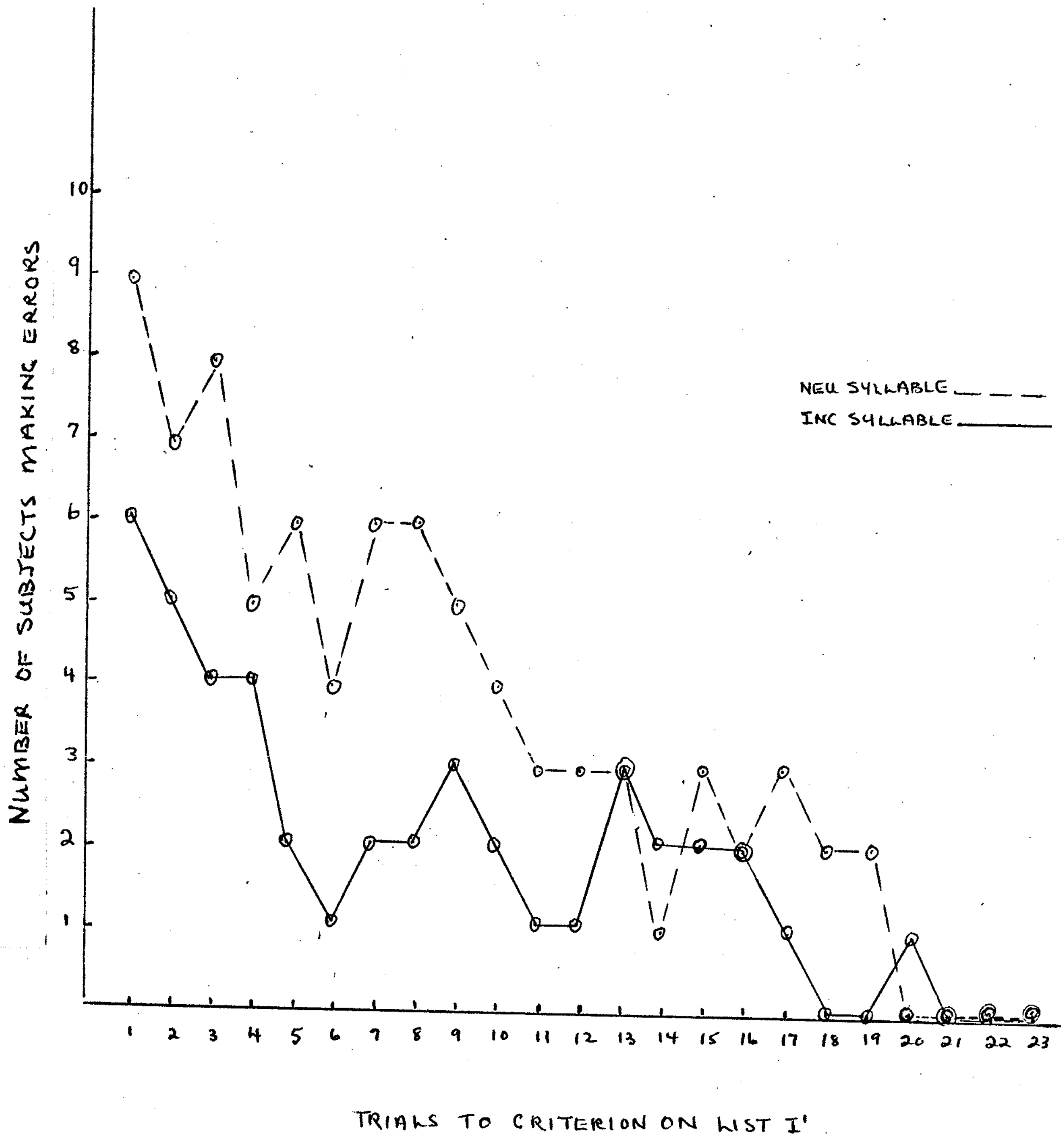

FIG. III. NUMBER OF ERRORS ON LIST I' FOR NEU. AND INC. SYLLABLES WITHIN GROUP E.

CHAPTER IV

DISCUSSION OF RESULTS

The experimental and control groups in this study did not differ in overall trials required to learn the nonsense syllables to criterion, although the sleep presentation group made fewer errors at each serial position in the test list. The presentation of material during sleep did, however, seem to have a facilitating effect on those learning trials which occurred immediately following sleep. This was indicated by the significant group differences in error scores on the first five test trials which followed the sudden awakening of the subjects. The hypothesis that learning during sleep occurs is thus partially supported.

These significant group differences might be explained as follows. The experimental subjects had an initial advantage in learning list I' because of the stimuli introduced to them during sleep; the control subjects had no such advantage because they received no input during sleep. The improved performance of the sleep presentation subjects during the initial 5 trials of recall appears to be a result of facilitation or transfer from the stimuli introduced during sleep to the responses elicited during recall on the post-sleep list I'.

At the end of the initial 5 recall trials the sleep presentation subjects were in essentially the same position as the control subjects. This result appears to be analogous to subjects being able to recall dreams only if awakened immediately after they have been dreaming (Barrien, 1930). As the time increases between dreaming and the recall of dreams, interference which affects the retention of the dream becomes greater. Similarily in sleep learning studies it would appear that as the period increases between the introduction of stimuli during sleep and the recall of these stimuli, interference, which would affect retention of the syllables, would become greater.

The question of whether one group started with an initial advantage over the other as a result of not having been asleep during the stimulus presentation was rejected, since the level of sleep for all subjects was closely monitored and was never lighter than stage C during the stimulus input period.

The results obtained in this study suggest that learning gains during sleep may be of short duration. This finding can only be regarded as tentative, however, until further studies have been made.

The results of the experiment are inconclusive with respect to the hypothesis that motivation will have a beneficial effect on learning during sleep. The effectiveness of incentive manipulation on the sleep presentation subjects as assessed by the number of errors to two successive correct reproductions of the neutral and incentive syllables yielded insignificant results. The number of errors made on the neutral and incentive syllables, while learning the entire list to a criterion of two successive correct reproductions, yielded a significant t-ratio.

While the first method is more precise for measuring the effects of motivation, the second method has the advantage of having less error variance than the first method. Also 2 perfect reproductions of the neutral and incentive syllable does not appear to provide as stringent a criterion measure of learning as does the second method. As shown by graphical representation (Fig. III), once the neutral and incentive syllable was reproduced correctly for two successive trials it was frequently missed, i.e. not reproduced correctly or omitted on subsequent trials. Although the difference using the first method is not significant, the difference is in favour of learning the incentive syllable, and is not inconsistent with results obtained using the second method. Thus, even though the finding of the present study is inconclusive, it does suggest that motivation has a facilitating effect on learning during sleep. This finding is supported by Zung and Williams (1961).

The present investigation was limited in that it based the effectiveness of motivation during sleep on a comparison of learning two syllables; in order to find out conclusively if motivation facilitates sleep learning more data on the neutral and incentive conditions should be obtained. This factor should be considered in future experiments.

The hypothesis that more EEG K complexes will be associated with incentive than neutral syllables, and with syllables that the subject learns quickly than those he takes longer to learn, was not testable on the basis of the data obtained in this experiment.

Detectable K complexes only occurred in the EEG records of a few subjects, thus rendering the data sample too small for analysis. Even in these records the K complexes were not evolved in a pattern systematically related to stimulus presentation. The reason that K complexes did not occur in a greater proportion of the subjects EEG records could in part, be due to the methods employed in this study. Introduction of stimuli was not restricted to stage C of sleep. In both Oswald's study (1961) and Beh and Barrat's study (1965) where EEG K complexes were evoked, the subjects were in stage C of sleep. Oswald stated that K complexes were evoked most readily in this stage and could be expected to occur only occasionally in stage D of sleep (Oswald 1960). Loomis (1937) reports K complexes to be a phenomenon characteristic of stage C of sleep. In the present study subjects were frequently in stage D during the stimulus input period. While this was not an ideal condition for the evokation of K complexes, it did ensure that Ss were asleep. If stimuli were introduced during this level of sleep in preference to stage C, lightening of sleep to a stage B or A level was less likely to occur.

The present study further suggests considerable individual variability in the occurrence of K complexes. When stimuli were introduced to some individuals during stage C there was no evidence of even a single K complex being evoked. In the case of two subjects where K was elicited, it occurred frequently. It is recommended that this factor be investigated in future research and that investigation on the K complex be carried out only during stage C of sleep.

CHAPTER V

SUMMARY AND CONCLUSIONS

An experiment was conducted to determine what effect presentation of verbal material during sleep would have on Ss subsequent learning of the same material when awakened. The influence of motivation on sleep learning was also studied.

Prior to sleep subjects were given an incentive to pay special attention to a syllable following a cue word in a list of syllables that would be read to them during sleep. During stage C of sleep or deeper, a list of nonsense syllables was presented to the E group. The C group received no stimulus input during sleep. Subjects were awakened immediately after the presentation of syllables. The post-sleep phase involved presentation and free recall of a list of syllables identical with the sleep list, but minus the cue word.

The results revealed:

(a) The sleep presentation group had a significant savings advantage during the first few trials of learning the post-sleep list. This is suggestive of immediate sleep learning gains. When overall trials to criterion of the list was considered, no significant sleep learning gains were detected, although between group differences were in favour of the sleep presentation group.

(b) The results of incentive manipulation on sleep learning indicated that the incentive syllable was learned faster than the neutral, non-incentive syllable. These results were suggestive rather than conclusive, but they illustrate the importance of the motivational variable in sleep learning experiments.

(c) No clear relationship between K complexes and stimulus presentation on speed of learning were observed.

APPENDIX A

SELECTION OF NONSENSE SYLLABLES

The 9 nonsense syllables presented to the Ss in this study (GUD, MIG, DUF, MEV, PEZ, YIT, POB, ZIM, HIB) were selected from a list of 105 nonsense syllables which appear in Steven's Handbook (pages 541 - 551). (ZON, JOM, VUC, MIG, NAF, PID, ZEL, REZ, TEG, KEC, WUC, WOY, JOD, NID, BUP, SOZ, ZAN, MAF, GUD, TOJ, BAZ, KUV, VAJ, YOG, PUV, NOF, WEG, YAN, DIJ, LIX, MEB, VUS, WEG, DAC, CAX, POB, ZIM, FUJ, SIF, YIT, MUP, DIB, VOD, KED, DUF, HAX, BIV, FIK, LUW, FAH, TIS, VOG, HEF, PIJ, CIB, PEM, SOJ, NAL, XIM, MEV, LAH, RUV, SUX, KEW, LUD, HAJ, COK, HIB, FOC, VAM, WAF, CIM, NOG, YIR, TIH, WAB, HUK, FUG, POW, FAX, POB, TOF, MIC, WEK, MUB, ZUN, LUH, WAP, YOG, DIB, VUS, PEF, RUC, LIX, ZIT, GOG, CEY, GEQ, QAY, CIH, PID, YUM, PEZ, VED, GEP.) The associative value of each of these syllables was obtained by presenting them orally to a class of 98 student nurses, drawn from the same population as the Ss participating in the sleep study. The following instructions were given to the students. "This is an exercise to find out how many associations you have to certain combinations of letters in the alphabet. You will hear a list of 105 three-letter syllables read from the tape recorder at 4 second intervals and you are to write down beside each of the 105 syllables what you associate with it, i.e. what the syllable means to you.

(e.g. Take the item 'TEX'. The syllable probably makes you think of 'Texas', 'Textbook', 'Cowboys', 'wide open spaces', 'oil', 'Texaco', 'gasoline', 'Texan', 'millionaire', etc..)

It is important that you do not produce chain associations. (e.g. Lemur - 'Dorothy', 'hope', 'faith', 'charity'. Here your response 'hope' acts as a stimulus for the response 'faith', which in turn acts as a stimulus for the response 'charity'.)

Now, are there any questions before we start? Remember you will hear 105 syllables played from the tape recorder. After the first syllable has been heard you are to write down beside #1 what the syllable means to you, in the 4 seconds allotted. Do the same for syllable #2, etc. until we reach syllable 105."

The associative value of the syllables was obtained by Glaze's method of dividing total actual responses by total possible responses. That is, the percentage of S's reporting an association was determined for each syllable separately. The original sample of 98 Ss was reduced to 73; 25 were rejected because they made recording errors on the test. Those syllables which had 70% associative value were selected to comprise list I in the sleep study. Seventy per cent was chosen since it was the lowest value for the 105 syllables at which 9 syllables of the same association could be obtained.

APPENDIX B

EXPERIMENTAL DATA

TABLE i

NUMBER OF ERRORS OBTAINED BY THE
SLEEP PRESENTATION GROUP AND THE CONTROL GROUP
AT EACH OF THE 8 SYLLABLE POSITIONS IN LIST I'

SUBJECT	1	2	3	4	5	6	7	8
	POSITION OF SYLLABLES IN LIST I'							
Group E								
#1	1	2	2	8	5	1	6	3
#2	0	0	1	1	2	1	1	0
#3	4	5	1	6	10	9	2	8
#4	4	1	0	7	3	1	5	6
#5	1	1	0	0	2	5	5	4
#6	11	10	5	1	4	10	6	0
#7	2	10	7	12	11	8	19	1
#8	8	14	14	18	6	9	12	6
#9	7	5	6	7	12	4	11	4
#10	3	2	2	9	6	9	15	6
Group C								
#1	9	4	2	12	13	8	12	5
#2	1	11	16	16	17	18	19	12
#3	4	12	3	5	8	7	10	11
#4	6	7	4	17	17	17	13	13
#5	3	18	14	7	17	16	3	3
#6	5	5	7	4	4	3	5	6
#7	29	35	29	28	21	26	16	15
#8	5	11	7	4	4	3	6	6
#9	0	5	3	1	3	1	6	0
#10	5	4	5	11	11	7	5	8

TABLE ii

TRIALS TO CRITERION ON LIST I' FOR EACH E & C S.

Group E N=10	Group C N= 10
12	22
04	26
15	18
16	24
08	25
17	11
23	40
21	17
19	8
18	15
15.3	20.6

E vs C $p. > .05$

TABLE iii

INCORRECT ASSOCIATIONS ON LIST I' FOR EACH E & C S.

Group E N=10	Group C N=10
50	98
9	142
69	88
94	114
23	117
94	57
120	212
126	70
110	35
78	62
77.3	99.5

E vs C $p. < .05$

TABLE iv

TOTAL NUMBER OF ERRORS FOR EACH S IN THE E & C GROUP ON THE FIRST 5 REPETITIONS OF LIST I'

Group E N= 10	Group C N= 10
18	25
6	27
26	24
15	28
15	22
18	32
20	40
33	25
18	18
23	34
19.2	27.5

E vs C $p. < .05$

TABLE v

NUMBER OF ERRORS ON THE NEU AND INC SYLLABLES TO 2 SUCCESSIVE CORRECT REPRODUCTIONS OF LIST I'

E Subject	INC Syllable	NEU Syllable
1	1	8
2	1	1
3	6	9
4	1	7
5	0	5
6	1	10
7	12	8
8	9	18
9	4	7
10	9	9
$\bar{X}$ Errors	4.4	8.2

Table vi

NUMBER OF ERRORS TO 2 SUCCESSIVE CORRECT REPRODUCTIONS OF THE NEU AND INC SYLLABLE ON LIST I'

E Subject	INC Syllable	NEU Syllable
1	1	5
2	1	1
3	5	10
4	0	6
5	0	6
6	0	1
7	14	3
8	5	19
9	3	0
10	9	2
$\bar{X}$ Errors	3.8	5.3

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