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ABSTRACT

This experiment tested the hypothesis that paired-associate learning accompanied by high arousal should lead to stronger permanent memory and weaker immediate memory than paired-associate learning accompanied by low arousal. During continuous recording of skin resistance and heart rate as measures of arousal, 32 Ss were given a one-trial, eight-item paired-associate task consisting of 0% association value nonsense syllables as stimulus terms and the digits 2 to 9 as response terms. The Ss were tested for recall following either a 2.87-min. or 24-hr. interval. The skin resistance was used as a measure of arousal, the results confirmed the hypothesis. Arousal level as defined by heart rate, however, showed no significant effects on retention. The manipulation of arousal was undertaken through the use of 75 db. white noise as has been done in previous experiments. The present research failed to show any significant effects of white noise during learning on either recall or physiological measures. (Author)

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Technical Report No. 184

THE RELATIONSHIP OF AROUSAL DURING LEARNING TO SHORT- AND LONG-TERM RETENTION EMPLOYING TWO INDICES OF AROUSAL

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Report from the Project on Motivation and Individual Differences in Learning and Memory

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Statement of Focus

The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the process of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to tl · improvement of educational practices.

This Technical Report is from the Motivation and Individual Differences in Learning and Retention Project in Program 1, Conditions and Processes of Learning. General objectives of the Program are to generate knowledge about concept learning and cognitive skills, to synthesize existing knowledge and develop general taxonomies, models, or theories of cognitive learning, and to utilize the knowledge in the development of curriculum materials and procedures. Contributing to these Program objectives, this project has these objectives: to determine the developmental role of individual differences and motivation-attention in the learning and memory process and to ascertain at what age certain individual differences become important in learning and memory and at what age certain motivation-retention relationships emerge; to develop a theory of individual differences and motivation in learning and memory; and to develop practical means, based on the knowledge generated by the research, as well as synthesized from other sources, to maximize the retention of verbal material.

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Abstract

This experiment tested the hypothesis that paired-associate learning accompanied by high arousal should lead to stronger permanent memory and weaker immediate memory than paired-associate learning accompanied by low arousal. During continuous recording of skin resistance and heart rate as measures of arousal, 32 *Ss* were given a one-trial, eight-item paired-associate task consisting of 0% association value nonsense syllables as stimulus terms and the digits 2 to 9 as response terms. The *Ss* were tested for recall following either a 2.87-min. or 24-hr. interval. When skin resistance was used as a measure of arousal, the results confirmed the hypothesis. There was a significant interaction ($p <$ .001) between arousal level and time of recall under conditions of high- and low-arousal as defined by amount of galvanic skin response deflection. Retention for material learned under low arousal decreased rapidly over 24 hours. High-arousal learning, on the other hand, showed a marked reminiscence effect. Arousal level as defined by heart rate, however, showed no significant effects on retention.

The manipulation of arousal was undertaken through the use of 75 db. white noise as has been done in previous experiments. The present research failed to show any significant effects of white noise during learning on either recall or physiological measures.

I
Introduction

Within the past 15 years electrophysiological research has brought to light many new facts about arousal and retention. Psychophysiological studies concerned with verbal learning have indicated that verbal learning as opposed to a resting or control condition is characterized by increased activity in the electrocardiogram (EKG), galvanic skin response (GSR), electromyogram (EMG), and electroencephalogram (EEG) (Andreassi & Whalen, 1967; Eason, Harter, & Storm, 1964; Thompson & Obrist, 1964). After learning is completed or during overlearning, physiological levels return toward control levels (Andreassi & Whalen, 1967; Eason, Harter, & Storm, 1964; Thompson & Thompson, 1965). There is also evidence that maximum physiological changes occur during the active phase of learning. Support for this conclusion comes from Thompson and Obrist (1964) who found maximal EEG arousal activity occurring at a time when correct responses for serial learning material are first elicited, from Kintsch (1965) who found GSR to be at maximum strength during an intermediate stage in paired-associate (PA) learning before items had entered a reliable learning state, and from Brown's (1937) report that GSR deflections associated with those trials in which the *S*s made the wrong response or no anticipation were greater factors in the correlation between total magnitude of GSR per syllable and the order of learning than were the responses associated with those items in which the correct anticipation was made. An experiment by Freedman, Hafer, and Daniel (1966) also suggested that the increased arousal associated with learning and the following reduction of arousal after learning is not due solely to a reduction of anxiety or habituation to the stimuli but is indeed associated with learning. The authors found systematic EEG changes in the PA learning group occurring *in advance* of the behavioral changes indicated by response probability. That is, arousal as indicated by alpha EEG desynchronization decreased before the *S* began to choose the right response.

Quite conceivably, these physiological changes reflect variations in attention during the course of learning. When *S*s are attending to the material to be memorized there is a corresponding increase in physiological activity. When *S*s are not attending either because they have already learned the material or are not yet prepared to, the physiological indicants of activation are not as high as when learning is taking place.

Although it seems relatively well established that physiological indicants of activation are maximal during the active phase of learning, the question, and issue, remains: What is the most optimal physiological level for learning? Several studies have dealt with the relationship between physiological activation level and the efficiency of memorizing verbal material. Brown (1937) considered the relation between gross skin resistance levels and the speed of learning nonsense syllables. A correlation of +.25 ± .14 (N = 18, N.S.) was obtained between the resistance at the beginning of the learning situation and the efficiency of learning as measured by the number of trials required for one successful completion. A correlation of +.57 ± .10 ($N = 18$, $p < .01$) was obtained between the resistance level at the end of the experiment and the number of trials required to complete the problem. In other words, the greater the arousal, especially at the end of the experiment, the faster the serial learning.

Furth and Richart (1961), employing 40 *S*s, measured skin conductance and pulse pressure from Trial 1 to 10 on a serial learning task. From Trial 1 to 10, there was a steadily increasing average learning score and a steady rise of average conductance level for the group as a whole ($r = +.92, p < .001$). Conversely, pulse pressure diminished and correlated negatively with average learning score ($r = -.92, p < .001$). A low pulse pressure is generally associated with arousal (Rudolf, 1955). It should be noted that by the tenth trial none of the *S*s used in the data analysis had yet reached criterion.

Composite scores of pulse pressure and skin conductance level indicated that a high initial activation level was significantly associated with better serial learning. Similarly, a high extreme composite score during serial learning was associated with significantly better serial learning as compared to low composite scores. It is interesting to note that only the composite scores, not pulse pressure or skin conductance alone, yielded significant results.

Berry (1962) measured skin conductance during exposure to 30 PA's and found that recall was highest in *S*s with intermediate conductance levels. Thus the data in Berry's study described the relationship between arousal and performance as an inverted U-shaped curve.

Kleinsmith, Kaplan, and Tarte (1963) replicated Berry's design using 30 PAs. For the 6-min. recall, which was used by Berry, the relationship between recall and conductance was again described by an inverted U-shaped curve. But, for *S*s tested for 1-week retention, the relationship between recall score and log conductance level was linear ($r = +.54, p < .01$).

These results have been interpreted as support for the notion suggested by Hebb (1949) that learning involves a consolidation process based on a dual physiological process, i.e., reverberation of neural circuits comprising the memory trace, followed by organic change between nerve cells. Under conditions of low arousal, relatively little nonspecific neural activity will be available to support the reverberating trace which will result in little consolidation and poor long-term retention. Under conditions of high arousal, the increased nonspecific neural activity will result in more reverberation and long-term retention will therefore be better. While this increased reverberation is taking place, however, recall may be poorer because the memory trace is relatively inaccessible to the organism. Thus at short-term retention, recall of those items learned under high arousal should be inferior to recall of those items learned under low arousal.

Other studies (Batten, 1967; Kleinsmith & Kaplan, 1963, 1964; Levonian, 1967; Walker & Tarte, 1963) have continued to reveal an interaction between arousal level and time of recall. Learning under conditions of low arousal has demonstrated a typical forgetting curve; immediate recall is excellent but retention decreases rapidly with time. High-arousal learning, on the other hand, has demonstrated reminiscence or a marked resistance to forgetting.

In a later experiment, Kleinsmith and Kaplan (1963) gave six groups a single learning trial on eight PA's while recording skin resistance as a measure of arousal. The stimulus words *kiss*, *rape*, *vomit*, *exam*, *dance*, *money*, *love*, and *swim* were expected to produce different levels of arousal. The response items were single digits from 2 to 9. The different groups were then tested for recall at intervals of 2 min., 20 min., 45 min., 1 day, and 1 week. A color-naming task was used to separate the arousal effects from one stimulus slide to the next. Any drop in the *S*'s skin resistance which occurred within 4 sec. of presentation of a given word was considered an arousal deflection. Each of the *S*'s eight GSR deflections were then ranked. The three highest deflections were designated as high-arousal learning and the three lowest as low-arousal learning. Thus two items for each *S* were omitted from the data analysis. The authors found a significant interaction between arousal level and time of recall. At immediate recall (2 min.), digits associated with the three lowest GSR deflections were recalled significantly more than numbers associated with the three largest GSR deflections. However, for recall at 45 min. through 1 week, this relationship was reversed.

To test the independence of the arousal phenomenon from the association value or other qualities unique to the stimuli in the Kleinsmith and Kaplan (1963) study, Kleinsmith and Kaplan (1964) essentially replicated their previous study substituting six nonsense syllables of 0% association value for the stimuli while retaining single digits from 2 to 7 as the response items. Recall intervals were 2 min., 20 min., and 1 week. The results were similar to their earlier findings. The high-arousal learning condition, again defined as the three greatest GSR deflections, demonstrated reminiscence. Low-arousal learning, on the other hand, showed decreased recall over time. A frequency distribution of the six nonsense syllables in terms of their high- or low-arousal classification showed no systematic trend. That is, a nonsense syllable that was associated with a small GSR deflection for one *S* was just as likely associated with a small GSR for another *S*.

Levonian (1967) has found the same relationship between arousal measured by GSR and retention of material presented in a traffic safety film. Although the results were not significant, information presented during high arousal (defined as a resistance decrease of at least half a standard deviation during the midpoint frame associated with the event to be remembered) led to poor short-term retention and enhanced long-term retention. Low-arousal learning, defined as a resistance decrement not included in the high-arousal category, showed the opposite trend. However, it should be noted that the same *Ss* were tested for both short-term *and* long-term retention.

Walker and Tarte (1963) partially replicated the Kleinsmith and Kaplan studies using homogeneous lists of high- and low-arousal words. Words defined *a priori* as high-arousal were *money, rape, slut, embrace, kiss, vomit, passion,* and *sex*. The low-arousal words were *white, pond, berry, flower, walk, pencil, glass,* and *carrot*. Response items were the digits 2 through 9. The interval between learning and recall was 2 min. for one group, 45 min. for another, and 1 week for a third group for each list. The data were first analyzed on the basis of the *a priori* designation of high and low arousal. Results showed that the predicted difference at immediate recall was not significant although the differences between the long-term recall scores for the high- and low-arousal words were in the predicted direction and significant. However, when the authors employed the same type of analysis used by Kleinsmith and Kaplan (1963, 1964), designating for each *S* the three words producing the lowest deflection as low arousal and the three words producing the greatest deflection as high arousal, there were significant differences in the expected direction in both long-term and short-term recall.

It is possible that arousal is present during both learning and recall. For example, a stimulus that was highly arousing when presented during the learning trial could be expected to retain some of its arousal value when presented again for the recall test. This increased arousal at recall could be the determinant in better long-term retention rather than a stronger memory trace due to perseverative consolidation. In other words, better retention of high-arousal items may be due to the arousal induced by the stimuli at the time of recall rather than the result of a stronger memory trace due to consolidation.

Since the Hebb theory of consolidation implies that any nonspecific arousal that is fed into the system will facilitate consolidation and thereby aid long-term retention, it would seem possible to use a means of inducing arousal that was not inherent in the learning material. In this way, one would be able to separate the effects of arousal during learning from arousal during the recall test.

Batten (1967) manipulated arousal through the use of drugs. High-arousal *Ss* were administered 10 mg. of dexedrine (a centrally active stimulant) 1 hour before the learning session and also given ego-involving instructions. The low-arousal *Ss* were given 10 mg. of phenobarbital (a centrally active depressant). After one presentation of eight word-number pairs, *Ss* were tested for recall at one of the following intervals: 2 min., 20 min., 45 min., 1 day, and 1 week. Although the results were in the direction found by the Michigan group (Kleinsmith & Kaplan, 1963, 1964; Walker & Tarte, 1963), a Duncan Multiple Range Test indicated no significant differences.

Berlyne, Borsa, Craw, Gelman, and Mandell (1965) and Berlyne, Borsa, Hamacher, and Koenig (1966) used white noise as a means of manipulating arousal. The assumption that white noise is arousing is supported by the evidence that white noise activates the reticular arousal system (Berrien, 1946; Costello & Hall, 1967; Gibson & Hall, 1966) and the finding that continuous white noise raises skin conductance and keeps it raised for at least 10 to 15 min. before the effect habituates (Berlyne & Lewis, 1963).

Berlyne *et al.* (1965) used white noise as an arousal manipulation during PA learning and/or during recall. Four half-lists of nine items each were constructed using adjectives as stimuli and male first names as responses Half of the *Ss* went through three training trials on two of the lists under white noise conditions and were given the remainder of the lists while white noise was either present or absent. The other *Ss* went through a sequence of events with the necessary counterbalancing to control for order of presentation of white noise and no white noise. Berlyne *et al.* found that on the training day there was significantly less recall for items learned under white noise than for items learned with no white noise. On the test day 24 hours later, however, items learned under white noise the day before were recalled significantly more often than non-white-noise items. Contrary to the findings of the Michigan group, high-arousal learning did not show a reminiscence effect. The difference made by the presence or absence of white noise during the test trial was not significant.

In another PA experiment, Berlyne *et al.* (1966) again used single dysyllabic adjectives as stimulus terms and single dysyllabic male names as response terms. Noise conditions were varied so that noise appeared only during the presentation of the stimulus, during the interval between items, during the presentation of the stimulus and response, or not at all. They found that the presence of white noise during the presentation of stimulus and response terms in training trials significantly increased recall in a test trial given 24 hours later. Whether white noise was present or absent after the response made no significant difference on the 24-hour retention measure. Berlyne also found that during training on Day 1, white noise under all presentation conditions had no detrimental effect on recall. This finding is contrary to the previous findings of Berlyne *et al.* (1965) and Kleinsmith and Kaplan (1963, 1964) in which arousal had a detrimental effect on immediate recall but enhanced long-term recall relative to the nonarousal condition.

Haveman and Farley (1969), using white noise to manipulate arousal during PA, serial, and free learning, found that arousal during learning led to significantly better 24-hour recall following free learning.

One difficulty with the white noise studies is the absence of correlative physiological evidence that white noise is an effective arousal stimulus. There have been at least two studies (Obrist, 1963; Lacey, 1963) indicating that white noise with a fluctuating db. level causes heart rate deceleration, a phenomenon that traditionally has not been associated with a general state of arousal.

The bulk of the foregoing studies employing arousal-producing stimulus terms, drugs, and white noise suggest that arousal facilitates long-term recall. One inconsistent finding of the studies cited has concerned the relationship of arousal and immediate recall. The Michigan group (Kleinsmith & Kaplan, 1963, 1964; Walker & Tarte, 1963) and Berlyne *et al.* (1965) have found arousal to have a detrimental effect on immediate recall. On the other hand, Alper (1948), Farley (1968), Haveman and Farley (1969), and Berlyne *et al.* (1966) found arousal to have no significant inhibiting effect on immediate recall.

The present experiment was designed to extend the study of arousal and retention through the concurrent measurement of two physiological responses, GSR and heart rate, during PA learning, with immediate and long-term recall tests. Such a study would represent an extension of the within-*S* arousal analysis reported by Kleinsmith and Kaplan (1964).

Additionally, the present study was designed to separate the effects of arousal *manipulation* during learning from the recall trial by using white noise as a means of manipulating arousal only during the learning trial. In order to delimit the effects of white noise, and thus presumably of arousal, *S*'s GSR and heart rate were recorded while learning under a noise or no-noise condition.

From the theoretical relationships elucidated above between arousal and consolidation, it was predicted that high arousal during learning would lead to poor immediate recall but superior long-term recall relative to low-arousal learning, where it was expected that superior immediate recall but poor long-term recall would be obtained relative to recall following high-arousal learning.

II
Method

Subjects

The *S*s were 32 students from an introductory course in educational psychology at the University of Wisconsin. There were 14 males and 18 females. Each *S* participated as part of a 3-hour laboratory requirement, although some choice was involved in that they could have participated in other studies.

Procedure

The *S*s were given a single learning trial with a list of eight nonsense syllable-number pairs. The following eight 0% association value nonsense syllables were used: CEF, QAP, TOV, JEX, DAX, SIJ, LAJ, and FEH. The response items were single digits from 2 to 9. Six of these nonsense syllable-number pairs were used in the Kleinsmith and Kaplan (1964) study.

A Kodak Carousel slide projector with an exposure time of 5 sec. was used to present the stimuli. Kleinsmith and Kaplan (1964) had used a 4-sec. interval. The procedure reported by Kleinsmith and Kaplan was followed. During the training trial, *S* was presented the nonsense syllable alone for 5 sec., followed by a 5-sec. period in which the nonsense syllable was repeated with a single digit response. In order to separate the arousal effects from one PA to the next, two slides containing five colors each were inserted between the PAs for 5 sec. each and *S* was instructed to name the colors. Red, green, orange, blue, black, and yellow were used randomly on these slides. Three colors appeared on the top row and two colors appeared on the bottom row.

Following Kleinsmith and Kaplan, the *S* was instructed to concentrate carefully on both colors and nonsense syllable-number pairs as he called them out loud, but to avoid rehearsal *S* was not told that he would be tested for recall. Rather, the *E*'s interest in the physiological correlates of attention was emphasized. The *S*s under a white noise condition were told that the noise would block out any sound that might come from outside the experimental room. A Grason-Stadler Model 901B white noise generator and a Telephonics TDH 39 binaural headset were used to deliver 75 db. of white noise. Reference level was 2 dynes/cm^2. The choice of 75 db. of white noise was based on Berlyne's use of this level (Berlyne *et al.*, 1966). Onset of white noise began with presentation of the first PA stimulus item and terminated 5 sec. after presentation of the last color slide.

During the recall session *S* was instructed to indicate the correct number for each nonsense syllable as it appeared and to guess if he was uncertain. Colors were not used as an interpolated task as in the training trial.

Design

Each of the *S*s was randomly assigned to noise (noise *vs*. no noise) and recall (short-term *vs*. long-term) conditions. Half of the *S*s in each condition were tested 2.87 min. after the presentation of the first PA stimulus and the other half were tested 24 hours later.

To control for serial order effects, eight different training lists were used. Each list was given to one *S* in each group. Assignment of list to *S* was random within groups. The lists were designed so that each of the eight nonsense syllables appeared once in each position in the list. The order of the recall lists was varied in the same manner. Each training list was systematically assigned a particular recall list such that the order of items was different between the two lists.

Materials and Equipment

In order to determine the specific arousal effects of white noise vs. no white noise and also the arousal state during presentation of each PA, three channels of bioelectric information were concurrently recorded during learning. A Grass Model 7 polygraph was used to obtain continuous records of GSR, heart rate (HR), and respiration. The electrodes used to record the galvanic skin response were of the zinc variety used by Lykken (1959). Electrode paste was inserted in the center of a Scholl's No. 453 foot pad to control for area of skin contact. After the fingers had been rubbed with alcohol, electrodes were placed on the first and third fingers of the left hand.

Heart rate in beats per minute was measured with a cardiotachometer on an arm to arm (inner forearm) lead using Johnson and Johnson disposable electrodes, with the ground electrode being a clip lead attached to the left ear lobe. To eliminate artifactual responses from the record, respiration was recorded by strapping a chest bellow around the *S*'s waist. Electrodes and recording apparatus also were used during the recall session to insure constancy of conditions although no physiological measures were actually taken.

Data Analysis

The physiological data for each *S* were quantified as follows: Separate estimates of resting and learning levels of HR and skin resistance level were obtained. Resting level was sampled for 2 min. after the *S* had been given 10-15 min. to adjust to the experimental situation. An estimate of resting skin resistance level was obtained by averaging the lowest value in each 30-sec. interval (Obrist, 1962). The mean of the six fastest HR's for each 30-sec. interval was designated as the *S*'s resting HR. This measure of HR has been shown in a previous study to correlate with total HR at, or above, +.98 (Lacey & Smith, 1954). Those 30-sec. periods of resting HR were omitted during which marked deviations (i.e. coughing, holding breath, etc., as indexed by the pen deflecting out of range or its channel span) were evident from the record of respiratory activity (Obrist, 1962).

An estimate of learning skin resistance was obtained by averaging the lowest resistance value in each 20-sec. interval for the duration of the learning task (2.67 min.). Similarly, the average six highest heart rates for each 20-sec. interval was used as an estimate of learning HR.

An additional analysis was performed on the physiological learning data. Any drop in a *S*'s GSR which occurred within 20 sec. of presentation of a nonsense syllable was considered an arousal deflection. This 20-sec. interval has been found to be in the range yielding the best prediction for recall (Kaplan & Kaplan, 1968; Levonian, 1966). Each *S*'s eight GSR deflections were then ranked. The three highest deflections for each *S* were designated high-arousal learning and the three lowest were designated low-arousal learning. In case of ties, a deflection occurring at a low level of absolute skin resistance was considered higher arousal than a similar deflection occurring at a higher absolute level.

The mean of the six fastest heart beats which occurred within 20 sec. of presentation of each of the eight nonsense syllables for each *S* was determined and these eight means were then ranked. For each *S* the three highest average heart rates were considered to be high arousal and the three lowest as low arousal.

In the PA task, the recall score was simply the total number of correct responses provided during the recall test.

III
Results

Arousal level as defined by both HR and GSR was significantly greater during learning than during rest. Mean HR during the rest condition was 81.6 beats per minute. This increased to 85.0 beats per minute during learning. Analysis of variance on the resting and learning HR data yielded $F(1, 28) = 10.27, p < .003$, as shown in Table 1. Average skin resistance was 243K ohms during rest and 167K ohms during learning. Again, as summarized in Table 2, these differences were highly significant: $F(1, 28) = 55.38, p < .0001$.

Product-moment correlations were obtained between all autonomic and learning measures for the 32 *S*s. The data were ordered so that for HR, a positive correlation would indicate an increase in performance (recall) accompanied by an increase in HR sympathetic-like activity. For GSR, however, a positive correlation between GSR and recall score would indicate superior performance accompanied by lower sympathetic-like activity. Change for both HR and GSR is the difference between a *S*'s resting and learning physiological level. These results are summarized in Table 3. The complete correlation matrix appears in Table 14 in the Appendix. Correlations were also computed separately for the noise ($N = 16$) and no noise ($N = 16$) conditions. These matrices can be found in Table 15 and Table 16, respectively, in the Appendix.

A strong correlation of .804 ($p < .001$) was found between basal and learning GSR. Likewise, there was a high positive correlation (.815, $p < .001$) between basal and learning HR. There was also a significant correlation of .633 ($p < .001$) between a *S*'s basal GSR and the amount of change from the basal to learning condition. The more sympathetic-like activity or the less resistance, the less change in the direction of more arousal from the basal to learning condition. In other words, the higher the basal level of functioning, the smaller the response to the learning situation. This relationship did not seem to apply for HR.

In general, linear correlations between total recall and any of the GSR or HR variables were very low, and none reached significance. It is interesting to note that the correlation between basal GSR and basal HR is extremely low (.066). The same low degree of correlation applies to learning GSR and learning HR (.166).

To determine the effects of white noise vs. no white noise during learning, analyses of variance were performed on the recall, HR, and GSR data. The mean correct recall for the short-term retention interval was 2.00 items (25%) for items learned under noise and 2.38 (30%) for items learned under no noise. Mean long-term correct recall was 1.88 (23%) for items learned under the noise condition and 1.75 (22%) for items learned under no noise.

Table 1. Analysis of Variance on HR for Basal and Learning Conditions

Source	*df*	*MS*	*F*
Basal	1	185.64	10.27*
Error Within	28	18.07	

*$p < .003$

Table 2. Analysis of Variance on GSR for Basal and Learning Conditions

Source	*df*	*MS*	*F*
Basal	1	93253.95	55.39*
Error Within	28	1683.59	

*$p < .0001$

Table 3. Product-Moment Correlations for HR, GSR, and Recall Variables

Variables	Correlation	Significance
Basal GSR—Learning GSR	.804	$p < .001$
Basal HR—Learning HR	.815	$p < .001$
Basal GSR—GSR Change	.633	$p < .001$
Basal HR—HR Change	-.026	
Learning GSR—GSR Change	.084	
Learning HR—HR Change	.326	
Total Recall—Basal GSR	.189	
Total Recall—Basal HR	.166	
Total Recall—Learning GSR	.259	
Total Recall—Learning HR	-.069	
Total Recall—GSR Change	-.055	
Total Recall—HR Change	-.331	
Basal GSR—Basal HR	.066	
Learning GSR—Learning HR	.166	
GSR Change—HR Change	-.116	

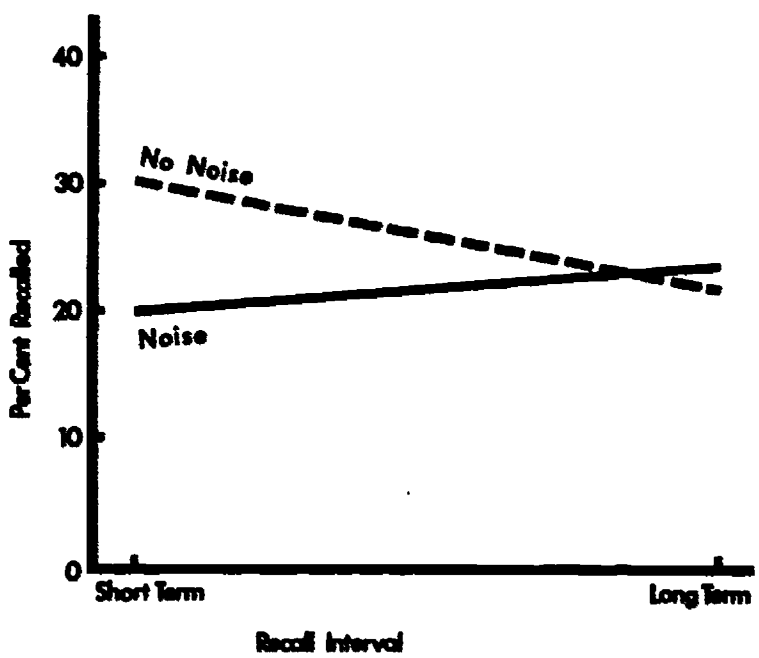

Fig. 1. Differential recall of paired associates as a function of noise condition.

These results are plotted in Figure 1 where it can be seen they are in the predicted direction. The analysis of variance of these data is summarized in Table 4. It is clear from Table 4 that no significant effects due to the retention interval, noise condition, or their interaction were obtained.

Turning to the effects of noise on GSR, the mean GSR during noise was 166K ohms, whereas during no noise the mean was 167K ohms. The analysis of variance of these data is summarized in Table 5, where it can be seen that this difference did not achieve significance.

Table 4. Summary of Analysis of Variance on Total Recall Scores for Recall Interval and Noise Condition

Source	*df*	*MS*	*F*
Noise Condition	1	.1250	.192
Recall Interval	1	1.1250	1.726
Noise X Recall	1	.5000	.767
Error Within	28	.6518	

Table 5. Analysis of Variance on GSR during Learning for Noise Condition

Source	*df*	*MS*	*F*
Noise	1	922.64	.55
Error Within	28	1683.59	

Table 6. Analysis of Variance on HR during Learning for [illegible]se Condition

Source	*df*	*MS*	*F*
Noise	1	11.39	.63
Error Within	28	18.07	

Where HR was concerned, the mean HR during learning was 86 beats per minute for the noise condition and 84 beats per minute for the no-noise condition. This difference was not significant as can be seen from the analysis of variance of these data summarized in Table 6.

The effect of noise on GSR change from the resting to learning condition was analyzed, with a mean GSR change of 84K ohms and 75K ohms being obtained for the noise and no-noise conditions, respectively. The analysis of variance of these data is summarized in Table 7, where it can be seen that this difference did not achieve significance.

The effect of noise on HR change from the resting to learning condition was likewise analyzed, with a mean HR change of 5.50 beats per minute and 4.06 beats per minute being obtained for the noise and no-noise conditions, respectively. This difference was not significant as can be seen from the analysis of variance of these data summarized in Table 8.

Since analysis of variance on the noise variable yielded no significant results, an analysis of the data similar to that of Kleinsmith and Kaplan (1964) was employed. That is, high- and low-arousal conditions during learning were based on a within-*S* analysis, with the three greatest deflections to stimulus terms in the eight-item list representing high arousal and the three lowest GSR deflections representing low arousal. Mean correct recall for items learned under the high-arousal condition was .625 (21%) for short-term retention and 1.188 (40%) for long-term retention. Mean recall for items learned under low arousal was .813 (27%) for short-term retention and .438 (15%) for long-term retention. Figure 2 illustrates the relationship between high- and low-arousal learning as a function of recall interval. Learning under high- and low-arousal defined by amount of GSR deflection revealed a significant interaction ($p < .001$) between arousal level and time of recall, as summarized in Table 9. Retention for material learned under a low-arousal state decreased rapidly over 24 hours. High-arousal learning, on the other hand, showed a marked reminiscence effect over 24 hours. The significant interaction is primarily attributable to the effect of the 24-hour condition ($t(15) = 4.095$, $p < .001$). The difference between high- and low-arousal retention at short-term recall was not significant ($t(15) = .779$).

The proportion of the variance, ω^2, accounted for by differences between the high- and low-arousal conditions under 24-hour

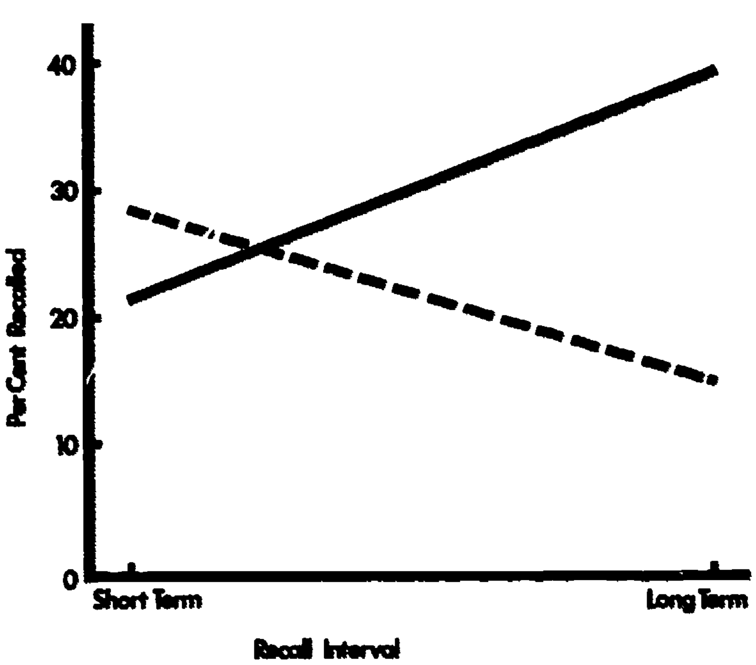

Fig. 2. Differential recall of nonsense syllables as a function of GSR arousal level.

Table 7. Analysis of Variance on GSR Change from Resting to Learning for Noise Condition

Source	*df*	*MS*	*F*
Noise	1	639.03	.21
Error Within	28	3069.86	

Table 8. Analysis of Variance on HR Change from Resting to Learning for Noise Condition

Source	*df*	*MS*	*F*
Noise	1	16.53	.74
Error Within	28	22.50	

Table 9. Summary of Analysis of Variance on Recall Scores for Recall Interval and Arousal Condition Defined by GSR Deflection

Source	*df*	*MS*	*F*
Between Subjects			
Noise	1	.141	.412
Recall	1	.141	.412
Noise X Recall	1	.141	.412
Error Between	28	.342	
Within Subjects			
Arousal	1	1.266	2.821
Arousal X Noise	1	.016	.035
Arousal X Recall	1	3.516	7.836*
Arousal X Recall X Noise	1	.141	.313
Error Within	28	.449	

*$p < .001$

retention was .50 (Hays, 1963, p. 325). ω^2 for the interaction was .17. Thus the capacity to recall items associated with low-arousal learning decreased as a function of time in a characteristic forgetting pattern. On the other hand, the capacity to recall numbers associated with high-arousal learning demonstrated a considerable reminiscence effect. Mean correct recall for items learned under high arousal within the noise condition was .500 (17%) for short-term retention and 1.25 (42%) for long-term retention. Mean correct recall for items learned under low arousal within the noise condition was .750 (25%) for short-term retention and .375 (13%) for long-term retention. These results are plotted in Figure 8 in the Appendix. In Table 10 is reported the frequency of recall for the eight nonsense syllables for both high and low arousal as defined by GSR deflection for the two times tested. This information is reported separately by noise condition in Table 17 and Table 18 in the Appendix. No systematic trends are present in the distribution of items which could account for the differences in behavior of high- and low-arousal learning.

A similar analysis to the above was undertaken using HR to define arousal level. Within each *S* the three highest mean HR values to stimulus terms in the eight-item list were designated as high arousal and the three lowest HR values as low arousal. Mean correct recall for items learned under the HR high-arousal condition was .938 (31%) for short-term retention and .813 (27%) for long-term retention. Mean correct recall for items learned under low HR arousal was .750 (25%) for short-term retention and .750 (25%) for long-term retention. These results are plotted in Figure 3. Arousal level as defined by HR, however, showed no significant effects on retention as summarized in Table 11. Mean correct recall for items learned under the HR high arousal within the noise condition was .750 (25%) for short-term retention and .750 (25%) for long-term retention. Mean correct recall for items learned under low arousal within the noise condition was .875 (29%) for short-term retention and .750 (25%) for long-term retention. These results are plotted in Figure 10 in the Appendix. Mean correct recall for items learned under high arousal within the no-noise condition was 1.125 (39%) for short-term retention and .875 (29%) for long-term retention. Mean correct recall for items learned under low arousal within the no-noise condition was .625 (21%) for short-term retention and .625 (21%) for long-term retention. These results are plotted in Figure 11 in the Appendix.

Table 10. Number of Times Each Nonsense Syllable Produced a High or Low GSR Arousal Reaction

	High Arousal		Low Arousal	
	ST	LT	ST	LT
CEF	0	1	1	2
JEX	2	2	0	1
DAX	2	3	3	2
QAP	0	1	1	1
FEH	2	3	2	0
SIJ	0	1	0	3
LAJ	2	2	1	1
TOV	2	2	4	0

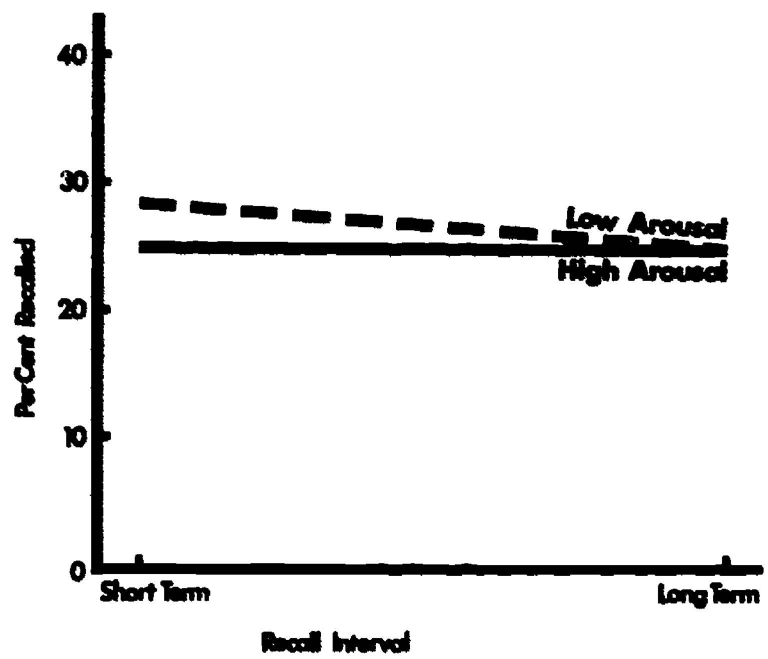

Fig. 3. Differential recall of nonsense syllables as a function of HR arousal level.

Table 11. Summary of Analysis of Variance on Recall Scores for Recall Interval and Arousal Condition Defined by Heart Rate

Source	*df*	*MS*	*F*
Between Subjects			
Noise	1	.016	.050
Recall	1	.141	.453
Noise X Recall	1	.016	.050
Error Between	28	.310	
Within Subjects			
Arousal	1	.391	.493
Arousal X Noise	1	.766	.966
Arousal X Recall	1	.016	.020
Arousal X Recall X Noise	1	.141	.178
Error Within	28	.792	

Table 12. Number of Times Each Nonsense Syllable Produced a High or Low HR Arousal Reaction

	High Arousal		Low Arousal	
	ST	LT	ST	LT
CEF	0	2	4	0
JEX	3	1	0	1
DAX	3	3	3	3
QAP	2	2	0	0
FEH	0	1	3	2
SIJ	1	2	0	1
LAJ	2	0	1	4
TOV	2	2	1	1

Fig. 4. Per cent correct short-term recall as a function of serial position.

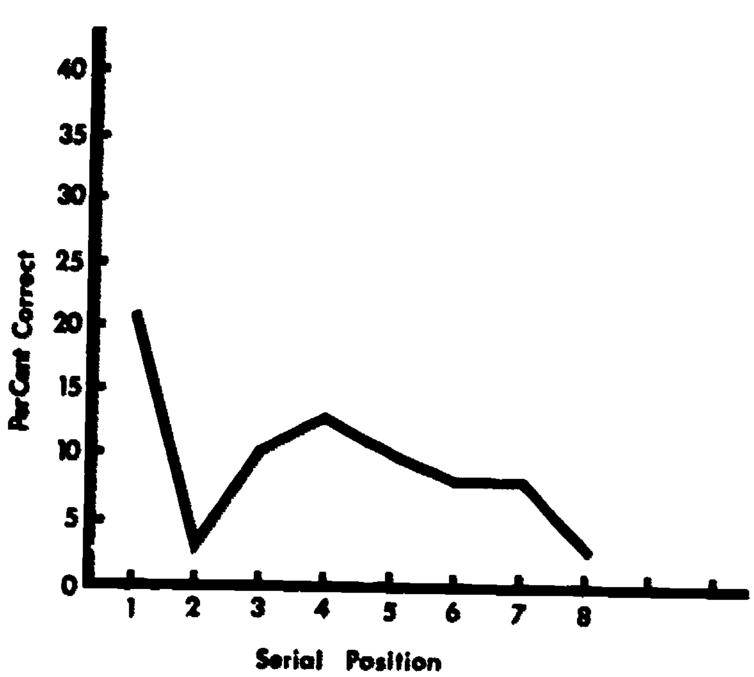

Fig. 5. Per cent correct long-term recall as a function of serial position.

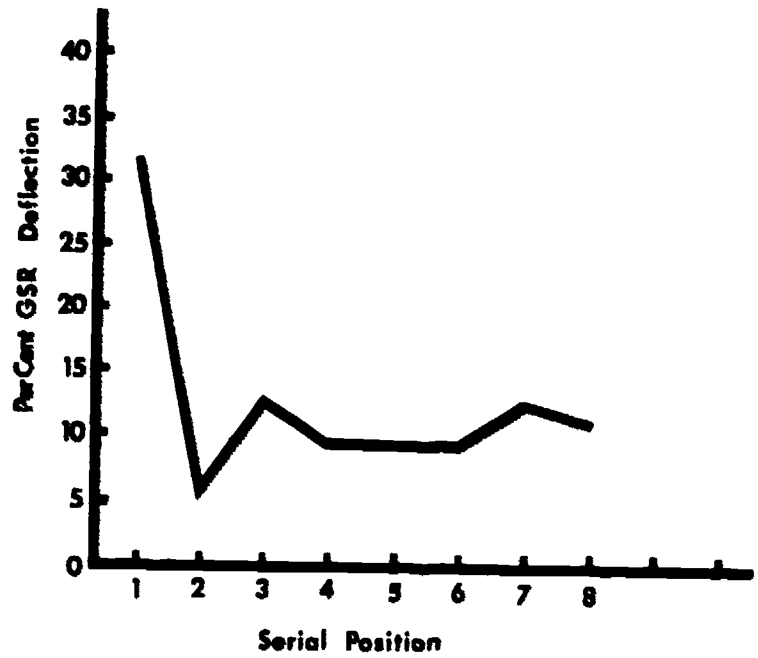

Fig. 6. Per cent GSR deflection in training as a function of serial position.

Table 12 shows the number of times each nonsense syllable produced a high or low HR arousal reaction for the two times tested. This information is reported separately by noise condition in Tables 19 and 20 in the Appendix.

Figures 4 and 5 contain plots of the serial position curves at short-term and long-term recall. It may be seen that there is a slight primacy-recency effect for short-term recall and a strong primacy effect for long-term recall. From the plot of skin resistance level as a function of serial position in Figure 6 it may be seen that the primacy effect in long-term recall seems completely accounted for by the relative arousal by serial position.

Since there is some tendency for the first item to contribute unduly to the high-arousal category, another analysis was performed with the item in the first serial position for each *S* omitted. The two stimulus terms (among the remaining seven) producing the largest GSR deflection were designated as high-arousal learning and the two producing the smallest GSR deflection were designated as low-arousal learning. Mean correct recall for items learned under the high-arousal condition was .375 (19%) for short-term retention and .625 (32%) for long-term retention. Mean recall for items learned under the low-arousal condition was .625 (32%) for short-term retention and .250 (13%) for lóng-term retention. These results as presented in Figure 7 are essentially the same as those shown in Figure 2. The analysis of these data is summarized in Table 13, where it can be seen there is a significant interaction between arousal level and time of recall ($p <$

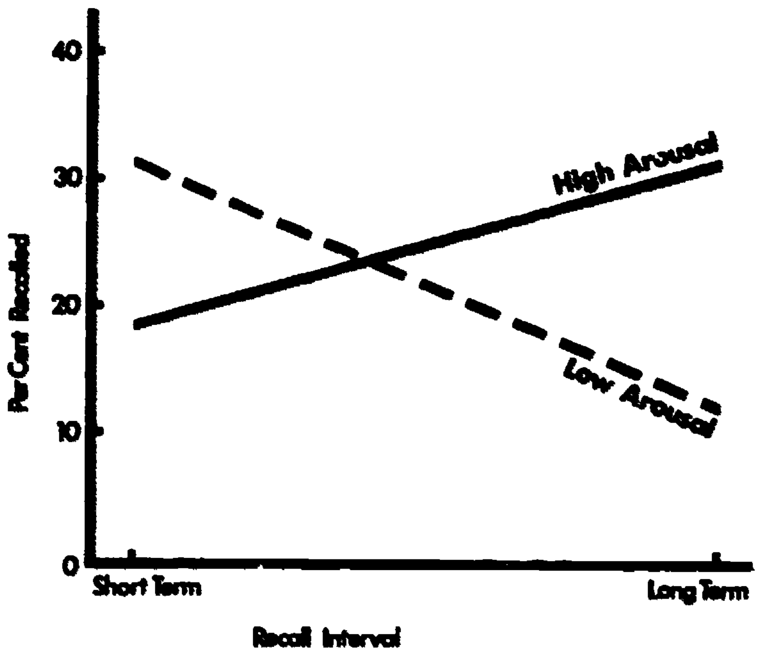

Fig. 7. Differential recall of nonsense syllables as a function of GSR arousal level with the first item omitted.

Table 13. Summary of Analysis of Variance on Recall Scores for Noise Condition, Recall Interval, and Arousal Condition Defined by GSR with Item in First Serial Position Omitted

Source	*df*	*MS*	*F*
Between Subjects			
Noise	1	.054	.175
Recall	1	.063	.203
Noise X Recall	1	.250	.812
Error Between	28	.308	
Within Subjects			
Arousal	1	.063	.192
Arousal X Noise	1	.000	.000
Arousal X Recall	1	1.563	4.795*
Arousal X Recall X Noise	1	.250	.767
Error Within	28	.326	

*$p < .04$

.04). A t test between high- and low-arousal conditions for short-term retention was not significant ($t(15) = 1.1536$). However, as in the previous analysis, there was a significant difference between high- and low-arousal conditions at 24-hour retention ($t(15) = 3.9144$, $p < .01$). Thus the primary relationships between arousal and time of recall are not essentially modified when serial position is controlled.

IV
Discussion

The results showing GSR and HR activity significantly greater during learning than during rest are consistent with studies of Andreassi and Whalen (1967), Eason, Harter, and Storm (1964), and the EEG work of Thompson and Obrist (1964). Similarly, the strong correlation between basal and learning activity for both GSR and HR is in agreement with existing literature. Lacey (1956) found significant positive correlations between prestimulus and response levels for heart rate and skin conductance, while Hord, Johnson, and Lubin (1964) established positive relationships between prestimulus and response levels for heart rate, respiration rate, and finger temperature. These and other studies suggest that for nearly all autonomic nervous system variables, the magnitude of response to stimulation depends at least in part on the preceding level of activity.

The correlation of +.63 between basal GSR and GSR change indicates that the higher the basal level of GSR, the smaller the response to the learning situation. This relationship between basal level and degree of response to the learning situation was not true for heart rate. Such a finding would be important if one were giving treatments to groups with different basal levels of physiological activity. However, as would be expected from the random assignment of *S*s to treatment groups, analysis of variance for basal physiological level among groups yielded no significant differences ($F < 1$).

The negligible correlations between HR and basal skin resistance are not unusual (Sternback, 1966). An individual may have a large skin conductance increase to a stimulus and very little HR increase relative to a comparison group (Lacey, 1959). Furthermore, although an individual's entire pattern of activation may be produced from one stimulus to another, there are also consistent differences in the average response pattern produced by different stimulus situations (Lacey, 1963). Thus it is becoming increasingly evident that there are patterns of arousal peculiar to the individual and to the stimulus.

The prediction that white noise could induce arousal and thereby facilitate long-term retention was not confirmed. Failure to find any significant effects of white noise on either GSR or HR levels suggests that white noise was not an effective arousal inducer. Furthermore, there were no significant differences in recall due to noise condition, recall interval, or the interaction between noise condition and recall interval. Possibly the physiological recording procedure and apparatus combined with the learning task was so arousal-inducing that the addition of white noise had no further arousing effect. The PA task may also have been too difficult to test the Berlyne *et al.* (1966) findings effectively. Haveman and Farley (1969) found that, generally speaking, the easier the learning task the more likely was noise to have an effect on retention. Further research will be required to substantiate these negative results.

The existence of a significant interaction between time of recall and arousal level (defined by within-*S* GSR deflection) replicates the finding of Kleinsmith and Kaplan (1964). The increase in the capacity to recall items learned under conditions of high arousal in contrast to items learned under low arousal provides some support for theory relating arousal to consolidation. A somewhat simplified physiological explanation of the processes involved may be pictured as follows. When a person perceives a pattern, a closed, reverberating neural circuit is set up in his brain corresponding to this pattern. The more arousal present, the greater the number of times the trace is likely to reverberate. And the greater this perseverative consolidation of the neural trace, the stronger the permanent memory.

Short-term recall for PAs learned under low arousal was superior to recall of PAs learned under high arousal but the difference was not significant as in the Kleinsmith and Kaplan (1963, 1964) studies. Thus the consolidation hypothesis that greater arousal increases perseveration but results in poorer short-term performance was not confirmed.

The GSR's extreme sensitivity to momentary changes can probably best explain the fact that GSR could be used to discriminate significant differences between high- and low-arousal and not HR. Changes in HR are likely to take place more slowly.

The primary effect in long-term retention seems largely accounted for by the relative GSR arousal by serial position. GSR arousal does not account for short-term retention. Recently there has been some question whether the reminiscence phenomenon in experiments like the present one is entirely attributable to the item presented in the first serial position. Walker and Tarte (1963) found that much of the effect was gone when the first item was omitted in the analysis. Items learned under high arousal were recalled better than those learned under low arousal for 2 min., 45 min., and 1 week retention. Most of the reminiscence effect over time was gone.

Kleinsmith and Kaplan (1964) have shown significant reminiscence over time if the first item is omitted from the data analysis. This was the case in the present experiment when the first item was omitted. Thus the data suggest that differential recall ability can be predicted on the basis of the individual *S*'s arousal change during presentation of a paired associate and is independent of the association value, serial position, or other quality unique to the stimuli.

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References

Alper, T. C. Task-orientation and ego-orientation as factors in reminiscence. *Journal of Experimental Psychology*, 1948, *38*, 224-238.

Andreassi, J. L., & Whalen, P. M. Some physiological correlates of learning and overlearning. *Psychophysiology*, 1967, *3*, 406-413.

Batten, D. E. Recall of paired associates as a function of arousal and recall interval. *Perceptual Motor Skills*, 1967, *24*, 10550-10558.

Berlyne, D. E., Borsa, D. M., Craw, M. A., Gelman, R. S., & Mandell, E. E. Effects of stimulus complexity and induced arousal on paired associate learning. *Journal of Verbal Learning and Verbal Behavior*, 1965, *4*, 291-299.

Berlyne, D. E., Borsa, D. M., Hamacher, J. H., & Koenig, I. D. Paired-associate learning and the timing of arousal. *Journal of Experimental Psychology*, 1966, *72*, 1-6.

Berlyne, D. E., & Lewis, J. L. Effects of heightened arousal on human exploratory behavior. *Canadian Journal of Psychology*, 1963, *17*, 398-410.

Berrien, F. K. The effects of noise. *Psychological Bulletin*, 1946, *43*, 141-161.

Berry, R. N. Skin conductance levels and verbal recall. *Journal of Experimental Psychology*, 1962, *63*, 275-277.

Brown, H. Part I: The relation between magnitude of galvanic skin responses and serial order learning. *Journal of Experimental Psychology*, 1937, *20*, 262-278.

Costello, C. G., & Hall, M. Heart rates during performance of a mental task under noise conditions. *Psychonomic Science*, 1967, *8*, 405-406.

Eason, R. G., Harter, M. R., & Storm, W. F. Activation and behavior. 1. Relationship between physiological indicants of activation and performance during memorization of nonsense syllables using differing induced tension conditions. *Perceptual Motor Skills*, 1964, *19*, 95-110.

Farley, F. F. Memory storage in free recall as a function of arousal and retention interval with homogeneous and heterogeneous lists. Unpublished manuscript. University of Wisconsin, 1968.

Freedman, N. L., Hafer, B. M., & Daniel, R. S. EEG arousal decrement during paired-associate learning. *Journal of Comparative Physiological Psychology*, 1966, *61*, 15-19.

Furth, H. G., & Richart, T. A. Autonomic responses and serial learning. *Journal of Comparative Physiological Psychology*, 1961, *54*, 139-142.

Gibson, D., & Hall, M. K. Cardiovascular change and mental task gradient. *Psychonomic Science*, 1966, *6*, 245-246.

Haveman, J. E., & Farley, F. H. *Arousal and retention in paired-associate, serial, and free learning*. Wisconsin Research & Development Center for Cognitive Learning, Technical Report No. 91, 1969.

Hays, W. L. *Statistics for Psychologists*. New York: Holt, Rinehart, and Winston, 1963.

Hebb, D. O. *The organization of behavior*. New York: Wiley, 1949.

Hord, D. J., Johnson, L. C., & Lubin, A. Differential effect of the law of initial value (LIV) on autonomic variables. *Psychophysiology*, 1964, *1*, 79-87.

Kaplan, S., & Kaplan, R. Arousal and memory: A comment. *Psychonomic Science*, 1968, *10*, 291-292.

Kintsch, W. Habituation of the GSR component of the orienting reflex during paired associate learning before and after learning has taken place. *Journal of Mathematical Psychology*, 1965, *2*, 330-341.

Kleinsmith, L. J., & Kaplan, S. The interaction of aroused and recall interval in nonsense syllable paired associate learning. *Journal of Experimental Psychology*, 1964, *67*, 124-126.

Kleinsmith, L. J., & Kaplan, S. Paired-associate learning as a function of arousal and interpolated interval. *Journal of Experimental Psychology*, 1963, *65*, 190-193.

Kleinsmith, L. J., Kaplan, S., & Tarte, R. The relationship of arousal to short and long-term verbal recall. *Canadian Journal of Psychology*, 1963, *17*, 393-397.

Lacey, J. I. The evaluation of autonomic responses; toward a general solution. *Annals of the New York Academy of Science*, 1956, *67*, 123.

Lacey, J. I. Psychophysiological approaches to the evaluation of psychotherapeutic process and outcome. In E. A. Rubenstein & M. B. Parloff (Eds.), *Research in psychotherapy*. Washington, D.C.: American Psychological Association, 1959.

Lacey, J. I. The visceral level: situational determinants and behavioral correlates of autonomic response patterns. In P. H. Knapp (Ed.), *Expressions of the emotions in man*. New York: International Universities Press, 1963.

Lacey, J. I., & Smith, R. L. Conditioning and generalization of unconscious anxiety. *Science*, 1954, *120*, 1045-1052.

Levonian, E. Attention and consolidation as factors in retention. *Psychonomic Science*, 1966, *6*, 275-276.

Levonian, E. Retention of information in relation to arousal during continuously presented material. *American Education Research Journal*, 1967, *4*, 103-116.

Lykken, D. T. Properties of electrodes used in electrodermal measurement. *Journal of Comparative & Physiological Psychology*, 1959, *52*, 629-644.

Obrist, P. A. Some autonomic correlates of serial learning. *Journal of Verbal Learning and Verbal Behavior*, 1962, *1*, 100-104.

Obrist, P. A. Cardiovascular differentiation of sensory stimuli. *Psychosomatic Medicine*, 1963, *25*, 450-459.

Rudolf, G. M. Clinical blood pressure in anxiety. *Journal of Mental Science*, 1955, *101*, 893-894.

Sternback, R. A. *Principles of psychophysiology*. New York: Academic Press, 1966.

Thompson, L. W., & Obrist, W. D. EEG correlates of verbal learning and over-learning. *Electroencephalography & Clinical Neurophysiology*, 1964, *16*, 332-342.

Thompson, L. W., & Thompson, V. D. Comparison of EEG changes in learning and overlearning of nonsense syllables. *Psychological Reports*, 1965, *6*, 339-344.

Walker, L., & Tarte, R. P. Memory storage as a function of arousal time with homogeneous and heterogeneous lists. *Journal of Verbal Learning and Verbal Behavior*, 1963, *2*, 113-119.

Appendix

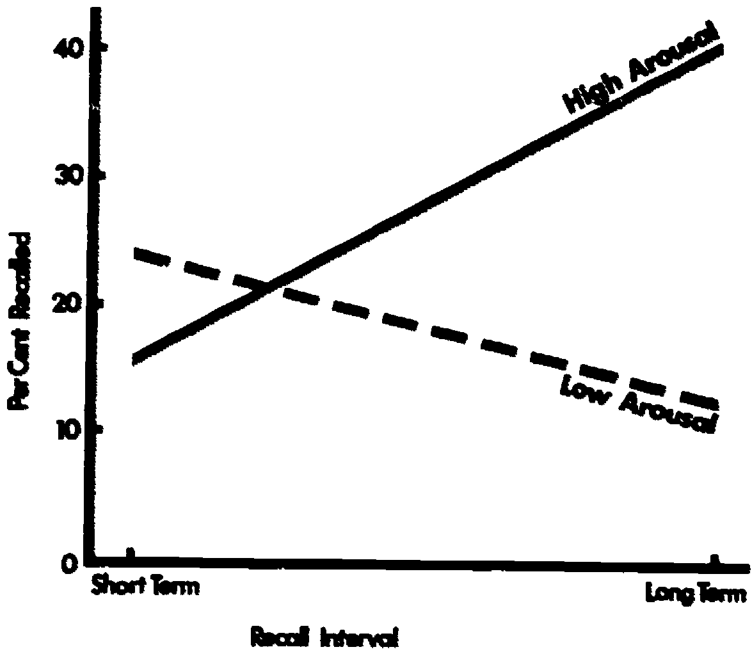

Fig. 8. Differential recall of nonsense syllables as a function of GSR arousal level for the noise condition.

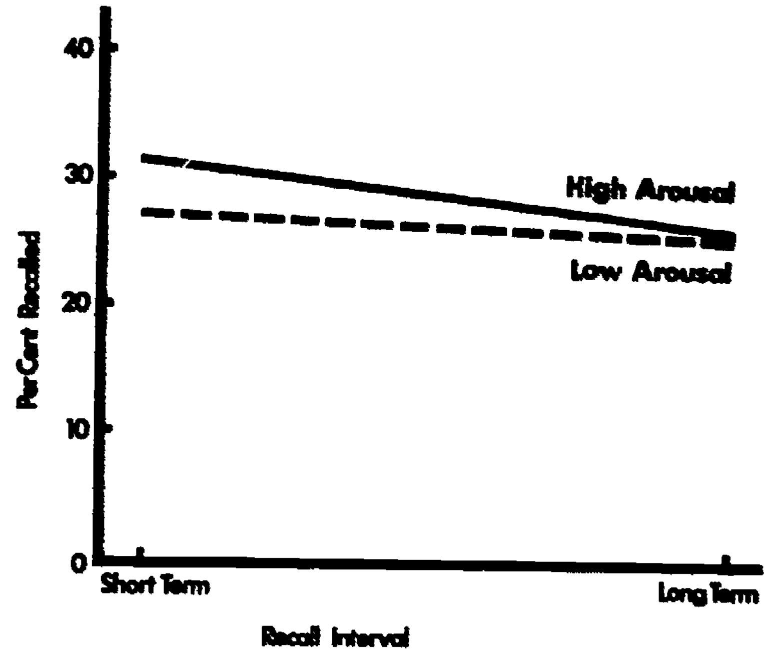

Fig. 10. Differential recall of nonsense syllables as a function of HR arousal level for the noise condition.

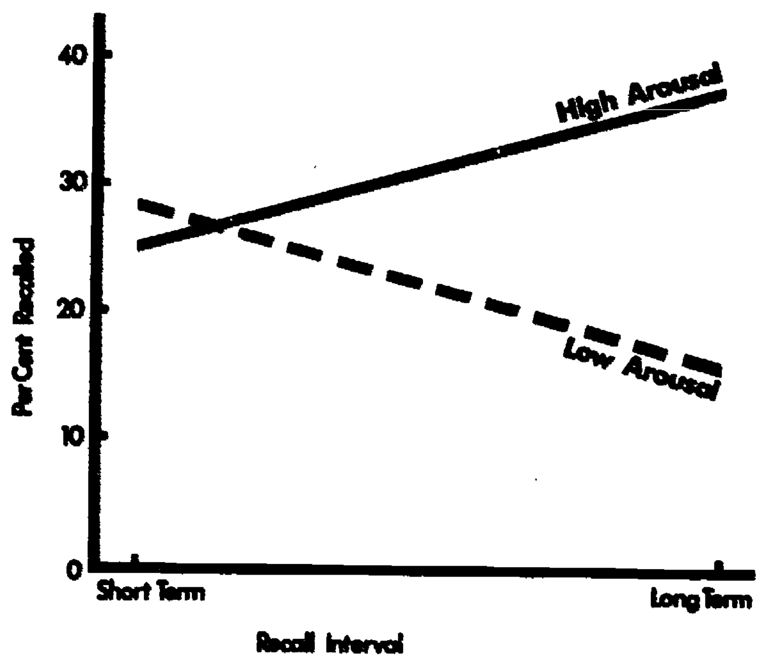

Fig. 9. Differential recall of nonsense syllables as a function of GSR arousal level for the no-noise condition.

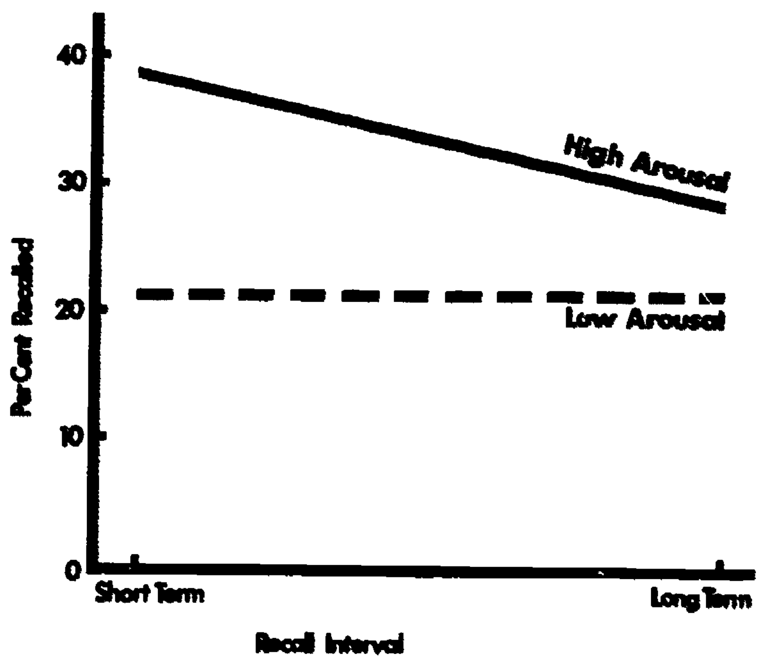

Fig. 11. Differential recall of nonsense syllables as a function of HR arousal level for the no-noise condition.

Table 14. Product-Moment Correlation Matrix for HR, GSR, and Recall Variables (N = 32)

	Basal HR	Learning HR	HR Change	Basal GSR	Learning GSR	GSR Change	Total Recall
Basal HR	1.000	.815	-.026	.066	.197	-.062	.166
Learning HR	.815	1.000	.326	-.074	.166	-.275	-.069
HR Change	-.026	.326	1.000	-.154	-.112	-.116	-.311
Basal GSR	.066	-.074	-.154	1.000	.804	.633	.189
Learning GSR	.197	.166	-.112	.804	1.000	.084	.259
GSR Change	-.062	-.275	-.116	.633	.084	1.000	-.055
Total Recall	.166	-.069	-.311	.189	.259	-.055	1.000

Table 15. Product-Moment Correlation Matrix for HR, GSR, and Recall Variables Based on *S*s Run under the Noise Condition ($N = 16$)

	Basal HR	Learning HR	HR Change	Basal GSR	Learning GSR	GSR Change	Total Recall
Basal HR	1.000	.876	.093	-.019	.011	-.046	.146
Learning HR	.876	1.000	.436	-.090	-.049	-.256	-.060
HR Change	.093	.436	1.000	-.282	.033	-.521	-.343
Basal GSR	-.019	-.190	-.282	1.000	.807	.618	.084
Learning GSR	.011	-.049	.033	.807	1.000	.034	.078
GSR Change	-.046	-.256	-.521	.618	.034	1.000	.038
Total Recall	.146	-.060	-.343	.084	.078	.038	1.000

Table 16. Product-Moment Correlation Matrix for HR, GSR, and Recall Variables Based on *S*s Run under the No-Noise Condition ($N = 16$)

	Basal HR	Learning HR	HR Change	Basal GSR	Learning GSR	GSR Change	Total Recall
Basal HR	1.000	.700	-.099	.181	.431	-.074	.149
Learning HR	.700	1.000	.272	.092	.429	-.266	-.117
HR Change	-.099	.271	1.000	-.026	-.230	.231	-.411
Basal GSR	.181	.092	-.026	1.000	.795	.650	.236
Learning GSR	.431	.429	-.230	.795	1.000	.130	.388
GSR Change	-.074	-.266	.231	.652	.130	1.000	-.129
Total Recall	.149	-.117	-.411	.236	.388	-.129	1.000

Table 17. Number of Times Each Nonsense Syllable Produced a High or Low GSR Arousal Reaction under the Noise Condition ($N = 16$)

	High Arousal		Low Arousal	
	ST	LT	ST	LT
CEF	0	0	0	1
JEX	1	1	0	1
DAX	1	1	2	1
QAP	0	0	1	1
FEH	1	2	0	0
SIJ	0	0	0	2
LAJ	0	0	1	1
TOV	1	2	2	0

Table 18. Number of Times Each Nonsense Syllable Produced a High or Low GSR Arousal Reaction under the No-Noise Condition ($N = 16$)

	High Arousal		Low Arousal	
	ST	LT	ST	LT
CEF	0	1	1	1
JEX	1	1	0	0
DAX	1	2	1	1
QAP	0	1	0	0
FEH	1	1	2	0
SIJ	0	1	0	1
LAJ	2	2	0	0
TOV	1	0	2	0

Table 19. Number of Times Each Nonsense Syllable Produced a High or Low HR Arousal Reaction under the Noise Condition (N = 16)

	High Arousal		Low Arousal	
	ST	LT	ST	LT
CEF	0	1	2	0
JEX	1	1	0	0
DAX	1	1	2	1
QAP	2	1	0	0
FEH	0	0	2	2
SIJ	0	1	0	1
LAJ	0	0	0	1
TOV	0	2	1	1

Table 20. Number of Times Each Nonsense Syllable Produced a High or Low HR Arousal Reaction under the No-Noise Condition (N = 16)

	High Arousal		Low Arousal	
	ST	LT	ST	LT
CEF	0	1	2	0
JEX	2	0	0	1
DAX	2	2	1	2
QAP	0	1	0	0
FEH	0	1	1	0
SIJ	1	1	0	0
LAJ	2	0	1	3
TOV	2	0	0	0

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